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Using Transplants in Vegetable Production

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Vegetables grown from transplants can be harvested earlier than those grown from seed. Growers who use transplants can target early-season markets and reduce the time needed to produce a crop, allowing them to produce a second or third crop during a single growing season. Transplants grown in the greenhouse can be protected efficiently against environmental stress, disease pathogens, and insect pests. Transplants can allow growers to establish near-perfect stands, optimal spacing, and uniform physiological plant age within field blocks.

Where the cost of seed is very high, the use of transplants may actually reduce the cost of establishing a vegetable planting because less seed is used and the need for thinning and early weeding is eliminated. Transplants also allow more efficient use of fertilizer and irrigation water during early growth stages.

Transplanting is both labor intensive and capital intensive. The successful production of transplants requires sterilized growth media, temperature and light control, effective pest and disease management, and appropriate sanitation practices.

PLANT ADAPTATION

When seedlings are moved from the greenhouse to the field, they undergo *tranplant shock* (a setback in growth). How quickly a plant overcomes this shock and establishes itself in the field depends on plant type, environmental conditions, quality of transplants produced, field preparation, and handling during the transplant process.

Different plant species vary greatly in their suitability for transplanting. A plant's suitability for transplanting is determined by the speed with which it can regenerate roots that are damaged during transplanting and to reestablish normal growth. Vegetable species that are well adapted to transplanting include tomato, lettuce, cabbage, Brussels sprouts, and broccoli. Celery, onion, pepper, eggplant, and cauliflower are intermediate in their adaptation to transplanting but often are successfully transplanted. Cucurbits, legumes, and sweet corn have very slow root re-development, but can be transplanted successfully if root disturbance is kept to a minimum. Seedless watermelon, for example, is a cucurbit that is transplanted on thousands of acres each year. Transplanting taproot crops like turnips, beets, and carrots generally causes root deformation and undesirable lateral root development.

TRANSPLANT ROOT INJURY

Whether transplants are grown in beds, flats, containers, or cell trays, some root injury occurs during removal of the plant from the container or soil. Transplants produced using the following practices experience less transplant shock and quicker reestablishment:

- widely spaced plants and deep planting mix to lessen competition
- plants grown individually to prevent root entanglement with neighboring plants
- transplants grown to maintain root-soil contact when they are transplanted

- seedlings grown to their optimal age for transplanting
- avoidance of shoot or root pruning or drying

The greatest damage occurs when bare-root transplants are pulled from the soil and when roots are intentionally pruned off. Cell tray transplant production systems minimize the disturbance of root-to-soil contact, but some root damage does occur when plants are pulled from the trays. The least damage occurs with pressed peat containers (peat pots), since the seedling container is planted to the field together with the transplant.

TRANSPLANT CONTAINERS

Years ago, transplants were produced in clay pots, peat pellets, or peat pots. Today, most transplants are grown in polystyrene or plastic trays. Most of these trays have inverted pyramid- or cone-shaped cells that taper in toward the bottom. Trays with 1.5-inch cells normally have 128 cells per tray, and trays with 2.5-inch cells have roughly 72 cells per tray. Smaller cells reduce production costs and decrease the size of the transplant, but because a transplant from a small cell has a much smaller root system and a greater proportion of its root-soil interface is disturbed at pulling time the small cells also reduce earliness and the quality of the transplant. The plant's adaptation to transplanting and its ability to reestablish normal growth quickly in the field are important considerations when determining the most desirable cell size.

Since transplant trays are reused, they must be sanitized after each use to prevent the spread of diseases. Containers can be sterilized with steam or sanitizing solutions. Problems can arise when a sanitizing rinse is used on improperly cleaned trays or when containers are not aerated properly after rinsing. Trays must be cleaned and washed after use so that no planting mix remains in the trays. Then the trays must be steam treated or sanitized with a registered sanitizing solution. Your County Agricultural Commissioner or a licensed pest control advisor can advise you on materials that are registered in your county for sanitizing transplant trays. Rinse the trays with clear water after the sanitizing treatment and allow the trays to air-dry to prevent any carryover of sanitizing materials that could cause toxicity in future plantings. Disposable plastic inserts available for some polystyrene trays cover the crevices caused by steam cleaning, extend tray life, and make the removal of plants easier.

PLANTING MIX

A planting mix serves three basic functions: it provides support for the plant, it holds water and nutrients, and it allows gas exchange for the roots. Bulk density and aeration potential are extremely important considerations when you are selecting a planting mix. You can increase root aeration by increasing the particle size of the mix, increasing the tray's cell size, and carefully controlling plant-water relations.

It is essential that the greenhouse planting mix be sterile—free of insects, disease organisms, nematodes, and weed seed. Most commercial transplant mixes come pre-sterilized. The basic components of growing mixes are generally sphagnum peat moss, perlite, vermiculite, and a wetting agent. Other ingredients may include washed sand, processed bark, composted green waste, and other biosolids. Most commercial transplant mixes are fine grained for ease in filling small cells and for good seed germination. Mixes used for bedding plants or potting soil are generally coarse in texture. Select a mix that drains well and supplies adequate aeration for healthy root development but that has a moderate water holding capacity.

Commercial mixes may come with or without starter nutrients (charged or non-charged). Mixes that contain slow-release fertilizers eliminate the grower's option to slow plant growth by withholding nutrients. Do not use field soils to extend or modify sterile planting mixes. Soil usually drains poorly and is often contaminated with disease organisms and weed seeds. No single planting mix is best for all situations.

TRANSPLANT PRODUCTION SYSTEMS

Three transplant production systems have been used by California vegetable growers: greenhouse-grown containerized transplants, in-ground transplant production with row covers and hotbeds, and in-ground transplant production in the open field.

In the greenhouse. Greenhouse containerized transplant production is the most common and successful transplant system used in California. This system usually involves the use of aluminum T-rails (shaped like an inverted letter T in cross-section). These rails are carefully spaced to support the edges of transplant trays in the greenhouse. The trays are filled with planting mix by hand or machine. Seed are placed in the trays by hand or by vacuum seeding machines that place a single seed into each tray cell. Care must be taken to sanitize hands and equipment used in transplant production and planting.

In-ground: Hotbeds. Historically, in-ground transplant production has used hotbeds for the production of sweet potato transplants (slips). A trench is dug and partially filled with decomposing organic matter that will generate heat. The organic matter is covered with a smooth layer of soil. Sweet potatoes are carefully placed on top of that smooth layer of soil, which covers the organic matter, and additional soil is used to cover the sweet potatoes and completely fill the trench. Plastic tunnels are used to cover the beds. Approximately 500 pounds of medium-sized sweet potatoes will grow enough slips for 1 acre.

In-ground: Field. Field production of bare-root transplants is not recommended in vegetable production. The benefits of container-grown greenhouse transplants in establishing superior stands and improving total yields far outweigh the added cost of their production. Field-produced bare-root transplants are less expensive than container-grown transplants, but bare-root transplants do not reestablish as well.

The production of bare-root transplants requires a site protected from high winds and a well-drained soil that is disease, nematode, and weed free. Seed is planted in rows 6 to 12 inches apart with in-row spacing of 1 to 5 inches depending on plant type. Sprinkler irrigation and floating row covers and are used for frost protection. Bare-root transplants are undercut prior to removal from the nursery beds. Undercutting and multiple handlings tear off root hairs, wound the young plants, and spread diseases.

IRRIGATION AND FERTILIZATION

Appropriate irrigation and fertilization together produce healthy, well-formed transplants that reestablish quickly after transplanting. Excessive water and fertilizer applications produce large, soft plants that are susceptible to disease and insect pests. Water and nutrient stress are important techniques used to alter the size, shape, and growth rate of transplants, and to toughen up (*harden*) seedlings before they are transplanted into the field.

In the greenhouse, soluble fertilizers are dissolved into a nutrient stock solution that is metered into the irrigation water in a process called fertigation. If seed is planted in a mix that contains starter fertilizers, fertigation is delayed for one or two weeks. Otherwise, fertigation should begin at the first true leaf stage of plant development. The nutrient solution should be applied to the transplant trays until it just begins to run out the bottom. This ensures that the trays receive adequate nutrition and prevents a build up of excess salts. The more often the nutrient solution is applied, the lower the nutrient concentration required for each individual fertigation.

Daily fertigation is preferable in most systems. For daily fertigation, start with nitrogen (N) concentrations in the 15 to 30 ppm range and modify the concentration as needed. Use slightly higher rates of N for tomato, pepper, and cole crops, and lower rates for cucurbits. If daily fertigations cannot be applied, the transplants should be fertilized at least once a week with nitrogen concentrations in the 200 ppm range. Only water-soluble fertilizer should be used to make the nutrient solutions. Use 3 ounces of ammonium nitrate and 4 ounces of potassium nitrate in 100 gallons of water for a nutrient solution that contains 100 ppm of nitrogen and potassium. With 10.5 ounces of 12–12–12 fertilizer dissolved in 100 gallons of water, the nutrient solution will contain 100 ppm each of nitrogen, phosphorous (P), and potassium (K).

If complete N–P–K fertilizers like 12–12–12 or 20–20–20 are used in transplant fertigation, the fertilizer stock solution should be tested in a jar before application. Mix the fertilizer stock solution with irrigation water to make sure that the phosphorous in the formulation does not precipitate or form a gel. The final fertigation solution should be tested in overhead watering on a few plants to ensure that no phytotoxicity (plant injury) occurs.

LIGHT AND CARBON DIOXIDE ENHANCEMENT

Supplemental lighting and carbon dioxide (CO_2) enrichment have been shown to increase transplant growth in greenhouses. These factors can help growers produce high-quality transplants when extremely short day lengths limit production. In commercial transplant production, CO_2 enrichment only has potential benefits in northern latitudes where greenhouses are closed for a significant portion of the day. Supplemental lighting is profitable only where electricity is inexpensive and where the heat from lamps helps to decrease other heating costs.

TRANSPLANT AGE

Transplanting at a very early seedling stage reduces transplant shock. Very old transplants may have reached a physiological age at which reproductive growth is initiated rather than vegetative growth. Premature flowering from very old transplants gives earlier fruit, but lowers yields because the plants are so small. Cell trays require a slightly root-bound condition if plants are to be removed without damaging soil-to-root contact. Root-bound transplants generally reestablish more slowly than younger transplants. Approximate times required to grow greenhouse transplants from seed are listed in Table 1.

Table 1. Time required for growing transplants from seed in the greenhouse*

Vegetable	Number of weeks	Vegetable	Number of weeks
Artichoke	6–7	Lettuce	5–7
Broccoli	5–7	Muskmelon	3–4
Cabbage	5–7	Onion	10–12
Cauliflower	5–7	Pepper	6–8
Celery	10–12	Summer squash	3–4
Cucumber	3–4	Tomato	5–7
Eggplant	6–8	Watermelon	3–4

*Table adapted from Lorenz and Maynard, 1988.

PEST AND DISEASE MANAGEMENT

A warm, moist greenhouse provides an ideal environment for the development of plant diseases. Clean seeds, sterile planting mix, sterile trays, and good greenhouse surface sanitation are essential parts of transplant production. A low relative humidity inside the greenhouse also helps to control diseases. Irrigation and fertigation should only be applied when plant foliage can dry quickly. Do not allow smoking in greenhouses or allow workers who smoke to touch plants unless they first wash their hands in alcohol. Spraying plants in trays with *Bacillus thuringiensis* (BT) before transplanting them to the field is an efficient way to protect seedlings from lepidopterous insects during their first days in the field. Integrated pest management (IPM) recommendations are available on the Worldwide Web at the University of California IPM website, http://www.ipm.ucdavis.edu.

BRUSHING TRANSPLANTS

High plant density in trays results in rapid elongation of the plants' stems. This can produce tall, weak-stemmed plants that are susceptible to breakage during transplanting. *Brushing* (the mechanical stimulation of seedlings) has been shown to reduce stem elongation during plant development. Research with tomato plants shows that ten gentle brushing strokes (accomplished by gently rubbing the top of the plants with a clean wooden dowel) each day beginning at a canopy height of 2.25 inches (6 cm) significantly reduces transplant height. Plants in the study grew 0.12 inch (3 mm) per day with brushing and 0.24 inch (6 mm) per day without. The plants' final height was directly related to the number of days that the plants received brushing. Brushing has proved successful in solanaceous crops (including tomato, pepper, and eggplant), but care should be taken with cucurbits, which are more fragile and can be damaged by brushing.

HARDENING TRANSPLANTS

Hardening is a practice of preconditioning transplants to tolerate field stress by exposing them to lower or higher temperatures and to lower moisture levels. Hardening reduces a plant's succulence, closes its stomates (leaf pores), lowers its transpiration rate, and changes its hormone balance (increases abscisic acid [ABA]), all of which contribute to a decreased growth rate. After hardening, plants should always be thoroughly watered to obtain full turgor prior to transplanting. Excessive hardening exhausts the plant's energy reserves. The degree of hardening should be tailored to suit field and environmental conditions. Favorable transplanting conditions and properly prepared fields require less hardening.

FOLIAGE AND ROOT TRIMMING

Trimming of transplant foliage or roots is an old procedure that is generally misunderstood, and almost always detrimental. The intention of topping is to reduce transpiration water loss and moisture demand by the leaves. Topping actually removes a source of photosynthates (plant energy), however, and the remaining photosynthates move toward shoot growth at the expense of root regeneration. In some situations, foliage trimming does become necessary: if transplanting must be delayed, foliage trimming can be a necessary corrective option for holding the plants until they can be used.

WATERING-IN TRANSPLANTS

At transplanting, water must be applied in one of two ways. Either the field must be irrigated immediately after transplanting or water must be put into the planting hole with the transplant. Transplant reestablishment is improved when water is applied to the soil-root environment at transplanting. This practice provides a temporary water reserve and helps to bring soil particles into closer contact with the roots. The transplant and growing medium should get a light covering of field soil to prevent moisture from wicking away from the lighter growing media used for transplant development.

Watering-in and placement of the transplant at the proper depth will reduce transplant loss attributable to in-field drying. Holes for the transplants should be of sufficient size and depth to allow planting without damage to the transplants. The bending of roots during transplanting ("J-rooting") can cause slower reestablishment and a loss of earliness. Transplants with very long root systems are often laid into a small furrow and covered with soil. This "L-rooting" is preferable to cutting the root system short to make the transplant easier to handle.

A slight increase in planting depth has been shown to be a growth stimulant in some transplanted vegetable crops. The standard practice has generally been to plant tomato and pepper transplants to a level between the cotyledons and the root ball. Several research studies in Florida and California have shown that planting tomato and pepper transplants deeper (down to the first true leaf) increases early growth and yield.

STARTER FERTILIZER SOLUTIONS

Dilute solutions of water-soluble fertilizers are sometimes applied at the time of transplanting to stimulate early growth. The water application often helps the transplant more than the nutrients. Starter solutions normally contain small amounts of N, P, and K, and varying amounts of micronutrients. Concentrated fertilizers applied at transplanting can injure roots and cause water stress for the transplants.

ANTI-TRANSPIRANTS

The maintenance of correct water balance in the transplant is critical to its survival and reestablishment. Anti-transpirants can reduce water loss at the leaf surface by inducing stomatal closure or providing a physical barrier to water loss. If you use anti-transpirants, apply them before you pull the transplants out of their trays.

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FOR MORE INFORMATION

You'll find detailed information on many aspects of vegetable production in these and other publications, slide sets, and videos from UC ANR:

Commercial Greenhouse Vegetable Handbook, publication 21575
Integrated Pest Management for Tomatoes—Fourth Edition, publication 3274
Integrated Pest Management for Tomatoes, slide set 98/103
Small-Scale Postharvest Handling Practices for Horticultural Crops, video V99-C
Vegetable Crops: Planting and Harvesting Periods for California, publication 2282

Also of interest:
Grower's Weed Identification Handbook, publication 4030
Weeds of the West, publication 3350

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