Plug and Transplant Production for Organic Systems

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Since the few large commercial suppliers of plugs do not produce organic plugs, growers must produce their own or buy them locally. This publication presents information on raising vegetable and ornamental plugs and transplants, but it is not intended as an introduction to the subject. Rather, it is a complementary piece of information, focusing on organic rather than conventional production methods and on conformity to the Final Rule of the National Organic Program. Although much of the research cited covers ornamentals, the information applies to vegetables as well.

Contents

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The traditional way to raise a lot of seedlings is to sprout seeds in trays, then transplant these fragile plants into larger packs or pots. This method is very labor-intensive and results in considerable mortality from transplant shock or root loss.

Since the 1980s, most seed germination has been done in plug trays; by 1998, 81% of annual seedlings were grown from plugs.(1) A plug is a containerized transplant with a self-enclosed root system.(2) The advantages to growing seedlings from plugs are many: less time and labor to transplant, reduced root loss, more uniform growth, faster crop establishment, and increased production. There are disadvantages, too. Much more attention has to be paid to scheduling and to cultural practices. While labor is decreased, mechanization and the need for specialized, well-trained workers increases.

There are a number of pros and cons to consider when deciding whether to grow plugs from seed or to purchase plugs and grow them to transplant size. The advantages of producing one's own plugs include rapid production, efficient use of greenhouse space, choice of species and cultivars, and self-reliance. The disadvantages can include extra labor to handle an exacting crop and increased heating costs in winter (since plugs are quite sensitive to temperature fluctuations). According to Kessler and Behe (3):

> The decision should be based partially on market considerations, labor availability and expertise, the number of plants to be produced, the cost per plug, and the specialized equipment and facilities required. This investment is often not economically practical unless production is large or plugs are marketed to other growers. For most small to medium sized growers, especially [beginners], it is often more economical to purchase...plugs from specialized growers and concentrate on producing finished containers. The issue of grow versus purchase should be reviewed periodically as the needs and facilities of the grower change.

Photo by Peggy Greb, USDA ARS.

The basic considerations in plug production include:

- Container size
- Media

- Seeding and germination
- Nutrition
- Temperature
- Watering and moisture management (especially during germination)
- Light and supplemental lighting
- Growth regulation
- Scheduling
- Pest management, especially of fungus gnats, shore flies, and root rots.

The book *Plug and Transplant Production*, by Drs. Roger Styer and David Koranski (2), contains the most extensive information on all the basics listed above. Because it focuses on specifics, it is good for troubleshooting. The book comes with three pullout tables—one each for vegetables, bedding plants, and cut-flower plugs. These tables provide extremely detailed information on specific crops. This publication should be on the shelf of every serious plug and transplant grower. See Reference 2 for information on how to order this book.

In 1990, and again in 1996, the editors of *GrowerTalks* magazine (4) compiled some pertinent articles on plug production into books entitled *GrowerTalks on Plugs* (5) and *GrowerTalks: PlugsII*.(6) The 1990 edition is no longer in print, but it may be available through interlibrary loan. The 1996 edition is available from Ball Publishing (see Reference 4). This edition focuses on the basics mentioned above, as well as automation (transplanters, shipping, boom irrigators), plug holding, stress, container size, growing your own vs. buying, seeds and germination, pest control, and culture by crop for 11 species of bedding plants.

Greenhouse Grower (7) and *Greenhouse Management and Production* (8) are periodicals that address plug production and related issues. *Greenhouse Grower* produces an annual bonus issue that targets plugs and propagation. *GrowerTalks* holds an annual plug conference that lasts for three days, usually in October. Although the conference is expensive (usually around $550 for all three days), it would be worth the money to talk with growers from around the country to see what they recommend and discuss solutions to problems. For more information, contact Ball Publishing at the address listed in the **References** section.

Commercial Suppliers of Organic Plugs

Mountain Valley Growers, Inc.
38325 Pepperweed Street
Squaw Valley, CA 93675
559-338-2775
559-338-0073 FAX
e-mail through Web site
www.mountainvalleygrowers.com

Can supply 128 types of ornamental and culinary herb plugs. Also certified organic seeds for basil and other annual herbs, sunflowers, and gourmet greens. Stocks 24 varieties of lavender. Web sales only; nursery is not open to the public.

Greystone Gardens
1187 Maple Street
Waterbury Center, VT 05677
802-244-8103
802-244-5075 FAX
greystonegardens1@verizon.net
www.greystonegardensvt.com

After research evaluating organic plug production techniques and economic feasibility (SARE grant FNE03-468), Brenda and Mike Hedges started offering organic vegetable and flower plugs grown in their 3000-sq.-ft. greenhouse in 2005. Large selection of certified organic plugs for vegetables and ornamentals. Some vegetatively propagated varieties offered only as conventional stock grown under organic methods.

Patchwork Farm and Greenhouse
470 Jackson Hill Road
Aaronsburg, PA 16820
814-422-8735

In business since 1976. Member of Slow Food of Central Pennsylvania.

Containers

Plugs are produced in multi-cell plastic trays, also called flats. The trays are available in a wide range of cell sizes and depths—anywhere from 50 to 800 cells in a single tray. The type of flat chosen will depend on the species being grown and the length of time spent growing it. Pansies, for instance, are most often grown in 288, 392, or 406-plug trays.(3) The time from sowing to ready-for-transplant stage is usually about 6 weeks in 288 trays and 5 weeks in 392 or 406 trays. Larger cells provide more moisture

The New Organic Program

Under the Final Rule of the National Organic Program, organic plug production must take place in a certified organic operation. Organic plug production begins with certified organic seed or certified organic plants from which propagation material is obtained through layering or other means of vegetative propagation. If certified organic seed (or vegetative propagation material) of the desired cultivar is not commercially available, untreated seed or slips may be used for plugs, as long as they are not derived from genetically engineered plants. Though high cost is not deemed "unavailability," in practice most certifiers will accept as evidence of unavailability proof that growers have tried unsuccessfully to get organic material from at least three different suppliers. The federal organic "seeds and planting stock practice standard" (§205.204) can be found at *www.ams.usda.gov/nop*. For a list of companies currently providing 100% Certified Organic seed for vegetables and herbs, see ATTRA's *Suppliers of Seeds for Certified Organic Production* database. A grower should always determine the name of the seed supplier's organic certifier, perhaps by asking to see the certificate. The official list of accredited certifiers is at *www.ams.usda/NOP*. To aid growers in choosing an organic certifier, *NewFarm.org* now offers a database with detailed certifier profiles at *www.newfarm.org/ocdbt*.

Federal organic regulations also address composting and the use of raw manures. These may have implications for plug production of early-harvested food crops. Federal standards also dictate what may and may not be used as growing media, fertilizer, or pest control inputs. For more details, it is advisable to read the relevant sections of the Final Rule. For information on some commercial products that meet the criteria set forth in the Final Rule, visit the OMRI Web site at *www.omri.org* and view their listings. For detailed information on organic production practices under NOP, see the NCAT publication *Organic Crops Workbook*. It is always a good idea to check with your certifier before using a particular commercial product in organic production.

and nutrients to the plant, but make much less efficient use of greenhouse space than the smaller cells.

Rigid foam cell trays (such as Speedling® flats) are an alternative to plastic trays. Though more expensive per unit, they have the advantage of greater durability and "stand-alone" ability—particularly important when using automated equipment. They are quite bulky, however, and will not nest for storage. Lightweight plastic trays, in contrast, are easy to store in the off-season and cost less, but they are less durable and usually require an undertray to maintain sufficient rigidity for convenient handling. Manufacturers offer other innovative designs, as well. Winstrip® trays, for example, have small slits down two sides of each plug to improve aeration, and holes between cells to allow air movement up through the tray.(9) Plugs grown in Winstrips usually have less root spiraling.

Occasionally, growers choose a soil-block system. Developed in Europe some years ago, soil blockers press a soil mix together into cubes that are handled in much the same manner as peat pellets. Commercial-scale blocking equipment is expensive, and many growers find the plants' tendency to grow their roots into adjoining blocks annoying. Small-scale blocking equipment has proved popular with some market gardeners. For more information on soil-block methods, see the book *The New Organic Grower*, by Eliot Coleman.(10)

Table 1 gives some idea of the sizes, cell shapes, and major suppliers of plug trays. See **Suppliers of Plug Trays** at the end of this publication for more information.

Related ATTRA Publications

Seed Production and Variety Selection for Organic Systems (2005)

NCAT's Organic Crops Workbook

Organic Farm Certification and the National Organic Program

Overview of Organic Crop Production

Suppliers of Seed for Certified Organic Production (new database 2005)

Potting Mixes for Certified Organic Production

Herbs: Organic Greenhouse Production

Vegetables: Organic Greenhouse Production

Integrated Pest Management for Greenhouse Crops

Table 1. Plug tray suppliers, sizes, and cell shapes.

Company	Sizes Available	Cell Shapes Available
Winstrip	50, 72, 72, 128, 162, 216, 288	Square
Dillen	72, 84, 98, 105, 128, 144, 162, 288, 512	Square, Round
Landmark	50, 72, 84, 98, 128, 144, 162, 200, 288, 384, 392, 406, 512, 648, 800	Square, Round, Octagonal
Blackmore	128, 144, 200, 216, 288, 338, 384, 406, 512, 648, 800	Star, Square Deep, Octagonal, Square, Octahedron, Waffle
Summit Plastic	72, 128	Round
Growing Systems	51, 73, 96, 104, 135, 170, 198, 200, 273, 288, 400, 512	Square
Speedling	72, 128, 162, 200, 242, 288, 338, 388, 392, 595	Square

Recent Research on Containers

Research conducted at the University of Georgia in 1995 showed that copper-treated plug flats affected the root growth and flowering of three species of bedding plants. Armitage and Gross reported that root spiraling and seedling height were reduced in impatiens, geraniums, and petunias. The copper treatment delayed the flowering of the impatiens and petunias by 12 days, and the geraniums by 21, but did not affect their mature heights.(11) The National Organic Standard [§205.601(i)(2)] permits copper sulfate and most fixed coppers (copper hydroxide, copper oxide, copper oxychloride) in crop production, as long as copper does not accumulate in soils or become a pollution hazard.

Container size can affect transplant characteristics. Researchers at the University of Florida tested four sizes of Speedling flats and found that lettuce grown in the two larger sizes took longer to reach harvestable size, but yield was not affected. In the spring-grown lettuce, there was no difference in head weights, but fall-grown heads started in the larger cell sizes were heavier. The researchers also tested media compression and found that compressing the media in the cells was not justified, since it was more costly and did not increase yields.(12)

In research done at the University of Kentucky, marigold plugs were grown in 512, 406, and 288-plug flats over a 16-day period. Size did not affect seedling growth until the 13th day, but after 16 days, seedlings grown in the 512 flats were about two-thirds the size of those grown in 288 flats. Container size also affected root branching: plants from the 288 trays had roots with fewer branches.(13)

Of greatest importance to the end user and the plug grower, however, is whether yield after transplanting is affected by container size. Researchers have yet to prove that container size affects ultimate crop yield.(14) However, studies conducted in England in the mid-1990s showed that organically grown vegetable transplants benefited from larger cell sizes.(15) The larger cells held more media and more nutrients.

Plug flat color has little effect on medium surface temperature, and temperature is important when germinating seeds. Researchers in Tennessee tested black, gray, and white flats, and found no significant differences among the three colors.(16)

Grower Jay Martin in Maryland mixes Pro-Mix Lite® and compost in proportions ranging from 12:1 to 15:1 (mix:compost), depending on the crop.(17) For example, brassicas, which are quick to finish, are grown in a mix with less compost; slower-growing solanaceous crops are raised in a mix with more compost.

Media

In organic production, plant health depends on the quality of the planting mix. Most producers opt for a soilless mix to reduce the risk of soil-borne diseases. The mix should contain sufficient amounts of the major nutrients to carry the young crop for the time it will be in the greenhouse.

Purchasing a commercially prepared organic mix is the easiest way to get started. However, most commercial potting mixes contain synthetic ingredients and do not meet organic standards. One alternative is to arrange a special order from a commercial supplier who agrees to exclude starter fertilizers and wetting agents. However, since freight is often prohibitive, many growers choose to mix their own. For more information on potting mixes, ask for the ATTRA publication *Potting Mixes for Certified Organic Production*.

Equipment: Seeders

Mechanical seeders are necessary when planting large numbers of plugs. Seeders are quite expensive, costing from $1,000 to $50,000. There are four types:

- vacuum template ($1,000–$5,000)
- vacuum tips or needles ($8,000–$13,000)
- vacuum cylinder or drum ($18,000–$50,000)
- electric eye ($10,000–$13,000)

Here is how the vacuum template works. The seed is scattered over a template that has small indentations on its surface. A vacuum holds the seeds in the indentations, while extra seed is knocked off. When the vacuum is turned off, the seeds drop into place in the plug tray, so the entire tray is planted at once. There are also manual wand seeders that use the vacuum needle system to sow one row of seed at a time. They cost less than $1,000.(1) For a list of suppliers of both kinds of seeders, see **Suppliers of Seeders**.

It is possible to make a simple seeder out of plastic. Dr. Charles Marr developed a planting template in the early 1990s at Kansas State University.(18) Here are his specifications:

> The template consists of two sheets of 3-mm acrylic plastic cut to rectangular dimensions of the seed flat. The upper sheet has a 6-cm-tall "wall" glued to the outside with a small opening in the wall at one end, so excess seeds can be poured out. The bottom sheet is held in place by four glued tabs on each side, so that the bottom sheet could slide laterally. The bottom sheet is left slightly longer with a slot cut as a handle.

Nutrition: Organic Fertilizers for Container Systems

There are four basic ways to fertilize containerized plants: incorporate, topdress, liquid feed, and foliar feed. In bedding plant culture, fertilizer incorporation in the mix combined with liquid feeding should provide sufficient nutrition.

Organic fertilizers that can be incorporated to provide nitrogen include alfalfa meal, blood meal, cottonseed meal, feather meal, hoof and horn meal, soybean meal, and animal manures, among others. Materials that provide phosphorus include oak leaves, bone meal, shrimp wastes, residues from raw sugar, and various forms of rock phosphate. Greensand, granite meal, soybean meal, ash from orange and potato skins, unleached wood ashes, and Sul-Po-Mag® all provide potassium. For more information on these

Grower Profile—The Henrys' Plant Farm

The Henrys' Plant Farm in Kansas, near the Missouri border, has been operated by Marcia and Roy Henry, and now their oldest son, Brian, for more than 20 years. The Henrys have 18 greenhouses with almost 13,000 square feet of growing space and sell more than 400 varieties of perennials and 100 of annuals, including 60 different tomatoes and 40 peppers. Marcia manages the operation of the greenhouses. Four theme gardens entertain visitors. The complete plant list may be downloaded in PDF from *www.thehenrysplantfarm.com*.

Marcia uses a vacuum seeder with five plates to accommodate different seed sizes.

Holes that are the same size or slightly smaller than the seed are drilled in the plastic. The method of operation is simple: The top and bottom sheets are kept out of alignment. Seeds are poured onto the top sheet and rolled around until all the cavities are filled. Excess seed can be poured off. The bottom sheet is then moved into line with the top, and the seeds fall through both sheets and onto the seed mix in the plug trays.

Marcia's production schedule is the result of many years of good record keeping.(19) She begins December 1 with geraniums, begonias, and perennials. At the beginning of January, she plants pansies, snapdragons, and vinca. By the end of the month she is potting up geranium cuttings and transplanting seed geraniums. On February 1, she plants petunias. With most of the best sellers and the tomatoes, she plants again on February 15. She starts most of the other annual flowers and vegetables in March.

She has found pre-printed tags available from her seed company to be helpful. Although the tags are expensive ($1,000 in 1997), customers appreciate the extra information they provide. She saves money by ordering her media by the truckload, which is 40% cheaper than buying it bagged. She also saves money on heating costs by contracting for propane gas each year.

For more information or to contact the farm, call 785-877-6544 (ph./FAX) or e-mail *henrysplants@aol.com*.

and other materials, see the ATTRA publications *Alternative Soil Amendments* and *Sources of Organic Fertilizers and Amendments*.

Another ATTRA publication, *Potting Mixes for Certified Organic Production*, provides many recipes for soil and fertilizer mixes. If formulating your own recipe, mix several experimental batches with different fertilizers and rates of incorporation and try them on a test group of plants.

Liquid feeding is done by proportioning nutrients through drip lines, proportioning through watering hoses, or drenching (from a measuring cup or bucket). Soluble fertilizers can be applied at each watering in a diluted solution, or on a 7- to 10-day basis with a concentrated solution.

***Fertile Soil** (20), by Robert Parnes, is an in-depth publication on organic fertilizers. Parnes's book provides detailed tables on the nutrient content of various manures and plant and animal byproducts.*

Nitrogen is the main nutrient supplied through liquid feeding. Soluble organic nitrogen sources include fish powder, fish emulsion, guano, and worm castings. Phosphorus is available for liquid feeding by using high-phosphorus guano or micronized soft rock phosphate.

Foliar feeding can be used to supplement soil and liquid fertilization, especially where certain nutrients are deficient and must be incorporated into the plant quickly. Filtered solutions of manure, seaweed, fish powder, and fish emulsion can be used (manures must have been composted by an approved NOP method). Seaweed is an excellent foliar material because it contains growth hormones (auxins, gibberellins, and cytokinins) as well as trace elements. Research suggests that foliar feeding programs enhance plant resistance to pest and disease attack.

Table 2. Fresh weight of cabbage plants at transplanting (16).

Fertilizer Regime	Fresh Weight (g) of 10 plants
Control (no fertilizer)	13.0
Conventional fertilizer	16.7
Blood 1 (1.5 g/liter 3x/wk.)	14.6
Blood 2 (3 g/liter 3x/wk.)	17.5
Blood 3 (15 g/liter 3x/wk.)	30.2
Hoof and horn (3 g/liter media)	21.7

Recent Research on Fertilization

A study conducted in 1998 at the University of Georgia found that nitrogen, rather than phosphorus and potassium, mainly determined the growth of plugs. The report recommended that growers focus their fertility programs on nitrogen and reduce phosphorus and potassium applications.(21)

Often, there are seasonal variations in growth, and the fertilization system must take this into account. A recent study in Florida showed that spring-grown tomato seedlings respond linearly to increased nitrogen fertilizer.(22) In other words, the more N applied, the more the plants grow. (The researchers used 15 to 75 mg/liter of N.) In fall-grown plants, however, the opposite is true. Researchers believe that increased light and higher temperatures in the fall were responsible for some of the differences in growth patterns. Other research has shown that anywhere from 75 to 400 mg/liter of N produces the largest tomato seedlings and often increases early yields.(22) Too much nitrogen, however, attracts aphids.

In an English study, cabbage seedlings were fertilized with conventional fertilizer, dried blood (applied in a liquid form), and hoof and horn meal (incorporated into the potting media).(15) Dried blood applied at a rate of 3 grams/liter, three times a week, increased plant growth about as much as conventional fertilizer. Table 2 presents the rest of the findings.

In 1993, Premier Peat Moss in Canada conducted research on organic wastes from the food industry, comparing their ability to fertilize greenhouse tomato transplants.(23) The researchers found that meal from blood, feathers, meat, crab shells, fish, cottonseed, and whey by-products increased shoot weight 57 to 83% over non-fertilized plants. The results of this study are shown in Table 3.

Irrigation

Thorough, even watering is extremely important to success in plug and transplant production. Water stress sets plants back and increases the chance that they will fare poorly once planted outdoors. Automatic or semi-automatic watering saves a great deal of work, but it will not eliminate the need for "touch-up" watering by hand, on a regular basis. The plants will do best, especially when in plastic trays, if they are supported off the ground to allow good air circulation and prevent waterlogging. As a general rule they should not be watered in late afternoon, lest they remain overly wet through the night.

Plug cell size will also affect the watering schedule. According to Biernbaum and Versluys, "While in larger containers water must be added to thoroughly moisten the entire medium profile, in shallow containers a less than saturating amount of water can be added without detrimental effects to roots since the water will distribute adequately."(24)

One of the most common problems in greenhouses is overwatering. Not only does this contribute to poor plant growth and health, it also encourages the spread of pathogens that thrive in wet conditions. It is especially easy to overwater young plugs; underwatering becomes a problem with older plugs.

There are five major ways to water plugs (24):

- hand watering
- stationary sprinklers
- traveling boom sprinklers
- fogging
- sub-irrigation

Of these, hand watering and sub-irrigation are most appropriate for small growers. The biggest problem with hand watering is labor cost. It is also less uniform than mechanized systems. Sub-irrigation eliminates both of these problems but can result in overwatering because of immediate saturation. Sub-irrigation is better when growing larger plugs.

Table 3. Effect of organic waste products on shoot weight of tomato transplants (24).

Fertilizer	N-P-K	Shoot wt. (grams)
Crab-shell meal	8.2-1.5-0.5	18.8
Blood meal	12.5-1.1-1.0	18.5
Dried whey sludge	5.3-2.5-0.9	18.3
Feather meal	13.6-0.3-0.2	17.3
Fish meal	10.1-4.5-0.5	17.1
Meat meal	7.7-3.1-0.7	16.3
Cottonseed meal	6.5-1.1-1.6	16.2
Fish-scale meal	10.0-3.7-0.1	15.8
Distiller's dried grains	4.3-0.9-1.1	14.5
Soybean meal	7.5-0.7-2.4	14.4
Wheat bran	2.9-1.4-1.3	13.5
Alfalfa meal	2.5-0.3-1.9	10.8
Canola meal	6.0-1.1-1.3	10.8
None (control)	0-0-0	10.3

Recent Research on Irrigation

A 1999 study at the University of Georgia showed that moisture stress tends to increase aphid populations on New Guinea impatiens and marigolds, but it has little effect on spider mite or thrips populations.(25) In the experiment, mite populations were lower on ageratum plants that were irrigated with an ebb-and-flow system, compared to overhead-irrigated plants.

Researchers at North Carolina State University found that environmental conditions, rather than plant growth, may dictate irrigation practices.(9) Their other findings:

- Plugs leach fertilizer, sometimes heavily.
- Plug trays (288s) can take 500 to 1000 ml of water per tray at each irrigation, depending on environmental conditions.

- Winstrip® trays used more water and dried out faster than conventional trays.
- Plants tended to be larger in Winstrip® trays and finish earlier than in conventional trays.
- Plants may use less than 2% of the water applied to the tray.
- Water per tray may be affected more by air humidity than by temperature or plant condition.

Lighting and Growth Regulation

Although supplemental lighting can increase transplant quality, it is generally not needed for most operations. The exception to this rule of thumb is in winter, especially in northern areas of the U.S. Low light levels result in "leggy" plants, making growth regulation techniques more important. Most growers use high intensity discharge (HID) lamps to light their greenhouses. This topic is discussed at length in Styer and Koranski (2) and in *Greenhouse GrowerTalks: PlugsII*.(6)

Light competition can cause plugs and transplants to elongate, resulting in spindly, leggy plants. Conventional growers use chemical growth regulators to combat this problem. There are, however, non-chemical means to control growth. Brushing is a kind of mechanical conditioning whereby the grower uses a tool (like a broomstick, piece of paper, or PVC pipe) to brush the plant tops and reduce their height. According to Garner et al., "Research concerning the effects of mechanical stimulation on floricultural crops is considerably more limited than that on vegetable crops, probably due to the availability of chemical growth regulators approved for use on bedding plants."(26)

Researchers at Cornell found that brushing is an effective method for controlling pansy plant size. Photo © 2005, clipart.com.

Researchers at Cornell studied the best ways to brush plants. They used a piece of polystyrene foam on tomato seedlings and found that ten strokes a day was enough to reduce the seedlings' ultimate height by about 20%.(28) Using more than about ten strokes a day was ineffective, and there was no difference between applying all the strokes at one time or spreading them out over a longer period. No matter what the seedling height was when brushing began (6, 8, or 10 cm), the reduction in height was 3 mm per day.

In another study, researchers studied the effects of brushing on tomatoes and on four species of bedding plants (geranium, impatiens, petunia, and pansy).(27) For the tomatoes, they found that 10 to 20 daily strokes were enough for height control, that there was no difference between morning and afternoon brushing, and that brushing did not affect yield. The best time to begin the brushing treatment was the first or second true leaf stage. Beginning later resulted in leaf damage. However, brushing the bedding plants had different effects. For geranium, impatiens, and petunia, brushing adversely affected the plants and even resulted in significant damage. The pansy plugs, however, responded to brushing in much the same way as the tomatoes. The authors concluded that brushing is an effective method for controlling tomato and pansy plant size.

Cucurbits and eggplants respond well to brushing, but peppers are damaged by it. Cole crops respond fairly well and seem to do better if brushing is started at the second or third leaf stage.(28) One study even showed that brushing helped to reduce thrips and mite populations.(25)

Controlling temperatures is another way to control plant height. Cooler temperatures generally slow down growth, and warmer ones speed up growth. "Both root and shoot growth increase linearly with temperature between the general range of 50 to 85°F."(1)

Recently, research has concentrated on adjusting day and night temperatures to control plant "stretching." A marked difference in day and night temperatures seems to promote internode elongation, and growers have found that keeping the day and night temperatures the same helps to prevent this from happening. Another strategy is to keep day temperatures below night temperatures. Although many species respond well to this kind of treatment, some react by producing chlorotic (yellow) leaves or stunted growth. For a list of species and their response to this kind of treatment, see the 1995 article by Myster and Moe from *Scientia Horticulturae*.(29)

In much the same way, adjusting moisture, nutrition, and light can slow down or speed up seedling development. For more information on these methods, see References 2 and 6.

Scheduling: Holding Plugs

Often, transplants are ready to be planted outdoors before the weather is conducive. This has prompted research to study the effects of storing or "holding" plugs at cool temperatures. An experiment conducted at the University of Georgia examined the effects of storing geranium plugs for 1 to 3 weeks at 5°C. Additionally, the researchers tested the effects of applying nitrogen just before storage. Below is the abstract of their findings (30):

> Pelargonium x hortorum L.H. Bailey 'Scarlet Elite' seedlings were grown in plugs from seed to transplant size. About 14 days before attaining transplant size, seedlings were exposed to various fertility or temperature regimes (preconditioning treatments), then stored for 1 to 3 weeks at 5°C. Seedlings receiving 150 mg N/liter before storage flowered sooner and required less crop time (days to flower - days in storage) than those receiving 0, 75 or 300 mg. Temperature preconditioning at 10 or 15°C delayed flowering compared to preconditioning at 20°C. Final plant height and dry weight were not adversely affected by varying N levels or temperature during preconditioning. Preconditioning seedlings with 300 mg N/liter resulted in seedling mortality rates up to 16% after 7 days' storage. Low temperature or fertility were not effective preconditioning treatments. Preconditioning seedlings with 150 mg N/liter attained best results.

Table 4. Recommended cold storage time limits for selected species and cultivars, at 45°F and with light (32).

Species	Cultivar	Weeks of Storage
Fibrous begonia	Viva	1
Coleus	Multicolor Rainbow	2
Impatiens	Accent Lilac	2
	Accent Red Star	2
	Super Elfin Orange	2
Marigolds	Scarlet Sophia	5
Pepper	Better Bell	2
Petunia	White Flash	5
Portulaca	Double Mix	5
Salvia	Red Hot Sally	4
	Red Pillar	4
Tomato	Better Boy	4
Verbena	Showtime Mix	4
Vinca	Bright Eyes	3
	Grape Cooler	3
	Little Linda	3
	Little Pinkie	3
	Polka Dot	3
	Pretty 'n' Rose	3

> Management of humidity, fertility, moisture, and light is important when holding plugs. Lower humidity is good for suppressing disease, but can lead to water stress. Plugs that have been given too much nitrogen tend not to store well. Research at Michigan State University showed that light above 5 foot-candles was beneficial for stored plugs.(31)

Researchers at Kansas State University tested several species to determine their holding abilities. Their results are presented in Table 4.

Pest Management

For pest management problems, consult the ATTRA publication *Integrated Pest Management for Greenhouse Crops*. Other publications in this series include *Greenhouse IPM: Sustainable Aphid Control*, *Greenhouse IPM: Sustainable Thrips Control*, and *Greenhouse IPM: Sustainable Whitefly Control*.

An excellent handbook is *Integrated Pest Management for Bedding Plants*, from Cornell

University.(32) This 112-page manual thoroughly covers the practical aspects of implementing an IPM program for bedding plants. Topics include scouting, developing and implementing control strategies, case studies, use of biological controls, and descriptions and controls of prevalent pests and diseases. See Reference 32 for ordering information.

Top Ten Pitfalls to Plug Production

Mark Bennett of The Ohio State University and Roy Larson of North Carolina State cite the following as the ten things to watch for when raising plugs.(34)

1. **Economics.** Should you grow or buy plugs? Do a cost accounting to make sure you are making the right decision for your operation.

2. **Poor equipment selection.** Choose equipment that best fits your growing and economic needs.

3. **Untrained employees.** You should not have only one person trained on plug equipment.

4. **Improper tray filling.** To achieve uniformity, don't fill plug trays improperly.

5. **Compaction.** Piling filled trays on top of each other leads to this pitfall.

6. **Poor fertilizer practices.** A good fertilizer program requires planning.

7. **Poor watering practices.** Same as #6.

8. **Waste.** Take precautions to avoid wasting seed.

9. **Improper timing.** Keep everything on schedule.

10. **Technology gap.** Take full advantage of all available technology.

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   Ball Publishing Co.
   P.O. Box 9
   Batavia, IL 60510-0009
   630-208-9080
   630-208-9350 Fax
   www.growertalks.com

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   Meister Publishing Company
   37733 Euclid Ave.
   Willoughby, OH 44094
   440-942-2000
   440-942-0662 FAX

   $29/year for 15 issues.

8) Greenhouse Management & Production (GMPro)
   Branch-Smith Publishing
   P.O. Box 1868
   Fort Worth, TX 76101
   800-434-6776
   817-882-4120
   817-882-4121 FAX
   www.greenbeam.com

   12 issues/year; free to qualified greenhouse growers; $96/year for non-growers.

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    Available for $24.95 from:
    Chelsea Green Publishing Co.
    P.O. Box 428
    Gates-Briggs Bldg. #205
    White River Junction, VT 05001
    800-639-4099
    www.chelseagreen.com

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Cornell University
7 B&T Park
Ithaca, NY 14853
607-255-2080

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SARE Farmer/Rancher Research

www.sare.org

FNE03-468 Organic plug production: Evaluating growing media, fertilizer, and economic feasibility.

In 2003 Brenda Hedges of Greystone Gardens, Waterbury Center, Vermont, began evaluating organic plug production feasibility, also comparing the performance of three media types and two fertilizers in organic production. The research confirmed that "growing plugs actually produced more income per square foot of production space than growing traditional bedding plants." Organic germinating mix performed better than did either the organic compost or a peat-based medium. A fertilizer made from liquefied fish protein (2-4-2) performed better than a fertilizer made from liquid fish and seaweed (3-2-2). In 2005 Greystone Gardens began offering a large selection of organically raised plugs. (See **Commercial Suppliers of Organic Plugs** box on page 2.)

Further Reading

Gaston, Michelle (ed.). 1999. Tips on Growing Bedding Plants (4th ed.). Ohio Florists' Association (OFA), Columbus, OH, 43215. 164 p.

Available for $25 to members and $35 to non-members from:
Ohio Florists' Association
2130 Stella Ct., Suite 200
Columbus, Ohio, 43215

614-487-1117
www.ofa.org

Other OFA publications on conventional production methods:

- Tips on Growing and Marketing Garden Mums ($22)
- Tips on Managing Floriculture Crop Problems: Pests, Diseases, and Growth Control ($15)
- Tips on Growing Specialty Potted Crops ($31)
- Tips on Growing and Marketing Hanging Baskets ($22)
- Tips on Growing Poinsettias ($12)
- An Introduction to Greenhouse Production ($40)
- Tips on Growing Zonal Geraniums ($12)

Holcomb, E. Jay (ed.). 1994. Bedding Plants IV. Ball Publishing, Batavia, IL. 452 p.

Available for $56.95 from Ball Publishing (see Reference 4 above).

Nau, Jim. 1999. Ball Culture Guide. Ball Publishing, Batavia, IL. 248 p.

Available for $49.95 from Ball Publishing (see Reference 4 above).

Pyle, Allen R. 1999. Planting the seeds of success. American Nurseryman. February 1. p. 52-54, 56, 58, 60.

This article details how to grow perennial plugs successfully. A chart of dozens of perennial species includes number of weeks to finish, whether to cover the seed or not, and germination temperature. The article also discusses watering, media, and tray filling.

Shores, Sandie. 2003. Growing and Selling Fresh-Cut Herbs [Chap. 9]. Ball Publishing, Batavia, IL. 483 p.

Web Sites

National Organic Rule
www.ams.usda.gov/nop/

Organic Materials Review Institute (OMRI)
www.omri.org

Greenhouse Bedding Plant Production and Marketing, Alberta, Canada.

The Ohio Florists' Association offers a publication on growing and marketing mums. Photo ©2005, clipart.com.

www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2864

Plug Transplants for Processing Tomatoes: Production, Handling, and Stand Establishment, Ontario, Canada
www.omafra.gov.on.ca/english/crops/facts/94-061.htm

Suppliers of Plug Trays

Blackmore Co.
10800 Blackmore Ave.
Belleville, MI 48111
800-874-8660
www.blackmoreco.com

Dillen Products, Inc.
P.O. Box 738
Middlefield, OH 44062
800-225-5093
www.dillen.com (e-mail through Web site)

Growing Systems, Inc.
2950 N. Weil Street
Milwaukee, WI 53212
414-263-3131

Suppliers of Plug Trays continued

Landmark Plastic Co.
1331 Kelly Ave.
P.O. Box 7646
Akron, OH 44306
330-785-2200
sales@landmarkplastic.com
www.landmarkplastic.com

Speedling
P.O. Box 7220
Sun City, FL 33586
813-645-3221
813-645-8123 FAX
tesch@sezsdr.com
www.speedling.com

Summit Plastic Co.
P.O. Box 117
Tallmadge, OH 44278
www.summitplastic.com

Winstrip
556 Jeffress Road
Fletcher, NC 28732
828-891-6226 (message phone)

Suppliers of Seeders

Blackmore Co.
10800 Blackmore Ave.
Belleville, MI 48111
800-874-8660
www.blackmoreco.com

Bouldin & Lawson
P.O. Box 7177
McMinnville, TN 37111
800-443-6398
www.bouldinlawson.com

Gleason Equipment
by Measured Marketing
395 N. Schuyler Ave.
Kankakee, IL 60901
815-939-9746
www.gleasonequipment.com

Growing Systems, Inc.
2950 N. Weil Street
Milwaukee, WI 53212
414-263-3131

Seed E-Z Seeder Inc.
1116 Peachtree Drive
Lake Placid, FL 33852
800-448-9371
www.sezsdr.com

Speedy Seeder
(Division of Carolina Industries)
1504 Cunningham Road
Kinston, NC 28501
800-635-4532
www.carolinagreenhouses.com

Notes

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This publication is available on the Web at:
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