Greenhouse Organic Transplant Production

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Introduction

Greenhouse grown flower, herb and vegetable transplants create a wide range of production and marketing opportunities. Whether you are just starting with transplant production or building on past experience, there are several areas of greenhouse management to consider. The first topic is the *greenhouse structure and equipment* which includes planning and selecting a design that will provide the necessary temperature and light intensity. The second area is the *management of light and temperature* for transplant production. The third area of *root zone management* includes the growing container, the root media, and the method of providing water and nutrients to the root zone. If the first three areas are properly managed, we won't have to worry much about the fourth: *insect and disease management*.

The goal is to present the important considerations related to transplant production. Many of these are the same regardless of whether the transplants will be certified organic. The root media, fertilizer and pest control considerations are more important for organic certification. Crop specific schedules will not be presented.

Part I. Structure and Equipment

Managing the greenhouse atmosphere to provide appropriate light and temperature conditions depends on design, covering materials, heating, cooling and ventilation. For the small-scale farmer, the availability of capital to invest may limit the options.

Site Selection and Layout

Locate the greenhouse to maximize light interception. At latitudes above 40, the standard recommendation is to orient the greenhouse with the ridge running east and west so that winter light is penetrating the length of the south side of the greenhouse, not from the end. Consider shading from trees and buildings. To avoid shading, locate a distance equal to at least twice the height of the shade source. Buildings attached to greenhouses are located on the north side to prevent shading.

Remember to provide drainage for the extra water coming off the roof. One option is to collect the water for irrigation. If there is not adequate slope to move the water quickly away from the greenhouse, provide drainage pipes. The most critical time will be the spring thaw, which is also when the greenhouse will be full and there will be little time to dig drainage ditches.

Design and Materials

During visits to small-scale diversified vegetable farms and CSA's I have seen a wide range of structures used for transplant production. Greenhouse vs cold frame, free standing vs lean-to, heated vs unheated, commercial vs home made; there are many possible options. Decision making depends on the monetary investment possible, available space, and the relative dependence on human verses mechanical environmental regulation.

Most commercial structures will be of galvanized steel pipe or square tubing. Metal end walls and side rails cost more but avoid the issue of treated lumber. The use of wood is influenced by the desire to not use treated lumber, although some certifying agencies differentiate between wood in contact with the ground (not allowed) vs wood used above ground (may be allowed). For hoop houses constructed at MSU, we avoided the use of treated lumber by attaching end wall posts to metal fence posts driven into the ground. We raised the 2"x4" pine baseboards off the ground and attached a readily available 24" x12' fiberglass panel so it went into the ground and provided a wind buffer and something to drop the roll down side against. In other projects where there were more funds available, we purchased and constructed all metal end walls and frames. While manufactured metal endwalls cost 3 or 4 times what wood costs, it looks like a good investment if funds are available.

The most likely covering material will be double layer inflated 3-4 year polyethylene film. Plastic films must be greenhouse grade, not hardware or construction grade. The second most common small farm option is a rigid, single or double wall polycarbonate or acrylic. While glass greenhouses are not likely justified for on farm transplant production, glass windows, sliding patio doors, or glass shower doors can be used for cold frame construction for hardening transplants.

The shape of the roof will influence light interception. For polyethylene covered structures, the rounder Quonset designs with a flat spot on top are being replaced by a more peaked or gothic design. The higher roof angle increases winter light interception, decreases summer light interception, often increases peak height, helps with snow and condensate removal from the roof, and is highly recommended. Gothic designs come in two pieces which makes shipping easier and less expensive.

Size

The primary factors determining size are the desired function, cost/budget, location or space available, method of ventilation and cooling, method of heating and fuel requirement. For the sake of providing some perspective, example sizes relative to small farms and transplant growers might be "small": less than 1000 square feet (20' x 50'); "medium": 2000 up to 4000 square feet (20' or 30' x 100' or more than one); and "large": greater than 5000 square feet . In 1000 square feet at 80% growing space efficiency (a full house), at least 400 flats (11" x 22") or 28,800 (72 cell flats) to 80,000 (200 cell flat) transplants can be grown.

Ventilation

If passive (vents only) ventilation will be used instead of exhaust fans (active ventilation) the greenhouse should be smaller to allow easier cooling. Widths of 20 to 30 feet and lengths of 40 to 50 feet are common. The larger the vent area, the easier it is to cool but usually the harder it is to close up to keep warm when necessary. If roll up sides are used, longer structures can be cooled without fans. Retractable roof designs are also becoming more popular because of the ventilation and cooling possible.

Heating

Forced air, natural gas or propane unit heaters are the most common form of heat for small greenhouses producing transplants. One limitation with this design is getting heat down near the plants. Plastic perforated convection tubes can be used to blow warm air beneath benches. Benches with plastic or solid tops and sides can also be located in front of a heater. With cold soil floors it is recommended that flats be separated or lifted off the floor. Bottom heat using hot water circulated beneath the flats is a very efficient way of maintaining growth while keeping air temperatures cool and can be provided with readily available water lines, water heaters and circulating pumps.

Costs

Complete commercial greenhouses including the structure, utilities, environmental controls, floors, benches, irrigation equipment etc range in cost from as little as $5 per square foot up to $25 per square foot. The upper end might include a glass structure with hot water heat. The cost for the least expensive hoop structure with nothing else added can be between $1.00 and $2.00 per square foot for a 30 x 100 greenhouse that is not assembled. Having something assembled or constructed typically doubles the cost. Shipping costs can also be significant and might be avoided by looking for the most local source.

Greenhouse management can be very simple and low tech or very detailed and mechanized. Take the time to learn the key concepts first and save money both in the short and long run. If you are going to build your own greenhouse, take the time to work out how you will integrate light intensity control, ventilation/cooling, and heating. There are choices to be made about the level and cost of mechanization verses the level of labor input. If you are on the farm (home) most of the time and available to alter vents and shading by hand, the need for automated vents and therefore the cost will be lower. If you don't want to be tied to the greenhouse, invest in thermostats and ventilation equipment.

When planning a greenhouse for the small farm, it is important to take into consideration the time and labor cost of planning and constructing personal plans or modifications as opposed to paying extra for a complete kit with all the parts. If capital is limiting and labor is not, there are low cost ways of building and operating a greenhouse. If however labor and time are the limiting factor, the extra cost invested in materials and having someone else build it can usually be justified by the value of the product coming from the greenhouse.

Part II. Light and Temperature

Managing the greenhouse to provide appropriate light and temperature conditions for quality transplants depends on understanding how plants respond to light and temperature.

Transplant Growth Stages

Transplant or plug production is generally described in four observable stages. The first two stages account for actual seed germination and emergence. Stage one includes the starting process from seed sowing and medium wetting to the emergence of the radical or root initial. Stage two continues from root emergence until the seed/cotyledon leaves are expanded. Stage three occurs when the primary growth phase of true leaves and an extensive root system develops. Stage four is the finishing or hardening stage. In general, the recommended moisture level and temperature tend to decrease and the amount of light and fertility will increase with the progression of each stage.

Light Management

Optimal seed germination may depend on the absence or presence of light, although most species will germinate in light or dark. Only low intensity light (50 to 100 foot candles) is necessary for the first stage of germination. High intensity (direct, full sun) is usually avoided because it causes excessive heat or rapid drying of the growing medium. Many large plug producers use germination chambers during stage one to efficiently maintain temperatures (70 to 75 F) and moisture levels. It is critical that light intensity be increased during stage two to prevent the rapid elongation that occurs, sometimes in matter of hours, as the hypocotyl (shoot) emerges from the soil. A stretched or etiolated hypocotyl will make the remainder of transplant production more difficult.

The question of whether to cover or not to cover the seeds with root medium is usually less dependent on light and more dependent on how moisture will be maintained. Covering is not essential but helps maintain moisture. Tiny seeds like petunia, begonia or trachelium are usually not covered. Additional germination medium is most commonly used when a covering is needed.

The initial stages of germination are very dependent on soil temperature (as opposed to air temperature). Soil temperature is influenced by the amount of light and the rate of moisture evaporation from the root media, which is influenced by relative humidity. Evaporation from media is significantly greater than transpirational water loss by the plant in the early stages of germination and plant growth. Soil temperature is also influenced by the color and type of growing container.

When considering greenhouse light management, light intensity (brightness measured in foot candles), duration (measured in hours), and quality (color or wavelength) are all concerns. Acceptable transplants can be grown under a wide range of light intensities, but the largest (weight, not height) transplants will be grown under the highest light intensities. For late spring and summer production, shading may be necessary, not to block an excess of light, but rather to reduce heat in the greenhouse. If ventilation is not adequate to reduce temperatures, shading compounds can be sprayed on the covering or shade fabrics can be used outside the greenhouse.

The amount of plant growth will be determined by both the intensity of the light and the duration of time the light is available. For example, if light quantity were considered, the expected result would be similar plant growth if 5,000 footcandles were provided for 5 hours or 2,500 fc were provided for 10 hrs. The product of both is 25,000-footcandle hours. This helps explain why good transplants can be grown under a fluorescent shop light if the light is kept close to the plants and left on for 18-24 hrs/day. It also helps explain why greenhouse plants do not grow as much during the winter when light intensity is low and days are short. High-pressure sodium (HPS) lamps (400 watt) are most efficient for supplemental lighting in greenhouses, and the most efficient use is in early stages of growth (stage two and early stage three) when plants are small and many plants are concentrated in a small area. A well placed light will also help increase the temperature in a small area of the greenhouse.

Light quantity influences the effect of nitrogen fertilizers on plant growth. Ammonium (NH_4^+) toxicity may occur under very low light and cold soil (less than 55F) conditions. For the plant to make use of ammonium nitrogen, there must be adequate production of sugars and carbohydrates from photosynthesis. Low light, together with low temperatures (see next section) that can occur in the winter greenhouse combined with unique requirements of early seedling growth can lead to problems. A limited number of high intensity sodium lamps (HPS) in a walled off corner of the greenhouse can provide the extra light and warmth needed at a low cost.

It is generally assumed that plants get taller or stretch in lower light. For most plants, however, there is not an increase in height with lower light intensity unless there is a change in light quality, for instance due to crowding or shading by other plants or the greenhouse covering. When plants are tightly spaced, the light quality or ratio of red to far red light changes as plant leaves absorb light. This can lead to increased plant height caused by longer stem sections between the leaves. More space between plants due to larger containers or more space on the bench means shorter plants.

Temperature Management

Relationships between day and night temperature, the 24-hour average daily temperature, and the temperature response of the plant species being grown, are important considerations to overall temperature management.

Average Daily Temperature (ADT). In general, the 24-hour average daily temperature will have the greatest influence on the rate of plant growth. Most plant species grow very little at temperatures less than 45 to 50 degrees Fahrenheit (F) and will continue to grow more rapidly up to a 24 hour average of 75 to 77 F. The rate of growth can be characterized as the rate of increase in weight of the plant, or the rate of formation of new leaves. Cool season vegetables like lettuce, spinach, cabbage, broccoli, etc will grow under temperatures not suitable for warm season vegetables like tomato or vine crops. The variation in growth rate with temperature also applies to cut flowers. An average temperature range for stage 3 would be 60 to 65F.

Greenhouse temperatures also have an effect on nutrient availability from organic fertilizers or compost based media. The mineralization of nitrogen and the conversion of ammonium nitrogen to nitrate nitrogen are dependent on the activity of soil microorganisms. At soil temperatures of 55F and above, nutrient and nitrogen availability are usually adequate and increase as plant growth increases. However, the soil warms more slowly than the air after a cold spell and the recovery time for the microorganisms may be longer than for the plant. Bottom or soil heat is highly recommended for seed germination and transplants if air temperature is maintained below 55F.

Day/Night Difference (DIF). Considering how day and night temperatures vary can help in determining how the plant will look. When the day is very warm and the night is cool or cold, plants will be taller. If the day and night temperature are both the same, plants will be shorter than with warm days and cool nights. If the night temperature in the greenhouse is kept warmer than the day temperature by using heating at night and ventilation during the day, the plants will be even shorter. Keeping day temperatures cool (<60) rather than letting the greenhouse get very warm (>70F) will help keep transplants shorter. The relationship is referred to as DIF, or difference between day minus night.

Relative Humidity and Condensation

Light, temperature and ventilation will also influence the moisture in the air. High relative humidity limits nutrient uptake and increases the potential for foliar and flower diseases. Condensation on the roof covering can also dramatically reduce light intensity. Ventilation to remove moisture will usually precede attempts to conserve energy or heat in the greenhouse.

Hardening Finished Plants

The transition from the greenhouse to the field involves changes in light, temperature and wind. A gradual transition over a few days with some protection from wind and temperature but full exposure to light can increase the survival rate of transplants in the field.

Part III. Root Zone Management

Irrigation water quality, irrigation method, root medium, and fertilizer all interact to define the root zone. For transplant production, the usually very limited root volume and the variety of container sizes and materials also play a major factor in managing the root zone. Rapidly growing plants with limited root volumes require careful water and nutrient management to provide a healthy transplant with proportioned root and shoot growth.

Growing containers

Transplants can be grown in all types and sizes of containers including no container at all if soil blocks are used. Before the routine availability of plastics, transplants were successfully grown in wooden flats and roots were simply pulled or cut apart at transplanting. Plastic or foam trays allow for less transplant shock and ease of handling individual plants with intact root balls. But they can also add to materials cost and be a disposal problem if recycling is not an option. Pressed peat pots are readily available in a variety of sizes but I have not seen many specific examples of their use for vegetable transplants. A decision will have to be made regarding whether germination and finishing will occur in the same container or whether germination will be done in one container followed by transplanting to a finishing container.

Seed Germination. My experience with the commercial bedding plant greenhouse was entirely plug oriented. Even "smaller" growers use some type of mechanical seeder that individualizes seed into cells or "plugs". From hand held needle seeders run with vacuum pumps, to inline needle seeders, to drum seeders, there is a wide range of options. Plug technology is over 30 years old and has been driven by the need to minimize labor and crop time while maximizing space efficiency. Shorter crop time and more time at high density plant spacing allow multiple "turns" of the greenhouse which greatly increases profitability. The organic transplant producer has to consider how critical these factors are for them.

Germination and a longer growth period in small plugs followed by shorter finishing times in larger cells does require more attention to detail than germination in open flats for shorter times and longer times in finishing flats. However, germinating and growing in 800, 600, 500 and 400 cell trays is the most challenging and probably best left to specialty propagators. If transplants will be direct sown and finished in 200 - 128 cell or larger trays, "plug" production is much easier to do and might better be called transplant production.

Plug production techniques have evolved based on soilless root media and frequent applications of primarily nitrate nitrogen water soluble fertilizer. Compost based root media and less frequent application of water soluble organic fertilizers like fish emulsion can be successfully used for plug production.

But what is most economical and efficient for the small grower producing a wide range of diversified crops? Efficiencies of plug production are partially based on specialty propagators producing large numbers of flats of fewer species and cultivars. Plug production is less an advantage with production of smaller numbers of a wide diversity of crops. Other questions to ask include whether labor in March, April, and May will be a limiting factor for the small farm like it is in a commercial flower greenhouse? Will the greenhouse space need to be filled and emptied more than once to be profitable like in a commercial flower greenhouse?

Standard flat inserts with 20 rows are one efficient way of producing a large number of species. These are used for transplant production in the MSU trial gardens were one 48 cell flat of over 1500 different crops are desired. These flats require very little germination root media. Crops with similar germination times should be grouped within a flat. If watering is a concern, or the time from sowing to transplant will be longer, individual 4 or 6 inch pots can be used for sowing seeds. With plugs or any germination container, the smaller the cell, the more frequent the need for water.

Transplants. A review of research regarding size and age led the authors to conclude that inconsistencies in experimental techniques and a wide range of variables resulted in no specific recommendations to make regarding a "best" age or plant size. Larger or small root balls, younger or older transplants, there are many acceptable approaches.

One key distinction that can be made is whether or not the plants are stressed or treated to favor the induction of flowering. For ornamental bedding plant transplant production, the market demands miniature plants in flower even though long term garden performance would likely be favored by more vegetative transplants. Drought and low nitrogen are frequently used to control plant size and initiate early bud set. This strategy would produce a totally unacceptable transplant for cut flower production. For field grown cut flowers it is important that growth not be checked or flower initiation encouraged prematurely.

What about vegetable transplants? The answer is most likely dependent on the market and desired result. For early but limited yield that might be desired for a homeowner vegetable garden, tomato and pepper transplants in larger containers can be stressed to induce early flowering. But for field production the goal will be to put a vegetative plant out and promote rapid vegetative growth that will produce the largest yields.

Production costs will likely be a primary factor influencing transplant size. Tomatoes and peppers in 4 inch pots do great when transplanted. But where is the greenhouse space or labor needed to handle such large transplants?

Root media

Physical Properties. While plants can be grown in all types or root media, seed germination and transplant production have perhaps the greatest requirement for a high quality, uniform medium. It is sometimes noted that coarse or large particle size media are desirable due to the need for high aeration during germination. However, most germination media are actual fine with small particle size in order to provide uniformity for filling small plug cells. Aeration is maintained instead by not over watering or saturating the root medium.

Chemical Properties. Nutrient levels in a germination medium need to be low but balanced. Excess soluble salts can reduce water uptake and damage young roots. Recommended electrical conductivity values are 0.4 to 0.6 mS for a 1:2 soil to water sample or less than 1.0 for a saturated medium extract (SME). The root medium pH should also be in the range of 5.5 to 6.5, although many species will germinate over a range of 5.0 to 7.5.

Biological Properties. The presence of plant pathogens is also a primary concern since germinating seedlings are very susceptible to root rot fungi. This is perhaps the main reason given for using soilless or peat-based media for seed germination. Compost is far from sterile but can be used for seed germination. Given these basic guidelines, the selection of root medium *components* and *amendments* together with fertilizer will likely have the greatest impact on whether transplant production is suitable for organic certification.

Components. Components are the materials used to provide the base media, and are present at rates of at least 10% by volume. Common components such as peat, perlite, vermiculite, coconut coir, and bark are acceptable for organic certification. Compost is the most renewable and a preferred organic substrate.

Peat: In my experience, peat is the leading transplant media candidate. There are many grades of peat and for potting media. Usually the best Canadian sphagnum grade available is worth the investment (Sungro, Fafard, Premier). Liming recommendations are different when more or less peat or different types of peat are added (5 to 10 lb per cubic yard range for 70% peat medium).

Coconut Coir: Another material like peat is coir. It is a renewable substrate like peat, but it is transported much further. It does work great for growing plants and has good water and air holding properties. The level of soluble salts (EC) would be expected to be higher than peat as would the pH. We choose between peat and coir depending on the pH of the compost.

Compost: Well made compost can have physical properties (air and water holding) similar to peat. However, the nutrient content would be much higher. It is also critical to recognize the difference in pH. While peat is often very acidic and requires the addition of lime, compost is often basic when first finished, but usually neutral when fully mature. We choose the mixture of peat and compost primarily based on attaining the desired pH. For the compost I have made from garden waste, straw, hay and sheep/horse manure, a 50/50 blend of peat and compost has yielded a pH of around 6.0 which is desired for a potting media. At pH of 5.8 to 6.3, phosphorus will be much more available, particularly if there is little or no soil present. Sieving or screening the compost helps provide a more uniform product. Compost feedstocks and maturity determine pH and the pH must be tested.

When it comes to making compost for potting medium, one could refer to a process of making “designer” composts. The quantity needed is not large, and the impact on the overall farm production can be very large. Transplants play such a key role that making compost specifically for transplants makes sense.

Following is an example of a non manure compost recipe for transplant production (or compost tea). The goal is to use readily available material that would be affordable and reasonably constant across geographic regions.

1 bale straw
1 bale grass hay or grass alfalfa mix
1 bale wood shavings for bedding
1 bale (3.8 cu ft) peatmoss
6 cubic feet (wheel barrow) of soil
6 cubic feet (wheel barrow) of grass clippings (If green plants are not available use alfalfa hay.)
6 to 12 cubic feet (wheel barrow) of green plants like comfrey, weeds without seeds, green manure, etc.

We make this mixture by layering the components in a small manure spreader and then letting them come out the back in a pile. Water is added during layering and while the material is discharge from the manure spreader. This mixture reached over 140F in four days and held a temperature above 130 for one week or more. The pile was put back into the spreader for mixing. Alfalfa meal was added (25 lbs or 5 gallon bucket to about 4 yards) to assure a rapid second heat. This mixing was done in June and July when green plant material was readily available.

The mixture was kept moist and allowed to mature through the remaining part of the summer. The piles were covered and left outside for the winter. Ideally the material would be brought into the greenhouse in the fall to be ready for spring transplants. Fertilizers such as rock phosphate or greensand could be added during composting or when the compost is brought in for the winter (although it is not likely needed). These materials have low solubility and may not contribute much, but they definitely will not hurt things and end up in the field with the transplant.

Perlite and Vermiculite: Coarse components like perlite or vermiculite are usually added because they help maintain airspace under conditions of fine particle peat or compost and improper irrigation. However, with quality peat and compost, they may not be needed for aeration. The level of soluble salts in the compost may be high enough that perlite and or vermiculite are needed to lower soluble salt concentrations to ranges acceptable for seed germination.

Bark and Sand: Based on my experience to date, even aged or composted pine bark would not be recommended because of the tendency to tie up nitrogen, which usually is in short supply with organic fertilizers. Nitrogen tie up with bark is not a problem with synthetic fertilizers because it is easy to add a little more N. While sand is often still listed as a possible component to add aeration, it rarely contributes to adding pore space in already porous media. The potential for chemical and disease contaminants are other reasons to not use sand.

A likely problem with peat-based media is the low nutrient content and holding capacity. With the addition of slowly soluble or available fertilizers (listed later), and water soluble fertilizers, organic fertilization can be accomplished. However, the addition of compost can significantly increase nutrient retention and capacity and is highly recommended.

Amendments. Examples of common amendments (less than 10% by volume) to peat-based media are lime, fertilizers (potassium nitrate, superphosphate, micronutrients), wetting agents or other additives. Synthetic fertilizers and wetting agents routinely added to peat-based media are not acceptable for organic certification. Wetting agents are needed primarily when peat is very dry. One option is to not allow the peat to get very dry. Another consideration is that other components like coconut coir, perlite and vermiculite wet without wetting agent. Sand also can help increase rewetting. If the peat is moistened with warm water while blending during formulation with other components, it is likely a wetting agent is not necessary. Peat does vary in wettability.

Formulations. The recommendation to date is for a blend of peat and compost or peat-based soilless medium and compost. The current greenhouse standard unit of measure for amendments is pounds added per cubic yard of medium (3' x 3' x 3' = 27 cubic feet). Amendments are not essential but can include: blood meal (nitrogen), rockphosphate (phosphorus and calcium), greensand (potassium and micronutrients) and other sources in the table provided. Elliot Coleman recommends combining equal parts of these three (although he does not state equal parts by volume or weight, we assumed volume), and then adding a rate equivalent to 14 lbs per cubic yard to a peat or peat-based medium and compost (50/50 by volume) blend. He recommends letting the blend sit for a month or more before using, although he does not state that this is essential. This or similar formulations were very effective for us with edible flowers and herbs.

The cost of commercial peat-based media typically ranges from $50 to $75 dollars per cubic yard in bags or bales ($2.00 to $2.50 per cubic foot). Assuming peat at $1 to $1.25 per cubic foot and perlite and vermiculite at $1.50 to $2.00 per cubic foot, component costs alone for a 70% peat medium would be $30 to $40 dollars per cubic yard. To add the Coleman recommended organic nutrients assuming bloodmeal @ $28/50 lb, greensand @ $6.75/50 lb, and rock phosphate @ $7.50/50 lb would cost $5 per cubic yard (plus the cost of lime). Additional costs would be equipment and labor. What is the cost (or value) of quality home made compost?

Coleman mentions mixing the media and fertilizers in the fall which results in allowing the mixture to sit for some time before use. During the fall of 1999 we grew poinsettias with several organic fertilizers in comparison with synthetic fertilizer. Poinsettias transplanted into media with soybean or alfalfa based fertilizer were initially stunted or killed. Fresh plants replanted into the same medium which was remixed after two weeks grew fine. After incorporating plant derived fertilizers (soybean meal, alfalfa meal) there is a noticeable amount of fungal growth during the initial breakdown. Our recommendation is to add adequate moisture for decomposition to occur and allow the medium to sit for 2 to 4 weeks before planting. Soak amendments like pelleted alfalfa prior to adding to insure adequate moisture.

Bradfield Alfalfa Fertilizer. Based on a number of greenhouse studies, Bradfield Natural Fertilizer (www.bradfieldind.com) can be added to peat-based soilless media or potting media containing compost or soil at a rate up to 10 to 20 lbs/yd3 to add complete nutrients that last over 2 to 3 months. The alfalfa based fertilizer also supplies carbon based compounds that can stimulate microbial activity in the root medium.

For alfalfa-based pellets like Bradfield Fertilizer (3-1-5), the nitrogen/nutrient availability might be in the 15% to 30% over the first two weeks but there is not good data to know for sure. The continued availability would depend on microbial activity in the potting media, moisture availability, and temperature. There might be greater nitrogen availability in a medium with compost or soil at 10 to 30% by volume (usually increased microbial activity) compared to a peat-based medium.

In our research we started with a high rate of 40 lbs Bradfield Fertilizer /yd3 of root medium (24 oz or 672 gram per ft3). Assuming 3% nitrogen, this rate would provide about 10 times the amount of total nitrogen as the potassium nitrate rate (1 lb/yd3) given above. We are assuming that about 10% of the nitrogen is immediately available. This rate was not used for seed germination but for a transplant medium for growing impatiens and other bedding plants. We had good results with this rate and grew impatiens for up to 12 weeks without additional fertilizer. We did not add other fertilizers for phosphorus or micronutrients. We did add lime to peat-based soilless medium but not the compost medium.

There are a number of factors that can influence results and nutrient availability as mentioned above. We did see greater nitrogen availability in a medium containing compost compared to a peat-based soilless medium. We did not do rate comparisons with Bradfield Fertilizer. A comparison of our rate to the manufacturers rate indicates that we were much higher than the recommended rate. A rate of 4 tsp/gallon as recommended in the literature is approximately equal to one gallon (5 lbs) of fertilizer per cubic yard. A garden rate on the bag is 25 lbs per 1000ft^2 which would equal 2.5 lbs per 100 ft^2 or cubic yard. (Similar rates are often recommended for 100 ft^2 or 1 cubic yard of medium.) Our rate of 20 to 40 lbs/yd^3 is almost 10 times the manufacture's recommended rate. A rate of one-half of the rate we used might be a better starting point – 20lbs/yd3 or 12 oz per cubic foot or even 10lbs/yd3. Based on the density of Bradfield fertilizer (5 lbs/gallon), this would equal about 1 pint fertilizer in volume per cubic foot root medium.

The cost of a quality peat-based potting medium is in the range of $40 to $80 per cubic yard. At $15 per 50lb bag, the addition of Bradfield at the 20 lb/yd3 rate would add about $6 per cubic yard. (At 480 6" azalea pots/yd3, the cost per pot is 1.25 cents per pot.) This is much more expensive than potassium nitrate, but what is achieved is a much longer term dose of nitrogen and other beneficial effects on microbial activity. When organic certification of the root medium is required, the Bradfield fertilizer is a valuable addition. The

Bradfield fertilizer also provides adequate P and K

Water Soluble Fertilizers

With the use of synthetic water-soluble fertilizers and mechanical injection devices (proportioners), fertilization is one of the easiest aspects of large scale greenhouse production. For Organic certification, there are materials available but few specific, published recommendations. With a well prepared root medium, only nitrogen (N) will likely require management during production. While some phosphorus (P) and potassium (K) can be added, it is N that has the greatest effect on plant size. (Assumes calcium (Ca), magnesium (Mg) and sulfur (S) are in the root medium or water.

Fish Emulsions. We have used soilless peat-based medium and coconut coir without synthetic fertilizer added and only fish emulsion (5-1-1) used as fertilizer for periods of several months up to almost a year without any apparent nutrient deficiencies. Use of fish emulsion as a sole fertilizer for potted plant production has been well demonstrated by others, many years before we tried. Although I did not expect it to work due to the low P and K content.

For a 5-1-1 liquid formulation, a dilution rate of 1 to 100 (1 gallon in 100 gallons or 6.4 ounces in 5 gallons) will provide 500 ppm. (1% liquid equals 10,000 ppm) A dilution rate of 1to 1000 will provide 50 ppm N. The best rate is in this range and will be determined by the N levels in the root medium, the desired growth and the frequency of application. When a fertilizer injector is available and rapid growth is desired, fertilization at every irrigation with low rates like 50 to 100 ppm N is common. However, with products like fish emulsion that have a fragrance to contend with, fertilization at biweekly or monthly frequency is preferred. Interval fertilization also prevents over fertilization. Fertilization can be delayed until the plants show signs of lower leaf yellowing or slowed growth that indicates more N is needed. A final shot of N just before transplanting may be beneficial.

Omega 666. We have also worked with Omega 666, a water soluble blend of digested organic fertilizers purchased from Harmony Farms in California (also available from Peaceful Valley Farm Supply (www.groworganic.com) . While the cost for 5 gallons of 6-6-6 was over $200, the material could be diluted as much as 1000 times to make 60 ppm N which would cost 4 cents per gallon. At 600 ppm applied every two or three weeks, the cost would be 40 cents per gallon diluted material. By comparison, synthetic water soluble fertilizer like 20-10-20 @ $20/25lb bag applied at 600 ppm N would cost 2 cents per gallon diluted solution. Buying small quantities at $2.00 per pint, fish emulsion costs 19 cents per gallon to apply at 600ppm N (1.5 fluid ounce per gallon water). A 5% N solution at 1:100 will provide 500 ppm N.

All the organic nitrogen applied is not readily available as with synthetic fertilizers. The proper rate to apply must be based on looking at the plant and considering the temperature and biological activity of the root medium. Nitrogen availability from organic fertilizers is expected to be quicker with compost and soil containing media compared to peat-based soil-less medium. Applications of organic fertilizers are not expected to show the rapid 1 to 2 day growth response seen with synthetic fertilizers. Synthetic fertilizers are primarily nitrate nitrogen which can be immediately used by the plant. Organic fertilizers are primarily complex nitrogen like protein which must first be broken down to ammonium nitrogen (mineralization) or ammonium nitrogen which is changed to nitrate nitrogen by bacteria (nitrification). Ammonium can be used by the plant directly, particularly rapidly growing plants in high light. But most nitrogen is taken up as the nitrate form. Too much ammonium nitrogen in low light (February, March) or cool soil conditions (<55F) can be toxic to plants.

Summary of Fertility Management Options:

#1. Purchase an organic approved/certified root medium and supplement with water soluble organic fertilizer as needed (possibly fish emulsion or fish hydrolysate). Probably higher cost option, but requires lowest amount of experience and little advanced planning.

#2. Formulate peat lite (peatmoss (60 to 70%), perlite and or vermiculite(30 tp 40%)) media without fertilizer and wetting agent but limed to a pH of 5.5 to 6.5. Apply water soluble organic fertilizer as need (usually soon after seed emergence or at transplanting). Most commonly used fertilizer is an approved fish emulsion. Little preplanning necessary, components are reasonably available but expensive in small quantity.

#3. Peat lite media as above with lime, blood meal or alfalfa meal for nitrogen, rock phosphate for phosphorus and green sand or organic approved potassium sulfate for potassium. Rates as recommended by Eliot Coleman. . Or consider Bradfield Alfafa Fertilizer. Water soluble organic fertilizer, usually fish emulsion, applied as needed. This method adds some nutrients to the root medium so everything is not dependent on liquid fertilizer application. Requires purchasing the organic nutrient sources and making sure the rate and method of application are correct.

#4. Mature, well-balanced on-farm compost blended with peat, (and possibly perlite and or vermiculite if aeration needed) to provide a medium with good aeration and water retention and all the nutrients to grow and finish the transplants (and perhaps help in the field also). Nutrients such as alfalfa, alfalfa meal, any organic approved nutrient source can be incorporated during the composting process. Lime is generally not necessary with compost but check the pH. Requires making compost the summer before transplant production. Compost will mature during the fall and then can be stored for use in the spring. Compost must have good physical, chemical and biological properties.

Irrigation

Water Quality. For a detailed discussion of water quality issues related to greenhouse production, refer to the chapter 5 in the book *Tips of Growing Bedding Plants* published by the Ohio Florists Association. Water quality refers to the concentration and species of chemical elements found in water that make it suitable or unsuitable for irrigation. In general, the shorter the crop time, as for transplants, the less effect water quality will have on plant growth. However, it is also true that the smaller the growing container and the more frequent the irrigation, the greater the effect of water quality. It is important to have your water analyzed and to know what desired or undesired elements are present and how they will effect your choice of root media and fertilization.

Method of Application. The success or failure of plants in a greenhouse is most often attributed to the person handling irrigation. The primary questions to be addressed are *When* to water, *How much or what volume* to water, and *What method of application* to use.

When to water will change over time. In early stages of seed germination it is critical that moisture availability be very high. Once root growth begins, moisture levels are gradually reduced over time. In finishing stages transplants may be wilted on purpose.

How much to water refers to whether or not to partially moisten the root media, thoroughly moisten the root medium, or water enough so excess drains from the root medium (leaching). Standard rules of watering to thoroughly saturate or leach at every irrigation do not apply to seed germination or transplant production. Root medium air space in shallow containers is maintained more by how much water is added than by the particle size of the root medium. Leaching is also not recommended unless soluble salt levels are excessive. Usually the intent is to retain as much of the nutrients in the root medium as possible, particularly with organic production methods and the small root medium volume.

Choices of how to water include overhead watering using hose and breaker or sprinklers verses subirrigation by flooding from below. Making sure the foliage is dry at the end of the day is important in the later stages for disease control. The best system may be one that combines overhead irrigation in the early stages and subirrigation in the later stages.

If water is going to be used to regulate plant size, it is important to recognize that there is more than one way to grow plants dry. One way is to water plants thoroughly and then allow them to dry until wilting occurs. This method does not reduce plant height nearly as much as frequent, light applications that do not saturate the root medium and keep the plant under a constant low level of drought stress.

Part IV. Pests and Diseases

It is totally within the realm of possibility that if your farm or greenhouse is relatively isolated, the greenhouse has been empty and at low temperatures over the winter, you have not over wintered plants in the greenhouse, you start strictly with seeds, as opposed to purchased cuttings, your potting medium doesn't harbor any noxious pests and diseases, you don't over water or over fertilize your transplants, and you minimize crop time in the greenhouse, that you could never see or experience any of the following pests and diseases. The best insect and disease management program in the greenhouse is based on a strong defense and a well thought out plan. A good starting place for basic information about integrated pest management in the greenhouse is the article available on the ATTRA web site (attra.org).

A good starting recommendation is to use the best cultural methods as outlined in the previous two sections and grow a healthy transplant. The much published and referred to pest and disease control triangle includes the environment, the host and the infesting or infecting agent. Start with a growing environment providing proper light and temperature conditions that favor growth of the plant and minimize the growth of the insect or disease. For example, warmer temperatures mean faster growing transplants, but will also mean greater potential for pest populations to develop. The third part of the triangle is knowing as much as possible about the pest or disease.

Pests

Identification. Based on experience with large, commercial greenhouse operations the ten most common greenhouse pests could be rated this way. The three that present the largest, routine problems are white fly, thrip, and fungus gnats/shore flies. The next three that are occasional problems or more crop specific problems are aphid, spider mite, and leaf miners. Less common but still a problems with certain crops are mealy bug, scale, chewing caterpillars and slugs.

In the first year of our research with edible flowers and herbs, we battled the white fly and thrips primarily by releasing purchased predators or parasites. The second year we used what we learned previously to keep the whitefly and thrip within acceptable levels, but the aphids were a major problem. We used more predators and occasional sprays, which were suitable for organic certification but were as hard on the purchased predators as they were on the pests. The third year we did not have any major outbreaks but we had some problems with spider mites and potentially devastating problems with mealy bug. For the previous mentioned research, we were located in a large greenhouse range of over one acre with many different research projects and crops. In general all the pests were present and chemical applications were heavy. We were an island in the middle and fairly constantly under scrutiny as a source of pests because we were not spraying chemicals. Crops were in the greenhouses year round.

In years since the experience described above, working in three separate greenhouses that were more open to the outside and not surrounded by other greenhouses being sprayed, insect problems have not been a major concern. We have discontinued all work with releasing predators. For three years we have been able to manage with minimal applications of soap to wash plants with a hose end sprayer and the occasional application of neem or Pyganic for aphids, whiteflies or thrips. Improvement in our fertility management may have something to do with the reduced insect problems.

Management. Perhaps one of the best recommendations is to minimize transplant crop time. Schedule carefully so plants are not in the greenhouse any longer than necessary. The longer the production and or holding time, the greater the probability for uninvited guests to move in.

An option in the greenhouse, particularly for short term crops like transplants, is to use either protectant or biorational pest control sprays: (sprays based on naturally occurring control agents or competitors). Examples of sprays acceptable for organic certification by at least some certifying agencies include insecticidal soap (Ex. M-Pede), *Buavaria* fungus (Ex. Botanigard), neem based products (Ex. Neemx, Azatin), garlic or hot pepper barriers, compost teas and herbal or mineral preparations.

We have experimented with most of these options. Effective timing and methods of application that allow thorough coverage are very important for success. Repeated applications at appropriate intervals are almost always necessary to reduce or eliminate a developing pest population.

Diseases

While healthy growing transplants are often resistant to infection by the ever present root rot fungi, the initial phases of seed germination and the early stages of seedling growth are perhaps the most susceptible parts of the plant life cycle. If root rot pathogens are present at high levels, plant losses can be complete.

Root rot pathogens potentially present in root media in conventional greenhouses are generally controlled by careful selection of the root medium, watering practices that minimize over or under watering, and use of selective fungicides that target a fairly narrow range of fungi. The use of selective fungicides is very important in routine large scale greenhouse production and widely practiced. This practice is not acceptable for organic transplant production. The techniques of steam or chemical sterilization (kill everything) or even pasteurization (kill most of the bad guys) are no longer commonly practiced in most commercial greenhouses. While there are authors that recommend baking or heat treatment of seed germination media, the practice is not practical to accomplish and of questionable value.

Germination and transplant media formulated from sphagnum peat, perlite and vermiculite will generally not require any additional treatment. The level of innoculum present in peat is typically low and perlite and vermiculite are sterile as a result of the manufacturing process. If compost is to be added, the composting procedures should be tested for the suitability to clean the compost of seed (root rot) pathogens. When the heat of composting (130-150 F) is maintained for adequate time (2 to 3 days) and the entire pile is heated at some time via mixing and reheating, the resulting compost should be fine for germination media assuming the quality and maturity are satisfactory.

Identification. The most common recognized greenhouse root rot pathogens are *Pythium* and *Rhizoctonia*. Also problems at times with specific crops are *Phytophthora*, *Fusarium* and *Theleviopsis*. The most common recognized greenhouse foliar fungal pathogens are powdery mildew and *Botrytis*. The most common bacterial pathogens in the greenhouse are *Erwinia*, *Pseudomanas* and *Xanthomonas*. The most common viral pathogen in commercial greenhouse currently is impatiens necrotic spot virus (INSV) which is transmitted by thrips. When soil is used in the greenhouse, nematodes could also be a concern (not likely).

Management. As previously stated, the best control for root rots is proper formulation of the root media, proper watering, and fertilization practices that favor healthy, undamaged roots. Foliar fungal pathogens are best minimized by keeping relative humidity in the greenhouse low (<80%) and water off the foliage. Reducing relative humidity may require venting warm moist air out of the greenhouse late in the day. For bacterial and viral infections, rouging (removing) potentially infected plants as soon as possible, minimize splashing water that can spread bacteria (use subirrigation if necessary), and controlling aphids and thrips that can spread viruses are recommended.

The use of insecticidal soap as a control agent for powdery mildew has been suggested. Compost tea or herbal preparations likely could be effective and are discussed in a publication available at the ATTRA web site (attra.org).

Pest Summary

I have written long explanations about all types of pest control methods suitable for organic certification including release of predators and parasites. The bottom line after many years of experience is that once we moved out of a university research greenhouse range where every other greenhouse but ours was sprayed regularly, and we learned how to properly use compost in the root medium to provide adequate fertility, we have had much fewer pest and really no disease problems. When we do have insect infestations, we start with washing the plants with Ivory soap diluted using a hose end sprayer. If that does not work, we have used Neem and Pyganic to successfully manage aphid, thrip and whitefly populations. In my greenhouse at home on the farm away from the University greenhouses, I have never used anything but soap. The ATTRA website has lots of information about pest management but I hope you don't need it. If you do, look at your growing methods and greenhouse temperature first.

Over All Summary

Transplant production is a key to successful farming in the field and greenhouses. While experience is a great teacher, attention to detail and good record keeping can reduce the mental stress and worry that might come with the first years of transplant production. I have broken the process down into parts for you to consider. Start with good seed, good root medium, and a clean greenhouse. Pay attention to light and temperature conditions and water carefully. Add more fertility if needed, but don't add too much. Keep an eye out for pests and problems and handle them quickly.

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