PRACTICAL REQUIREMENTS FOR CONTROLLED ENVIRONMENT NURSERY STOCK PRODUCTION

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Over the last 10 or 20 years, a revolution has been taking place in the nursery industry. Retail nurseries deal almost exclusively with containerized plants which can be handled, transported and planted at almost any time. Conifer seedling produces are adding greenhouse complexes to provide container or "plug" seedlings to help avoid the availability, mortality and planting shock problems associated with field-grown stock. Methods are being investigated which will allow the grower to eliminate inclement weather losses, such as those caused by unexpected frosts and dry spells, and provide a system of production not dependent upon the traditional spring labor forces required to compress huge quantities of work into several weeks. New propagation processes will enable the nurseryman to reproduce, for himself, sufficient quantities of best selling ornamental cultivars and thereby avoid the supply problems faced by other retailers.

At Michigan State University, research has been progressing and experience has been gained in this field of controlled environment nursery stock production; we would like to share some of our results with other growers.

SPECIES AND SIZE REQUIREMENTS

To effectively prescribe controlled growing conditions for plant material, it is important to specify whether hardwoods or conifers are to be produced and stock should be grouped accordingly. Lighting, heating, watering and essentially all other provisions may vary significantly when growing one type or the other. Producing forest tree seedlings for large scale plantings will require substantially different production facilities than necessary for retail potting stock. One must decide what target quantity and size is required in order to efficiently utilize a controlled environment.

MATCH CONTAINER TO SIZE GOALS AND PRODUCTION PHILOSOPHIES

In keeping with the basic goal of trying to completely regulate plant growth for optimum benefit, containerization is generally considered of paramount importance. This will allow each individual tree its own root environment free from competition by adjacent seedlings and results in maximum uniformity for a given crop. In addition, containers allow the transfer of seedlings from the shadehouse to the field without severing large number of feeder roots thereby reducing transplant shock.

There are probably almost as many container systems as growers themselves and certainly each container has corresponding advantages and disadvantages. The Leach tubes are hard plastic bullets which fit into a receptacle and are easily rearranged for consolidating filled cavities or grading for shipping purposes. The soft plastic styroblock and hard plastic multipot have extruded cavities which are not removable but provide a plug plant without the inconveniences of handling many individual tubes. The styroblock can be reused 3 or 4 times and the multipot 8 to 10 times. The Japanese paper pot and Kys peat sticks are containers which can be planted with the seedling. This allows very little of the accompanying soil to be lost in transit so root disturbance is kept to a minimum.

The paper pot must be filled with soil as all the others; however, the peat stick is made of a compressed medium which is ready for wetting and sowing. To aid in plug extraction the book planters, such as Rootrainers, were designed. These units lay flat in storage but when closed form cells which can be filled with a soil medium. When the seedlings reach the desired size, the "books" are opened up and the plants extracted with little soil ball disturbance.

Probably the most flexible container system is the plant band system used in the Forestry Department at Michigan State University. Paperboard containers are inserted into polyethylene (high density) receptacles one foot square. Their square shape controls root curling and the open bottom design encourages air pruning of roots. Different size plant bands can be substituted to generate seedlings ranging in size from 6" blue spruce, (*Picea pungens*), to 3' black walnut, (*Juglans nigra*), using the same basic components.

One key consideration which should be focused upon at the beginning is the degree of production system mechanization desired. Using highly mechanized facilities, it is possible to produce a million forest tree seedlings with only two employees. The styroblock and multipot are probably the best suited for mechanized filling and sowing equipment. One problem, however, is that it is not feasible to produce 3' English oaks, (*Quercus robur*), or sugar maples, (*Acer saccharum*), with the block sizes available.

MATCH SOIL MEDIUM TO CONTAINER

Once a container is chosen, the next step is to determine the growing medium. A mixture of peat, topsoil and sand has been a longtime favorite for potted plants, but with rising greenhouse overhead costs, many growers have switched to soilless media. Mixtures free from pathogens, herbicides and weed seeds, and which vary little from year to year provide perfect substrates for total growth control and maximum yield. Shipping costs are lower for the finished plant due to the lighter weight soil mix. The most common mixes contain approximately 50% milled Canadian peat moss and various percentages of vermiculite, perlite, sand, or bark.

The goal is to develop a mixture which works best with a specific container and growing system. It is important to employ a mix which, when compacted, will maintain the proper balance between moisture and aeration and permit a firm soil plug to be extracted at harvest time. Coarse mixtures with perlite score the inside of small styrofoam cavities, thereby reducing reuse life, but may be required in deeper containers to prevent waterlogging. When using a commercially prepared mix containing 50-50 peat-vermiculite, we found it necessary to keep the soil almost bone dry to avoid yellowing from excess water on jack pine (*Pinus banksiana*), and western white pine (*Pinus monticola*). Since then we have used a mixture of equal parts of Canadian peat, #3 vermiculite, and perlite; this works well with over 50 species. The only problem we have encountered with this mix is a lack of firmness in the soil plug. This problem has been resolved in two ways — by slightly greater compaction at the time of filling and by increasing the vermiculite fraction in the mix.

THE CONTROLLED ENVIRONMENT

One must next choose a suitable facility in which to control the environment to achieve the highest yields for given crops. This can vary from a large greenhouse complex to a growth chamber. Excellent results have been attained with plants grown on a growth frame in an enclosed room with exclusively artificial light. Still another possibility which shows promise is a hybrid of these two extremes and consists of multiple layers in a standard greenhouse. The chief benefits of a 2-layered production scheme is the ability to produce twice the number of plants without investing in and heating another structure and at the same time use solar energy rather than electricity for most of the lighting.

Whatever construction is chosen, the temperature should generally average 21° to 29°C (70° to 75°F) with extremes not lower than 10°C (50°F) or higher than 30°C (85°). In many climates cooling pads are mandatory for adequate cooling during summer days. With poly greenhouses, the humidities are usually high enough to make additional humidification unnecessary. In an air conditioned growth room, however, humidifiers are desirable.

Other than the obvious temperature considerations, the single most important environmental factor to be regulated for nursery stock production indoors is photoperiod. Night lighting is essential for most species to keep the plants in an actively growing phase. The result is that 3 or 4 years of growing time can be telescoped into one continuous production phase of 4 to 9 month duration. To effect this physiological control, red light (650-700nm) must be used continuously or for short periods at properly spaced intervals during the dark hours. Cool-white fluorescent lighting at approximately 40 foot candles is effective if continued at night to provide at least an 18 hour day. This would amount to roughly forty 4-foot 40-watt, 2-bulb cool-white fluorescent fixtures in a 30′ × 96′ house. At our greenhouses we use fluorescent lights which are switched on in the evening and remain on long enough to extend the photoperiod to 20 hours. Incandescent sources provide light rich in the red wavelengths, and can be cycled in short intervals and be, therefore, less costly. The Colorado State Forest Service at Fort Collins, Colorado schedules their lights to run for 25 seconds every six minutes and this is enough to "trigger" the plants for continuous growth.

If only artificial light is used in a growth room, cool-white fluorescent high-output lamps @ 900 ft. c are very effective in providing blue, yellow, orange, and some red wavelengths for good growth response. An even better spectrum is achieved when incandescent lamps are included at the ratio of 1 incandescent for every 3 fluorescent units to provide a better red-blue balance.

SEEDING

It is of paramount importance to grow a crop from genetically superior seed, that is, seed with proven qualities of high germination, superior color, growth rate or any other desired characteristic. Pretreatment of seeds is required in some species. Black walnut, and sugar maple need moist stratification at 4° (38°F) for 3 months while others such as white birch, (*Betula papyrifera*), blue spruce and Douglas fir, (*Pseudotsuga menziesii*) need little or no stratification. At MSU we sow seed at a density of 3 to 5 seeds per cell depending on germination test results and cover lightly with medium to a depth of 1½ times seed thickness.

After misting several times daily to prevent surface drying, the seedling hypocotyl should emerge in about 1½ weeks. A few days after sowing we treat the surface with a light application of benomyl to control damping-off fungi and repeat the procedure at 2 weeks. At 4 weeks, seedlings from overfull cells are transplanted into empties and at 6 or 8 weeks excess seedlings are thinned so that each cell contains only 1 tree. Barber shears work well for snipping unwanted germinants.

FERTILIZING AND WATERING

Prior to sowing, the soil medium should be fertilized several times with a fertilizer complete with trace elements such as Peters 15-16-17 or 20-19-18. The medium should also be watered with clear water to thoroughly moisten it for sowing. The seedlings should be fertilized once per week for approximately 6 weeks with a full strength solution with one such application containing STEM micronutrient mix. After 6 weeks, a switch to 25-0-25 is necessary to keep phosphorus buildup from occurring and upsetting other nutrient balances.

Occasionally, additional amendments are required. Calcium sulfate (gypsum) can be blended in with the soil at time of mixing or "salted" on the surface and rinsed in at a rate of 15 to 20 lbs per 100 sq ft. Chelates of zinc, iron, manganese, or copper may be necessary to correct deficiencies. Magnesium sulfate (Epsom salts) at 10 lbs/100 gal is effective as a foliar spray to green up chlorotic, magnesium deficient leaves. Soil samples taken from each species at 3 or 4 week intervals should be analyzed by a reliable soils lab. Posting the results indicating present nutrient status will insure that deficiencies are corrected promptly and toxicities will be avoided before they occur.

For most species, the quantities listed in Table 1 have proven to be generally sufficient and safe to guide our fertilizer program. These figures are based on a saturated paste extract method of soil analysis.

Table 1. Fertilizer salt mix.

Parameter	Level or Concentration
pH	4.5-5.5
Nitrate nitrogen	80-150 ppm
Phosphorus	10-20 ppm
Potassium	120-200 ppm
Calcium	150 ppm
Magnesium	$>60<120$ ppm
Soluble salts	150-250 mhos $\times 10^{-5}$

(mhos $\times 10^{-5}$ mult. by 6.4 gives ppm of sol. salt)

Enhanced carbon dioxide levels up to 2000 ppm can double the growth rate of some plants and are easily provided by a gas-fired CO_2 generator.

PEST PROBLEMS

Once a crop is sown, optimum conditions provided for such rapid growth that it is critical to maintain control over pests and other cultural problems. Overwatering could easily have been the cause of at least 50% of the crop failures we have studied, so some method of evaluation and monitoring soil moisture is desirable.

For insect threats there are methods available for adequate control. We have tried to maintain predator mites to control two-spot spider mites (*Tetranychus telarimus*). We have released tiny wasps, (*Incartia formosa*) to parasitize white fly eggs and provided ladybugs and praying mantis to help moderate populations of some other harmful species. When an outbreak occurs, however, all ideals of biological control are shoved aside and judicious use of pesticides is essential.

For sucking insects such as aphids, lindane or malathion is good for immediate control, but a systemic such as Orthene is more thorough. Control for two-spot mites can be achieved with Plictran. Sevin works well on chewing insects such as caterpillars and leaf beetles. For light infestations of white flies or fungus gnats, yellow boards covered with tanglefoot provide some control, but with heavy populations, closing the house and releasing an aerosol bomb containing Resmethrin is more effective. For soil insects such as fungus gnat larvae or root weevils a dilute malathion, chlordane, or diazinon soak can be used.

Mechanical traps and treated bait such as Ramik are sufficient to avoid rodent damage. We have had countless nuts of English oak dug up, assorted spruce seeds buried in larch (*Larix* sp.) experiments, and various hardwoods chewed off at the base by these unseen "visitors of the night".

It becomes evident that a highly artificial environment devoid of most natural buffers, is very sensitive and must be monitored closely. Under ideal conditions for plants, we often find ideal conditions for pests and pathogens. The so called "salad bar" of greenhouse crops must be constantly monitored to avoid massive outbreaks and the infected plants removed if nothing else. Here containerization allows the flexibility of efficient mobility not found in other systems.

RECORD SYSTEM

Another technique to insure the highest crop success from one year to the next is the employment of a comprehensive record system. This begins with a stroll through the greenhouse facility every couple of hours and up each aisle at least once per day. Look for tears in the poly, holes, cracks, broken fan belts, water lines off, pumps or nozzles plugged, and so forth.

Jot down any observations relating to the condition of the stock such as leaf wilting, curling, or chlorosis, insects, etc. The minimum and maximum temperature should be recorded daily and preferably graphed by a hygrothermograph to indicate fluctuations. Every watering, fungicide, and insecticide application should be logged and described as to concentration, dosage, method of application and time applied.

In addition, a sample of plants should be measured weekly and their height graphed to indicate whether or not the crop is progressing satisfactorily. Using well-recorded growing techniques, one can not only help ensure himself greater crop uniformity but he can also describe his past actions in a form that is easily understood by future employees or other growers from whom he is seeking advice.

GROWING TIPS

We are continually screening various species' response to controlled environmental production and several recommendations can be made. When sowing conifer seeds in the cloudy winter months in a dark, humid greenhouse, a fungicide such as benomyl should be applied soon after sowing and continued weekly for 4 weeks to avoid damping-off. It is very important to follow this schedule for 6 to 8 weeks with Douglas-fir seed, or grey mold (*Botrytis cinerea*), will claim numerous seedlings.

It has been our experience that trembling aspen, (*Populus tremuloides*) and sycamore, (*Platanus occidentalis*), generally need foliar applications of magnesium to reverse chlorosis. Green ash, (*Fraxinus pennsylvanica*), has required applications of iron chelate to ensure proper leaf color. Jack pine needs high iron concentrations in combination with low (4 to 4.5) pH to provide healthy green stock. If full strength fertilizer solutions are used on warm or sunny days, slight burning and leaf cupping might occur on hardwoods.

In our greenhouses, aspen, fruit trees, and willow species invariably are infested by two-spot spider mites in about the 3rd month. Sycamore, honeylocust, (*Gleditsia triacanthos*), northern white cedar, (*Thuja occidentalis*), and green ash will probably get mites, especially if they are in the same greenhouse as the other hardwoods just mentioned. Sycamore often gets large aphid populations also. English oak is likely to harbor aphids and occasionally a few mites.

Avoid spraying pesticides on warm or sunny days. Cloudy days or evenings are ideal times to spray. Care should be used when spraying malathion on European black alder, (*Alnus glutinosa*), as it has caused complete defoliation subsequent to an application.

We would not recommend the constant injection of fungicides into the watering system. In fact, they should be used only for direct control of specific problems. By accidentally eliminating the wrong population of fungi it is conceivable that another more damaging population might become even more extensive. One should always experiment on a number of plants before subjecting a whole crop to an unfamiliar fungicide. We almost totally ruined a section of blue spruce seedlings several years ago by applying a toxic level of the fungicide, Dexon.

When applying water, avoid heavy sprays which cause the seedlings to bend over, or irreversible stem curvature may result. Watering should not be done in the heat of the day as the temperature shock to the plants can be damaging. Partial warming of the irrigation water will help to reduce shock to the plants.

HARDENING OFF

When a crop of seedlings approaches the desired height the supplemental lighting should be discontinued and hardening off procedures started. A normal photoperiod will permit cessation of growth and, on conifers, one should expect to see bud development beginning after 3 weeks. During the months of June through August in Michigan, the seedlings can be taken directly from the greenhouse to a shadehouse. Actively growing seedlings of larch might turn yellow and defoliate if no protection is provided from the summer sun. Birch will have some scorching and leaf curl.

For those seedlings needing overwintering, good success has resulted from placing units tightly together directly on the ground, covering containers completely with sawdust and thoroughly soaking with water in the fall. Fencing and poison bait are needed to avoid rabbit and mice damage.

To harden seedlings off in the winter months, the greenhouse temperature should be adjusted to a maximum of 13° (55°F) during budset. Approximately 3 or 4 weeks after beginning short days, the temperature can be lowered to 10°C (50°F), a week later to 7°C (45°F) and so on down to 3°C (37°F). Most conifers require 4 to 6 weeks of chilling at less than 5°C (40°F) to permit reflushing when the temperature is increased. If a crop of blue spruce or English oak reaches the targeted size and is actively growing at the end of February, one should not expect those seedlings to reflush in May or June after hardening, shipping and planting.

OPERATING PHILOSOPHY

One rather blunt recommendation can be offered for those interested in controlled environment nursery stock production and that is "don't be cheap". Hire a good manager who is a dedicated jack-of-all-trades type of person and don't let him go. Put financial incentives on obtaining successful crops and allow him the authority to direct the operations. One large company employed a staff of six people individually trained in pathology, ecology, physiology or a related specialty. There must be, however, final one-point responsibility on the part of the grower and he must have a reliable staff who can handle the program in his absence.

The greenhouse should have safe, automatic temperature regulating devices rather than manual vents or doors. If at all possible, one should have backup systems for water, electricity, and heat as it is not hard to lose an entire crop of a million seedlings in one day during an unexpected power failure.

LOOKING AHEAD

The future of controlled environment agriculture is going to be filled with challenging opportunities. New greenhouse design, perhaps sunken below ground level, will probably incorporate passive heat storage and thermal blanket systems. We might see Christmas tree growers and high value hardwood producers planting large containerized trees for rapid plantation establishment. We will see various combinations of tissue culture, vegetative reproduction and controlled environment greenhouse growing being employed to generate new and traditional exotics in fractions of the usual time. Species with high unit values can be cultivated from a seed to a saleable potted plant within 1 year. This will enable those growers with indoor production facilities greater independence than their competitors who must depend on shipping in bareroot stock from other states.

Controlled environment production offers a flexibility which does not exist with outdoor facilities. Research is being done continually to locate the best seed sources, determine optimum growing conditions and discover potential production practices for each species of interest to commercial nurserymen. Conventions and meetings are vitally important to having an effective program of controlled environment production in order to share and discuss our successes and failures. These will provide encouragement and knowledge to enable us all to make dramatic advances in this new and exciting method of nursery stock production.

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GERALD KLINGAMAN: We have tried some plants in plant bands and obtained nice whips. I am worried about the rooting after we plant them in the field. Do you have any thoughts on whether the roots will continue to concentrate at the bottom or will branching occur further up?

JOHN HART: That has been a problem. A few years ago our plant band did not have any holes in it and it was deep. Perhaps with things that are going to be balled and burlaped after a few years it may be better to use a shorter band so you will not have a concentration of the roots coming out of the bottom.

GERALD KLINGAMAN: Have you done any work with mycorrhizal fungi?

JOHN HART: We tried it once but could not keep it going. In a greenhouse with optimal fertilization practices we feel that the mycorrhizal influence will not be that strong.

VOICE: What do you use to control green algae?

JOHN HART: We do not get much algae unless we overwater. The surface usually dries out quickly.

BRUCE MacDONALD: We have a problem in England with algae and use Algofen and Gloquat.

DON SHADOW: What fungicides do you use to control damping-off?

JOHN HART: We use benomyl. We also use Canadian peat which helps to control damping-off.

BRUCE BRIGGS: Have you worked with the "bug light" on growth acceleration?

JOHN HART: Most of our work is done with cool-white fluorescent tubes. One can use incandescent lamps to obtain red light.