OBSERVATIONS AND NEW INFORMATION ON GREENHOUSE CONTAINER SYSTEMS

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Starting A New Greenhouse Container Operation

In the process of helping a number of people get started over the last two years, I have seen many errors made. Sooner or later I think all of you nurserymen will be involved in container operations, and I would like to pass on some pointers so that you can avoid repeating the mistakes of others.

First of all, decide what to grow, when it is to be outplanted, how large it must be, and how many plants are needed. Second, determine where the operation will be located, and the construction budget available. This will determine greenhouse design. Because of all of these variables, probably no two greenhouse systems will be identical.

Rule 1: Don't take a package design and build it without checking it out thoroughly to see if it will fit your needs.

Let us now assume we have a preliminary design. Usually the nurseryman does not have the last word on design and budget and these are usually passed upon by someone higher up. The tendency is to try to make it as cheaply as possible.

Rule 2: Don't take pieces out of the system to make it cheaper. Instead, redesign the whole thing. For example, the effect of reducing a double walled structure to a single wall is to cause it to burn much more fuel and reduce the ability to maintain uniform conditions, especially near the walls. Another example: There is a tendency to leave out of the budget a man to run the operation. This can be a serious deficiency.

Corollary: Recheck the final design if it has been in the hands of anyone else, especially an architect. Sometimes changes are made to improve the aesthetics or make the system match th architecture of adjacent buildings, or mechanical changes are made which will have serious effects on the operation of the system. For instance, the Kansas State greenhouse was designed with an overhead fan jet system using clear polyethylene ducts. After a pass through the state architect's office, these became a $3,000 steel (opaque) ductwork. In addition, the photoperiod control system uses incandescent lights equipped with an internal reflector. The state architect added to the design custom made bowl reflectors which were expensive and unnecessary. Fortunately, the greenhouse cover is of fiberglass, and the shade resulting from these fixtures and ductwork is not excessive.

Let us now assume we have a final design and are ready to contract. Construction is always slower than you think. It is never completed on time and so you need a .margin for error in the first crop. Furthermore, operating a greenhouse nursery is different from operating a bare root nursery even for an experienced bare root nurseryman.

Rule 3: Plan an easy first crop, something that is unfussy and fast growing, even if it is not your most pressing need. For example, the State of Kansas planned a first crop of Juniperus virginiana, a species which requires a rather lengthy stratification period. At the time the seed was ready and beginning to germinate in stratification, the greenhouse was not A second batch of seed was put into stratification, but then its stratification period was only half over when the greenhouse was ready. Between the two batches of seed, they got a stand of 12,000 juniper out of 100,000 containers.

Rule 4: The first crop must be a good one. Usually you are presenting your customers with a product they have not used before. If it is not up to their expectations, the second crop will be that much harder to sell.

Greenhouse culture is more demanding, because by having tight control of the environment and rapid growth rates, the trees will also respond to poor conditions more quickly than they will in the bare root nursery.

Rule 5: There must be a man in charge. The greenhouse must be his sole or at least principle job. For example, in the past two years I have trained 4 different men in the North Dakota State Forest Service in greenhouse culture. Their first crop suffered considerably from this kind of turnover. For another example, the Assistant State Forester of Kansas is in charge of the greenhouse operation, but he is also in charge of tree distribution and has staff responsibilities. As a result he is unable to spend the time necessary to insure that the trees are healthy and growing at their maximum rate. His assistant is a mechanical genius who can keep the machinery running correctly but is not a substitute for a knowledgeable nurseryman.

If newcomers to the greenhouse container field will follow these 5 simple rules, it will not solve all of the problems but at least you can begin making original mistakes right off.

New and Original Systems Planned

Speaking of originality, two unique nurseries are planned. These are miles apart in both concept and location, but they have in common the fact that the preliminary design was tackled by engineers who had never designed a greenhouse and had a very rudimentary knowledge of biology. One advantage of an arrangement like this is that they are unpredjudiced and more likely to come up with new concepts as long as they have biologists around to keep them on course.

The province of Alberta is planning to build a combination bare root and container nursery with a capacity of 10,000,000 bare root and 10,000,000 container trees grown in three crops per year, mainly white spruce and lodgepole pine. All shop facilities, administrative offices, the bare root preparation area„ greenhouse preparation area, and greenhouse itself are in a single building. The greenhouse is sandwiched between the bare root preparation area and the container preparation area. The intention is to conserve on heat in the greenhouse, since this will be located 90 miles northeast of Edmonton. The greenhouse will be approximately 100 feet wide by 600 feet in length and will be equipped with 1500 foot-candles of sodium arc lights, whose function will be to supplement the sunlight which they lack at those latitudes in the winter. The bare root nursery location was picked according to favorable soil type, but there is little water on the site. A 11/2 mile pipeline will have to be built to the North Saskatchewan River. A generating plant operating from natural gas will supply electricity to run the whole operation. This is an ambitious project whose estimated cost is $12,000,000. It is biologically sound but expensive.

The U. S. Forest Service is also planning to build a combination bare root and container nursery at Albuquerque. It would produce approximately 20,000,000 bare root and 2,000,000 container trees, the container trees to be grown at the rate of two crops per year. Eighty percent of the seedlings would be ponderosa pine with the remainder mostly blue spruce, but including some Douglas fir and white fir. The greenhouse portion would be L0 feet wide and 900 feet long with a headhouse on the north side at the middle. Trees would be loaded in the headhouse onto a gantry which would place them in the greenhouse. There would be aisles at the walls but no aisles through the middle. In addition to this gantry, which would also be used for access for thinning and weeding, a second gantry would carry the lights and irrigation system. It has been calculated that this system should be much cheaper than a fixed overhead system of either lights or water. The air flow would be across the house, and the fans and heating-cooling systems would be modular so that the greenhouse Could be extended in either direction by adding modules. The unique feature of this house is that it will be solar heated. Albuquerque is an ideal location for a solar heated greenhouse, and it is estimated that solar energy will provide between 70 and 95% of the total energy needs. Furthermore, using the greenhouse itself as a solar collector, air for the heat transfer medium, and a gravel bed for the heat storage, the cost of the entire complex will be about the same as a greenhouse designed for conventional heating and cooling.

The remainder of the needs for fuel will be supplied by natural gas, which will also be burned to elevate the CO_2 level in the greenhouse. Because it has a heat storage system, the heat from the natural gas burned for the purpose of generating CO_2 can also be put into storage and utilized when needed. Because of the large heating and cooling reservoirs, it is possible that this greenhouse may be operated totally enclosed for most of the time. This would enable them to hold the CO2 level high throughout the day and may be the first system in which that is practical to do.

Another idea which is being considered in the light of declining natural gas supplies and rising prices is to generate biogas in a digestor. There is a feedlot nearby, and 2 tons per day of manure from as few as 200 cows would make the operation energy independent.

Another proposed use of solar energy is to heat the irrigation water. This will prevent the growth loss from application of cold irrigating water as well as make the greenhouse climate more easily controlled by matching water and air temperatures.

At Bottineau we have tried a number of new ideas ourself. Our three new greenhouses have roller carts for the pallets of containers. These carts roll, on 1 inch steel pipe, and can be wheeled outside of the greenhouse through a panel which is removable. Underneath the carts is a fan jet air duct. We have found that this under-the-bench airflow system gives good uniformity throughout the house and eliminates the need for a perimeter heating system which is needed with an overhead air duct. The roller carts can be slid apart to create a lateral aisle anywhere it's needed.

Frequently the container nurserymen need to sterilize potting medium. An ingenious device for doing so has been invented by Lee Hinds. This consists of a pipe frame which has been perforated and laid in the bed of a truck. The truck is filled with peat to be sterilized and tarped. The pipe is then connected to a source of steam. In trials last winter, we able to steam an entire pickup truck load of peat in 2-1/2 hours at 90 °C. This device could be scaled up to any size truck desired.

We are still testing every type of tree growing container that we can lay our hands on. As yet all container systems have drawbacks of one kind or another.

Everybody seems to be getting into the mine reclamation action, and we are no exception. This spring we grew 26 varieties of grass in the small book planter (Ferdinand size). The rootball was firm within four weeks. We could probably have done it even quicker, if we knew the optimum conditions for growing grass. These were outplanted on an old sandblow from which all of the existing vegetation had been stripped at the Denbigh Experimental Forest. Now two months later, all 26 varieties have established themselves as plugs. Only two varieties have become established from seed which was planted in adjacent rows at the same time.

Last year we shipped container grown Austrian and Ponderosa pine to Robert Fewin of the Texas Forest Service. He planted these at windy, dry sites at Lubbock and Amarillo in conjunction with bare root stock. The bare root stock did not last long. Survival was zero. The container stock did not grow but it survived remarkably well. Survival of Austrian pine at Lubbock and Amarillo was 70 and 55% respectively, of the Ponderosa pine, 87 and 84% respectively. Fewin reports that this year the container seedlings have doubled in size.

Growing Regime for Black Walnut

I recognize that few of you are interested in growing black walnut. But since we have been working intensively on this species for the last 9 months to develop a system of growing walnut for Kansa, I would like to use this species as an example of the kind of data needed and how it is acquired.

The first important variable is temperature. We have four growth chambers, and by raising seedlings in color coded #10 cans and shifting them between chambers twice a day, we can obtain 16 combinations of day and night temperature. From the results of these experiments we plot contour graphs which show the best combination of day and night temperature, and what happens when these optimum conditions cannot be held. The best combination for black walnut turns out to be day temperature 27 $^\circ$C, night temperature 22 $^\circ$C. The day temperature is more critical than the night temperature. Nights could be warmer but usually this would involve expending fuel without any gain in size of tree.

We then determined the effect of photoperiod. We have an apparatus through which we run every species that we study, to determine the length and intensity of light needed to prevent dormancy in the greenhouse. All of the conifers we studied have a very strong response to lengthened photoperiod. So far bur oak, hackberry, and black walnut did not show much of a response. Treatments that did receive light at night were larger than the control, but not much. I begin to think that perhaps there was an interaction between the long photoperiod and high CO2. Our growth chambers for the temperature experiments are operated at 1500 ppm CO_2 and have a long day. The greenhouse in which the photoperiod experiment is run has a normal atmosphere, low in CO_2. We set the growth chambers for 12 hours of high intensity light and for a 2 x 2 factorial experiment with and without high CO_2, and with and without long day. The long day was provided by low intensity, incandescent light given 1 minute out of 15. Table 1 shows that with the extended photoperiod only, there was no response. With the high CO_2 only, there was a rather considerable response. But when the two were combined, there was a significant increase in all of the growth parameters measured, and dry weight more than doubled. The greatest increase was in stem dry weight, and for Plains plantings under windy conditions, this is important because a tough stem withstands the wind and sand blasting.

For' many species seed germination is a problem. In the case of walnut, one of the problems is the size of the seed. It must be grown in a large container, and only one seed per pot will fit. Because of this we plant germinating seed, and we do not have the option of multiple seeding to allow for low germination of a seedlot. Figure 1 shows the results of some germination tests we ran. The nuts were collected and placed in stratification in early November. After 70 days of cold, moist stratification, they were not ready to germinate. After 110 days, about 30% were ready to germinate. After 148 days, about 38% were ready. The nuts that did not germinate from the 70 day stratification were put back into stratification, and at the end of 254 days, 15% had germinated in stratification, and a total of 70% germinated within 5 days. This means several things for the container nurserymen. First, he must have seed that has had at least 110 days of stratification. For multiple crops in the greenhouse this means that he must collect at least 1 1/3 years supply. Second, when the crop is ready to be started, the nuts can be brought out of refrigeration, allowed to warm up under moist conditions, and the greenhouse filled from the germinating nuts, which may be only 30% of the total. The remainder can be put back into stratification and held until needed for the next crop.

Table 2 shows the cropping schedule that has been followed to date at Bottineau. Dates in parentheses are projections. As you can see, walnut crops can be grown and moved out very quickly. However, the first 3 crops have not required any hardening other than a couple of weeks in a lathhouse. Starting with crop L, they will have to be winter hardened. This is going to take more time, and we have some unsolved problems. In preliminary experiments, we found that although conifers harden well under high CO_2, the high CO_2 inhibits leaf abscission of hardwoods. Furthermore, under conditions of low temperature under which conifers harden well, bur oak was found to break dormancy. This fall we will attempt to use ethylene, a hormone that causes abscission, to speed the process of leaf drop. It appears likely that for winter hardening we will need separate greenhouses for conifers, which harden well under high CO2 and do not need to drop their leaves, and hardwoods which must be under a low CO2 regime, and possibly receive other atmospheric gases like ethylene. Nevertheless, it appears feasible to produce 5 crops per year of black walnut in the greenhouse.

Progress Using Pure Cultures of Mycorrhizal Fungi

In cooperation with Dr. Jerry Riffle, Rocky Mountain Station at Lincoln, Nebraska, we are studying the possibilities of using pure cultures of mycorrhizal fungi on container grown trees. Our objectives are to determine which fungi are best for the tree, how to mass produce these fungi, how best to inoculate the tree with them, and whether or not they stay with the tree after it is outplanted, or whether they are replaced by native fungi.

We have an experiment in progress to determine which of 6 species of fungi are best for Ponderosa and scats pine. These trees are 3 months old, which is about the age that mycorrhizal infection normally occurs, and although it is too soon to be sure what we have, there does appear to be a response in tree height. Table 3 indicates that the response to date of soots pine is greater than ponderosa pine. Some fungi especially _Thelephora_ on soots pine, seem to be better than others in promoting height growth. And third, more inoculum tends to give a larger response. I emphasize that these are very preliminary results however.

Dr. Riffle has successfully developed laboratory procedures for growing the fungi, and we are now checking with pharmaceutical companies to determine possible methods of large scale production. As far as methods of inoculation go, we may have a problem. Last winter an experiment indicated that the size and quality of the tree produced was proportional to the level of mineral nutrition. However, the infection rate of mycorrhizal fungi was inversely proportional to the level of mineral nutrition. We need both a quickly grown tree and one that is mycorrhizal. In order to obtain this, we may have to try applying the inoculum later in the growing cycle, or perhaps fluctuating the nutrient level to allow the fungus to take hold.

All of this emphasizes that we have a great deal to learn, and .all we can say at the moment is that we will keep you informed of our progress.

Table 1. -- Interaction of long day and high CO2 in the growth of black walnut seedlings. Least significant difference at 5% level is 14%-

Growth Parameter	Long Day	High CO_2	High CO_2 + Long Day
	- percent increase over control -		
Height	0	0	+40
Caliper	0	+16	+29
Number of Leaves	0	0	+14
Dry Weight - Total	0	+70	+102
- Leaf	0	+74	+86
- Stem	0	+51	+151
- Root	0	+75	+99

Table 2. -- Sequence of events in development of a multiple crop schedule for black walnut in Kansas. Date in parentheses are projections.

Operation	Crop 1	Crop 2	Crop 3	Crop 4
Germinate nuts	Apr 3	May 23	Jul 18	Aug 22
Plant nuts	Apr 14	Jun 13	Jul 23	Aug 27
Move to Lathhouse	Jun 6	Jul 23	Aug 27	
Ship	Jun 15	Aug 13	(Sep 10)	
Outplant	Jun 20	(Aug 18)	(Sep 17)	

Table 3. -- Tree height as a percent of uninoculated seedlings at age 3 months. Least significant difference at 5% probability level is 15%.

Fungus spp.	Tree spp. Ponderosa Pine Inoculum Level 10%	20%	Scots Pine Inoculum Level 10%	20%
Pisolithus tinctorius	-	-	+20	+22
Cenococcum grandiforme	+15	+24	+22	+31
Thelephora terrestris	-	+25	+56	+71
Suillus couthernatus	-	-	-	+33
Suillus granulatus	+15	-	-	-
Rhizopogon roseolus	-	-	+22	+38
Mixture of all 6	+15	+24	+40	+43
Forest duff	-	-	+17	+24
No inoculum	58 mm		90 mm	

Fig 1. Germination curves for Kansas black walnut with varying stratification times. Germination temperatures: Day 27°, Night 22°.