PRODUCTION AND USE OF CONTAINER SEEDLINGS IN THE WEST

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INTRODUCTION

Container seedlings and greenhouse production are no longer new concepts in North American Forestry. Container technology has become an important part of the total reforestation effort--especially in the West. Growth of container nursery capacity has now slowed from the exponential rate it experienced in the first half of the decade, and at least one large organization is taking a close second look at their program. But new container nurseries are still being planned and built, and additional organizations are producing and using container seedlings.

In 1976, about 55 million container seedlings were produced in Oregon and Washington (Ter Bush 1977). That is one-fourth of the forest seedling production in these two States. Production of container seedlings in the other Western States totaled about 20 million. Alaska is even getting into the act on a small scale. Most of the tree seedlings produced in the West are conifers.

We assume that most readers are familiar with the basic techniques for producing container-grown seedlings: So, we will highlight recent trends and developments rather than describe the A, B, C's in detail. We will also briefly present our latest data on field performance and cover current ideas for the best uses of container seedlings.

SEEDLING PRODUCTION

Facilities and Energy Sources

Container seedlings are produced in a single growing season or less by accelerating growth through environmental control. Facilities needed for such control range from simple shadehouses for growing-season production in mild climates along the west coast to elaborate greenhouses further inland or wherever seedling growth is extended beyond the normal growing season.

The function of a shadehouse is to take the "edge" off of environmental extremes. Solar radiation, high temperatures, and wind are reduced; reduction of outgoing radiation at night provides some protection against light freezes. Partial protection from rodents and birds is also provided by some shadehouse designs. Initially, 47-percent shadecloth was used. The current trend is to provide only 30-percent shade. In areas such as the Willamette Valley of western Oregon, shadehouses actually have better mid-summer growing temperatures than found in many greenhouses. Shadehouses also provide more natural conditions for hardening seedlings in late summer and fall. In fact, seedlings started in greenhouses are sometimes moved to shadehouses in mid- to late summer for hardening. Shadehouses are relatively inexpensive, but they may not provide adequate control of moisture supply or wintertime temperatures.

Fully enclosed greenhouses represent the other extreme in environmental control. They provide conditions needed to further accelerate growth or extend growing seasons. Greenhouses have provisions for supplemental heat, and they are cooled by ventilation or evaporation. They often have some type of supplemental lighting. Greenhouses are usually covered with fiberglass or polyethylene sheeting. They are often used to produce more than one crop per year.

Induction of cold hardiness can be a problem in a fully enclosed greenhouse. It must have excellent cooling equipment or other means to provide the cooler temperatures required.

Another drawback of sophisticated greenhouses is the cost of fuel for heating and electricity for cooling. Year-round operation of forest-tree greenhouses that use energy from conventional sources is simply no longer economically nor, for that matter, socially justifiable. There are cheaper and more energy-conserving ways to achieve fast seedling production.

One way to conserve energy is to avoid the need for it. Required heating capacity and energy consumption can be reduced by effectively using the normal growing season to grow one crop per year. In some areas, shadehouses serve this purpose. In greenhouses, cooling needs in the summer can be reduced by using vented roofs and sides that open all the way around. Such facilities, called shelterhouses, can also be used effectively in place of shadehouses for seedling conditioning. Shelterhouses protect the seedlings from excessive moisture or freezing and can provide the gradual cooling that is necessary.

Another way to avoid the energy crunch is to use solar, geothermal, or waste heat. These alternate energy sources are described in another paper in this proceedings.

Containers and Potting Mixtures

In the West, almost all container seedlings are grown in plug-mold containers. These are rigid, non-degradable containers that must be filled with a potting mixture. Prior to planting, the seedlings are pulled from the containers either in the nursery or in the field. With their intact mass of roots and potting mix, the pulled seedlings are often called "plugs."

The common types of plug molds come in a variety of sizes. Small ones range from 2-1/2 to 5 cubic inches in volume per cavity, large ones from 7 to 32 cubic inches. The size to use depends on species, size of seedling needed, and length of the growing period. For all but slow growing species, seedlings become larger in large containers than in small containers in the same length of time.

A good plug-mold container has ribbed or grooved sidewalls to direct growth downward, tapered and rigid walls to allow easy extraction of plugs, provision for good water drainage and air pruning of roots, and a convenient system for handling in the nursery and field. None of the available containers are perfect in all respects, but they come close enough for practical use.

Biodegradable containers would have some distinct advantages; they are discussed in another paper in this proceedings.

The potting mixture is usually a combination of peat moss and vermiculite, with the latter ingredient comprising no more than 50 percent of the volume. Some growers prepare their own, but many purchase a pre-mixed material. The pre-mixed type can often be ordered with specific amendments. Whatever is used, natural variation in peat moss from batch to batch complicates the standardization of cultural practices and the successive production of uniform crops. Its pH level is very critical. Growers must be careful to use acidic material. At least one author believes that new methods of harvesting peat moss result in weed and disease contamination, and thus, all peat moss should be treated with heat or chemicals prior to use (Bluhm 1977).

Filling and Sowing

Assembly line procedures are normally used in filling and sowing containers. Basic steps are: moistening the mix and feeding it into a hopper; dispensing mix into containers and tamping or vibrating it to obtain uniform filling; preparing small depressions in its surface; sowing seed; and covering the seed to minimize physical disturbance, moisture loss, and algae or moss growth. In most instances, stratified seed is sown.

Equipment used in filling and sowing varies considerably in sophistication, depending primarily on the size of the job. Sowing capabilities achieved in larger operations range from 100 to 250 thousand cavities per day.

Efficient use of seed is a particularly important concern and one of the oft-touted advantages of container seedling technology. But efficiency doesn't come automatically. In fact, some operations have been grossly inefficient because they sow more heavily than necessary and then throw away all the excess germinants. This procedure is acceptable if seed is plentiful and inexpensive; but that is very seldom the case for western conifers.

Approaches now being taken to reduce the need for multiple sowing include extra cleaning of seed lots, planting of pre-germinated seeds when poor germination is expected, and transplanting "extra" germinants into blank cavities. There has been a longstanding need for research to improve the quality of conifer seed used in all nurseries.

Growing Schedules and Cultural Practices

Sowing times in the West range from February to early June and depend on such factors as species, degree of environmental control, and anticipated planting date. March and April are the main months for sowing in the Northwest; resulting seedlings are large enough for planting and have set bud by mid-September. But planting usually doesn't begin until the seedlings have developed cold hardiness and fall rains have replenished soil moisture in field sites. These conditions usually aren't met until late October or early November.

Single-season production of sturdy, well-conditioned seedlings usually requires good control and knowledgeable handling of irrigation, fertilization, and temperature. In some situations, control of light intensity, photoperiod, mycorrhizae, or carbon dioxide are desirable. Detailed discussions of these practices can be found in the Proceedings of North American Containerized Forest Tree Seedling Symposium (Tinus et al. 1974). We will illustrate by mentioning only the effects of varying several practices.

Irrigation intensity and season-long temperature levels affect seedling size. These factors also influence seedling conditioning. Seedlings that grow largest under heavy watering or high temperatures are often much more susceptible to frost damage than those that are produced under less than optimum growth conditions. Conditions experienced by seedlings in the nursery may also affect their drought resistance the first year after planting by influencing top/root ratio and transpiration capacity (Owston 1972).

Photoperiod can either be lengthened or shortened if the facilities are available. Extending the photoperiod by using only low intensity light at intermittent intervals produces larger seedlings of species such as hemlock that grow slowly during their 1st year. Long photoperiods will also prevent early bud set of species or ecotypes that have adapted to short growing seasons.

Shortening the photoperiod by covering seedlings with black cloth part of each day during late summer and early fall is a useful conditioning technique. This technique stimulates early bud set and frost hardiness; however, it is somewhat difficult to use on a large scale. Reductions in both irrigation and fertilization are the most common techniques used for inducing dormancy. Frost hardiness can be promoted by exposing seedlings to cool temperatures after buds develop.

Use of high intensity light to increase photosynthesis for off-season production is biologically feasible, but it has become impractical from an energy standpoint. Use of supplemental carbon dioxide to improve growth is also feasible, but it has very limited value in ventilated houses. Mycorrhizal inoculation on a large-scale is still under study; it offers good potential for production of seedlings with healthier, more efficient root systems.

Cool storage facilities are needed at a container nursery. Coolers provide a convenient way to hold seedlings at the nursery from mid-winter to spring. Often, cool storage is required to prevent premature bud-break of stock destined for spring planting. As with bare-root trees, container seedlings planted in succulent condition are prone to damage from both cold temperatures and drought. Empirical observations indicate that container-grown seedlings store well in coolers under the same conditions as for bare-root stock.

Sanitation and Monitoring

Improperly used greenhouse practices can accelerate container seedling decline just about as readily as they can increase growth. Diseases, insects, moisture stress, mechanical breakdowns, improper fertilization--even a few mice or birds--can create havoc in short order. Cavities that are empty after germination, remain empty during the rest of the production period. Cost of survivors is then higher, and the number of seedlings reaching the planting site is less.

Good sanitation practices are important for disease prevention, and they reduce the need for chemical controls. A clean and orderly facility also promotes employee safety, morale, and general job performance.

Constant vigilance is required to prevent problems or to nip them in the bud. By contract with the Missoula Equipment Development Center of the U.S. Forest Service, the Electrical Engineering Department at Oregon State University has developed and nearly completed the installation of a computer-based monitoring system at the Forest Service greenhouse nursery near Corvallis, Oregon. This system will automatically monitor air and "soil" temperature, relative humidity, and fan activity within each of the five greenhouses at the facility. The data will be displayed on a cathode-ray tube in the nurseryman's office for instant observation, and they will be recorded on tape for later reference and use in calculations of trends and averages. Other data such as pH values, "soil" moisture determinations, and growth measurements can be entered into the computer manually for easy storage and use. There is sufficient additional capacity for various inventory purposes. A demonstration session will be held once the system is fully operational.

But no electronic monitoring system will ever replace the nurseryman's eye. He has to look at the seedlings as much as possible, take pH readings, and measure growth periodically to make sure that disaster isn't lurking around the corner. The pH level in container potting mix is particularly critical, because it controls nutrient availability and is subject to rapid adverse changes. Most growers try to maintain a pH of 5.0 to 5.5 for western conifers, which provides some leeway in both directions.

Seedling Sizes and Costs

Seedlings grown in small containers are characteristically younger, thus, smaller and less woody than typical bare-root seedlings. Although no firm guidelines have yet been developed on desirable sizes, 12-cm top height and 2.5-mm stem diameters are generally considered minimum for container seedlings of several western conifers. Much larger seedlings are often required for shelterbelts and specialty plantings.

The intact root system is the big attraction of container-grown seedlings. Roots generally arrive at the planting site in good condition, the shaped plug facilitates their placement in the ground, and the intact roots have good potential for rapid growth. Their bulk, however, adds transport burden that managers must take into account.

Production costs are, of course, very important. We are going to dismiss them quickly, however, by saying that they are highly variable due to a myriad of factors. We have heard of prices ranging from $45/M to $130M for seedlings in the 2-1/2- to 4-cu. in. containers. Although it's generally believed that container stock costs more than bare-root stock, we know of several organizations that grow container seedlings because they consider them cheaper or, at least, very competitive with bare-root seedlings.

PLANTING PRACTICES

Container-grown seedlings lend themselves to a wide variety of planting techniques. The small plug-mold containers were originally designed for planting with dibbles of the same shape as the root plug. Dibbles are particularly useful in rocky or debris-covered areas where it is hard to plant trees with hoes or shovels. Dibbles also speed planting on open, well-prepared ground. But many container seedlings are planted with conventional planting hoe because planters are accustomed to the tool and it is good for scalping planting spots. Also, dibbles may glaze the sides of the planting hole in heavy soil; this retards root growth. Container-grown seedlings are also planted with augers or planting machines where sites are suitable.

FIELD PERFORMANCE

We will update only that performance information developed by the U.S. Forest Service testing program in Oregon and Washington. Broader field performance summaries have already been published in the Proceedings of the North American Containerized Forest Tree Seedling Symposium (Tinus et al. 1974) and by Stein (1977) and Stein and Owston (1977).

In our program, we have emphasized use of numerous small field tests to compare container-grown seedlings with the bare-root stock that is normally planted on the particular test sites. Some tests were made using more than one kind of container stock, and we also have some relatively larger tests of a variety of treatments.

The field performance testing program was started on a small scale in 1969, and preliminary results looked promising (Owston 1973, Owston and Stein 1972). In 1973, we began a larger cooperative effort involving both the Research and National Forest System arms of the Forest Service. We published a study plan for comparing stock that administrative units can use, and it serves as the standard plan for the cooperative program (Owston and Stein 1974). So far, about 80 sets of plots have been established in a variety of forest types in Oregon and Washington.

Survival Results

Most of the tests compare seedlings grown in 2-1/2- to 4-cubic inch containers with 2+0 bare-root stock. A few involve 8- to 10-cubic inch containers or 3+0 bare-root seedlings. Survival comparisons now available are for 1 to 3 years after planting.

Percent survival varies substantially from test to test due to variability of site and weather conditions. Instead of listing survival averages with large standard errors, we sum results as the number of tests in which container-grown seedlings are surviving better, the same as, or poorer than the bare-root stock planted for comparison. These results must be considered preliminary; final results will be based on 3- to 5-year records from the test sites. Growth results are so preliminary they will not be presented.

Tests of Douglas-fir are spread widely over western Oregon and Washington. In 15 comparisons, survival of container seedlings is better than for bare-root stock, in 6 the difference is less than 5 percent, and in one instance survival is poorer. The test sites differ greatly in climatic severity, but only a few of them are very hot and dry.

True fir container seedlings survived better than bare-root seedlings in eight tests, nearly the same in three, and poorer in two cases. Most true firs are planted at higher elevations in the Cascades. Western hemlock tests in the Coast Ranges of Oregon show four cases where container seedlings have higher survival, two that are the same, and two where survival of container trees is poorer.

Results with ponderosa and lodgepole pine are considerably different. In none of the tests did container stock survive better. In five tests, seedling survival was relatively even; and in seven instances, less container seedlings survived than bare-root seedlings. The pines are planted in central, eastern, and southwestern Oregon. Among nine tests with a variety of other species, survival of container seedlings is better than bare-root stock in three tests, no different in two tests, and poorer in four tests.

These preliminary results show that, on the average, container-grown seedlings survive better than bare-root seedlings on National Forest lands in Oregon and Washington. The difference is greatest on moist sites; on dry sites container seedlings are not doing quite as well as bare-root seedlings. It appears that on dry sites the container seedling's physiological advantages are counteracted by the relatively shallow depth of its root system and its greater susceptibility to animal damage than the larger, more woody bare-root seedling. Most tests where container pine survival is lower than bare-root stock are located on sites with high populations of ground squirrels or deer. Microsite conditions such as frost pockets and compacted soil seem equally detrimental to both types of stock.

Root Development

Root development is a very critical aspect of field performance of seedlings. Effects of malformed or weakened root systems that result from spiralling of roots or excessive growth in small-volume containers might not show up for years--after many thousands of acres have been planted with container-grown seedlings. Two recent papers describe poor root development of some container seedlings (Carlson and Nairn 1977, Hellenius 1976).

But there is good evidence that root spiralling and root binding can be controlled by container design and cultural practices (Van Eerden and Arnott 1974, Hiatt and Tinus 1974). In fact, plug-mold systems were developed because root growth of seedlings outplanted in rigid plastic tubes was impeded. Ribs or grooves were added later in plug-mold side-walls to direct root growth downward.

We must remember that improper practices can also cause bare-root stock to develop malformed roots. Our current outlook is one of cautious optimism. We haven't seen or heard of any serious root form problems with properly grown and planted plugs, but we plan to watch carefully as early plantings grow large enough for anchoring problems to be observed.

OUTLOOK

Container-grown seedlings will undoubtedly merit a continuing role in western reforestation programs. We believe they are particularly suited for the following purposes (Stein and Owston 1977):

1. Maximizing seedling return from genetically improved seed.
2. Best maintenance of seed source identification for small lots.
3. Making up for production falldown in outdoor beds.
4. Producing seedlings on short notice for areas denuded by fire or off-schedule timber harvest.
5. Providing large stock for shelterbelts and specialty purposes.
6. Growing species that do better in containers than in nursery beds--hemlocks, true firs, spruces, and some hardwoods.
7. Reforesting rocky, debris-covered, and brushy sites where dibbles are easier to use than hoes.

8. Extending planting seasons into early fall or late spring.
9. Replacing bare-root seedlings wherever cost per surviving seedling is less or growth is better.

Knowledge derived from development of container technology will also help improve bare-root production. The existence of competing systems should benefit the entire reforestation effort in the West.

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