PRODUCTION OF CONTAINER-GROWN HARDWOODS

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Production of container-grown hardwoods is limited to special cases, and their greenhouse culture differs somewhat from conifers.

There are probably more than 100 million container-grown seedlings produced annually in North America, but fewer than 1 percent of these are hardwoods The reason is that container nurseries arose in response to acute regeneration problems of conifers. Hardwoods were grown in containers only as an afterthought. This does not mean that the container nursery is not suited to hardwood production, but it indicates that there may be differences in the justification for growing hardwoods in a container nursery and in the growing schedule required.

Differences between hardwoods and conifers

Although there is variation between species among both hardwoods and conifers, there are some consistent differences between the two. Hardwoods tend to be faster growing, which means shorter growing time to produce a given sized tree. This is one reason why relatively few hardwoods are container grown. Even in the northern states and Canada, many hardwoods can be produced as 1-0, and almost all can be grown to plantable size in half the time required for conifers.

Field establishment of most species of bareroot hardwoods is much easier than that of conifers and early growth is much more rapid. Therefore, there has not been the same urgency to improve establishment and growth of hardwoods as there has been for conifers.

When container hardwoods are used, it is usually: (1) because they will be planted on a particularly harsh site, as in mine reclamation; or (2) the container greenhouse solves a special production problem at the nursery, as is the case with bur oak; or (3) it is an unusually valuable tree, such as walnut.

Cultural practices in the greenhouse need to be somewhat different for hardwoods. To be useful in field establishment, hardwood seedlings generally must be larger than their conifer counterparts and, therefore, are grown in larger containers. Some species, such as walnut, oak, or pecan, require large containers because of the size of the seed; however, the best pot mixes are generally the same. Hannah and and Lowe (*3*) found peat moss and vermiculite mixtures widely used for conifers and highly satisfactory for growth of sweetgum *(Liquidambar styraciflua* L.) and shumard oak (*Quercus shumardii* Buckl.).

The broad horizontal leaves of hardwoods shed water, which makes uniform watering harder and increases the edge effect. Because hardwoods generally grow faster and often transpire more, the available moisture in the pot mix does not last as long, and as they grow they must be watered more often. It is easy to tell when hardwoods are moisture stressed, because wilting of the leaves is obvious. Damage to the foliage occurs more quickly, and it is more important to avoid wilting during the exponential phase of height growth.

Hardwoods will grow at the same low pH used for conifers, but they seem to be healthier and faster growing when the nutrient solution is kept at pH 6-7. After watering with nutrient solution, the foliage is usually rinsed to remove salts and to avoid leaf injury when the droplets dry. Conifer needles rinse clean easily, but broadleafed hardwoods require more thorough rinsing.

Hardwoods require more protection against insects. Anything that can bite or suck will attack hardwoods, whereas conifers rarely have major insect problems. Every hardwood nurseryman should familiarize himself with the appearance of aphids, whiteflies, spidermites, and plant bugs, and the damage they cause. The best control for these insects is to empty the house completely between crops, and then fumigate. Since insect populations start small and grow rapidly, spot spray with insecticide when harmful insects are first noticed. If populations are increasing, begin regular weekly spraying and alternate insecticides to kill a wider spectrum of insects and retard the development of resistance.

Another major difference is that most hardwoods are deciduous, and normal leaf abscission is an important part of the hardening process. Chemical means to accelerate leaf abscission without damaging seedlings have not been very successful. Fuchigami and Fuchigami et al (*1,2*) found that chemicals that effectively removed the leaves caused dieback the following spring.

High CO_2 during the first stage of hardening is beneficial to evergreens, because it promotes caliper and dry weight growth. However, the high CO_2 must be turned off when deciduous species begin to harden, because it also retards leaf abscission and may promote bud break and renewed height growth.

In contrast to most conifers, many hardwood species concentrate their initial growth in a large thick taproot. Sometimes this growth pattern makes it difficult to get the desired top growth in the nursery. However, most hardwood seedlings will sprout from the root collar if the top is killed. The enlarged root undoubtedly contains food reserves which enable hardwood seedlings to recover from considerable shoot damage or stress. This type of growth means that nursery grading standards based on the appearance of the top alone are not reliable indicators of expected field performance.

The strategy for raising any container seedling is basically the same: get prompt and complete seed germination; get rapid height growth until the seedling is as tall as desired; and then apply the first stage of hardening to set and develop the buds and add caliper and lignification. However, the procedure to accomplish this plan may vary considerably with the species, some examples follow.

Seed Germination

Although germination methods are available for most tree species, the greenhouse container nursery is much more demanding than the outdoor bareroot nursery. Problems with bur oak (*Quercus macrocarpa* Michx.) were found to be: (1) the acorns germinated slowly and incompletely, (2) they were infested with weevils, and (3) acorn seeds were large and could only be planted one per cavity.

The following procedure yields prompt germination and ensures an almost 100 percent stand.

1. Collect the seed from the ground or shake the tree, but do not pick seed that is green, and do not collect the first few to drop.
2. Immediately pour the seed into a bucket of water. Stir several times. Keep the sinkers and discard the floaters.
3. Place the wet acorns in a plastic bag.
4. Store them for 120 days or more in a cooler just above freezing, but do not freeze them.
5. When ready to plant, spread the acorns one layer deep in trays in a warm room or greenhouse.
6. Plant germinating acorns.

The float test at time of collection does three things: (1) it eliminates low viability acorns (0-30 percent for floaters vs. 80-90 percent for sinkers); (2) it stops moisture loss; and (3) it provides about the right amount of moisture for stratification. Acorns will be killed by freezer storage at -18° C. This seems remarkable, because then surely all acorns must freeze outdoors in North Dakota. Perhaps they are not killed if they dry out, before freezing. But we also have found that the germination drops off in almost direct proportion to the loss of fresh weight (fig. 1). Somehow, a few of the acorns escape being killed by the combination of freezing and drying. This kind of storage may be sufficient to perpetuate the species, but is not the way to run a nursery.

We found the acorn weevil (*Curculio* spp.) is not particularly damaging if acorns are collected, float tested, and stored as suggested. More than 2,800 acorns were examined, germinated individually, and sorted according to the scheme shown in figure 2. Germination was reduced only if the weevil damaged the embryo axis. In this experiment, that happened in only 12 out of 437 weeviled acorns.

North Dakota sources of bur oak do not germinate readily without stratification, and for prompt and complete germination, at least 90, and preferably 120 days are required (*4*). Treatment with gibberellic acid does not accelerate this process (*9*). However, a minimum amount of stratification can be used. Then the acorns can be placed in a warm room; kept moist, and allowed to germinate. The germinants are planted, and the rest are returned to the cooler for continued stratification to be planted in a second batch. Planting germinants and continued stratification of nongerminants also works nicely with other large seeded species, such as pecan and walnut.

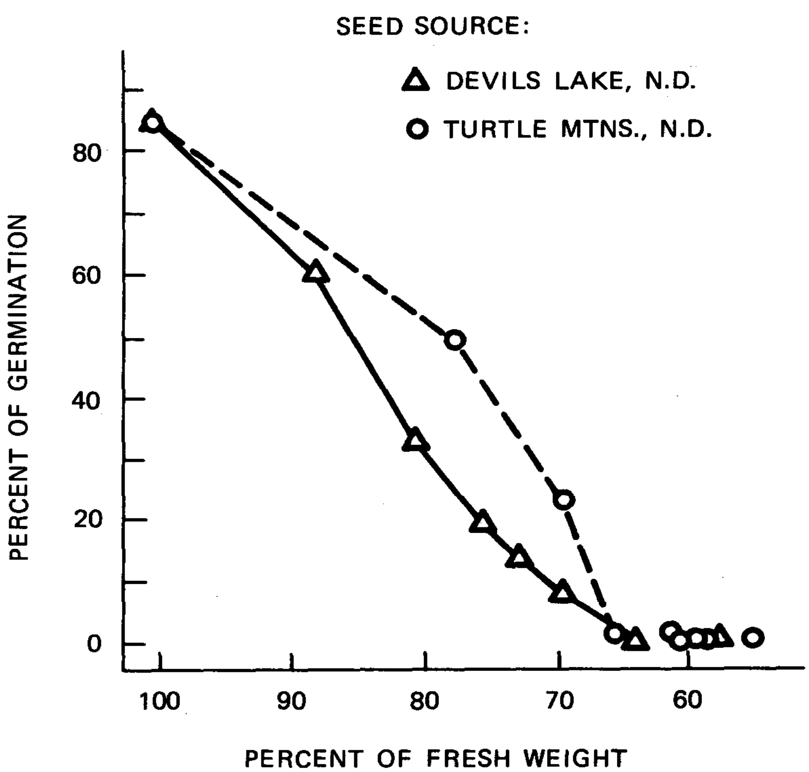

Figure 1.—*Germination of Quercus macrocarpa acorns as a function of weight loss due to drying.*

Prevention of bud dormancy

Long days prevent dormancy of many woody perennials. It is not necessary to have continuous light; for most species tested, if it is effective lights are on as little as 3 percent of the time, provided no dark period is longer than 30 minutes. Light intensities of 450 lux are generally sufficient, although this varies somewhat by species.

North Dakota sources of bur oak did not respond to photoperiod. Instead, high temperature was found to be the key to continued shoot growth. The apparatus used to test response to light intensity and duration was in a greenhouse with about a 20° C night and 25° C day temperature. Under these conditions, the oak came up from seed, put out one spray of leaves, and set bud. However, when the night temperature was raised to 25° C, and day temperature to 30° C to 35° C, the oak flushed several times, tripling and even quadrupling in height. High temperature worked not only with bur oak, but also with northern red and black oak (*Quercus rubra* L. and *Q. velutina* Lam.).

If neither long photoperiod nor proper temperature maintain growth, perhaps an interaction between several factors is involved. Black walnut (*Juglans nigra* L.) did not respond to photoperiod in our greenhouse, but grew much larger in growth chamber temperature experiments at the same day and night temperature combination as in the greenhouse. The difference between the two environments was the level of CO_2 in the air. With this lead, we ran a growth chamber study with and without extended photoperiod and with and without high CO_2. Compared to a short day (14 hours) and ambient CO_2 concentration, addition of 1 minute of incandescent light at 450 lux every 15 minutes did not increase growth. When 1,200 ppm CO_2 alone were added, there was a 70 percent gain in dry weight, and a small but significant increase in caliper growth. When long day and high CO_2 were combined, all of the growth parameters measured showed significant gains, and dry weight was doubled (table 1).

Hormone treatments sometimes help. Canyon maple (*Acer grandidentatum* Nutt.) from Utah set bud at the two-leaf stage, and even with manipulation of temperature, photoperiod, CO_2 mineral nutrients, and water, the best we could do was to produce a rosette of small leaves. Gibberellic acid promotes stem elongation which seemed to be what was needed. Some canyon maple were sprayed weekly with 50 ppm potassium salt of GA_3 in 1:50 ethanol: water with no surfactant. Treatment was applied from 1 to 10 weeks of age and then discontinued. Stem elongation was successfully maintained

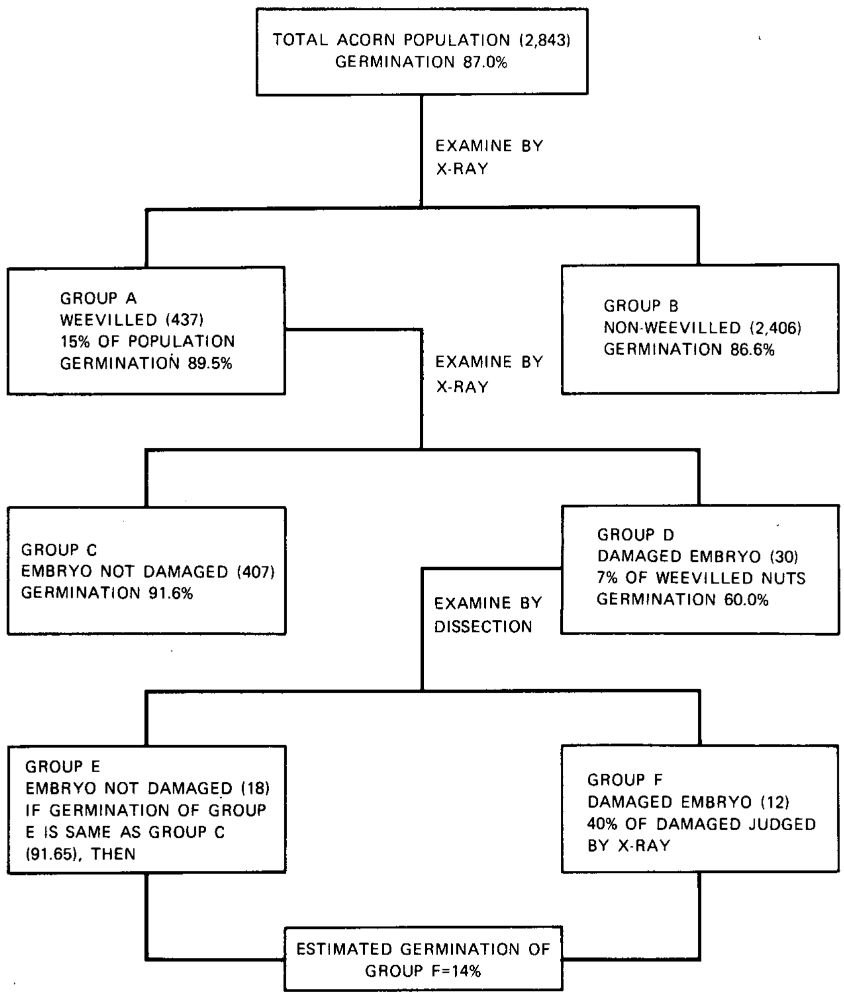

Figure 2.—*Effect of weevils on germination of Quercus macrocarpa acorns.*

Table 1.—*Interaction of long day and high CO_2 in growth percent increase over control of black walnut seedlings*

Growth Parameter	Long Day	High CO_2	High CO_2 + Long Day
	— (Percent increase over control)[1 2] —		
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

[1] Least significant difference at 5 percent level is 14 percent.
[2] Values not significantly different from the control are shown as 0.

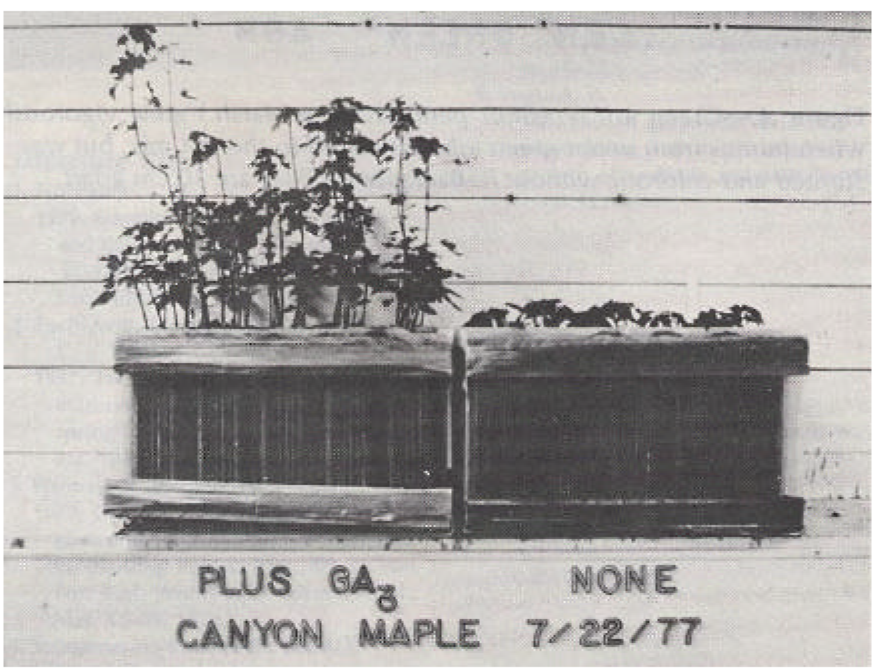

Figure 3.—*Canyon maple (Acer grandidentatum Nutt.) responded to weekly spraying with 50 ppm GA_3. Background lines are 10 cm apart.*

(fig. 3), but the leaves were abnormally small. The field performance of these seedlings has not yet been tested.

Mycorrihizae

The need for ectomycorrhizae on roots of containerized conifers has been well established (5, 6, 7, 8). The same is just as true of hardwoods, many of which have endomycorrhizae. Unlike the ectomycorrhizal symbionts on conifers, endomycorrizal fungi do not produce airborne spores and, therefore, do not spread rapidly. If container seedlings are to develop endomycorrhizae, then spores of endomycorrhizal fungi or root segments containing these fungi must be added.

Three unsuccessful attempts were made to grow big sagebrush (Artemesia tridentata Nutt.) in sterilized peat-vermiculite. Each time all of the seedlings damped off and died at the cotyledon stage. Soil collected from under big sagebrush was mixed about 5 percent with the pot mix. This time the seedlings grew rapidly and soon needed thinning. The seedlings that were removed were transplanted bareroot into sterilized peat-vermiculite that did not contain soil, but they continued to grow as well as the ones that remained in the original containers. By staining and microscopic examination of fungal vesicles and arbuscules in the cortical tissue 5 out of 6 randomly selected root systems of sage plants were found to be endomycorrhizal. These observations strongly suggest that mycorrhizal fungi were responsible for the greatly improved growth of big sage.

Half of our 1977 crop of green ash *(Fraxinus pennsylvanica* Marsh.) was inoculated by adding to the pot mix 2 percent by volume of freshly collected humus layer from under vigorous green ash. The rest of the crop was not inoculated. Inoculated seedlings grew normally, while the non-inoculated ones ceased growth and became stunted and chlorotic (fig. 4). Riffle[1] found endomycorrhizae in abundance on a large healthy seedling and none on a stunted seedling. Although only one healthy and one stunted seedling were examined, and no attempt was made to isolate and identify the fungi from the humus, the differences were striking.

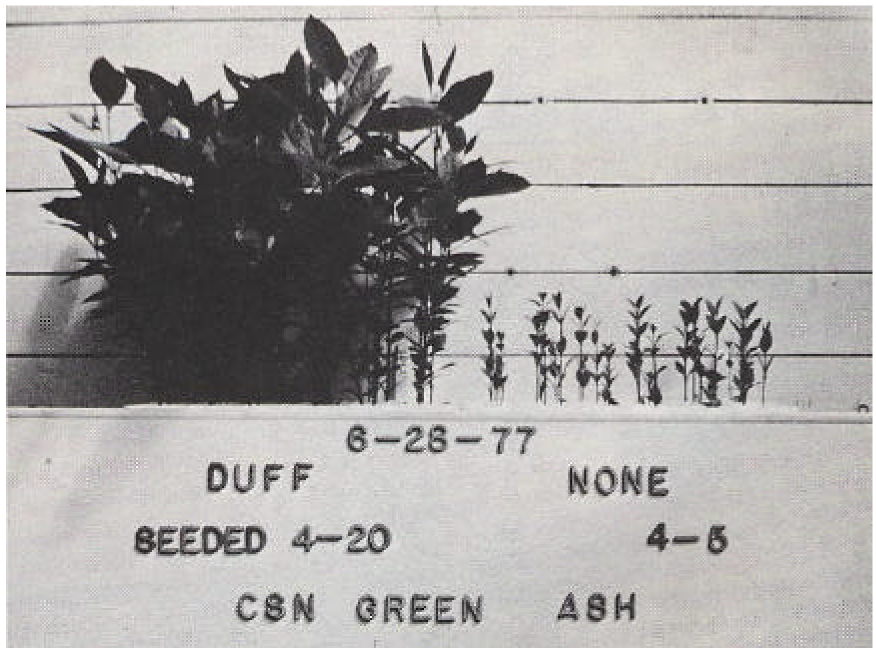

Figure 4.—*Green ash (Fraxinus pennsylvanica Marsh.) grew vigorously when humus from under green ash was added to the pot mix, but was stunted and chlorotic without it. Background lines are 10 cm apart.*

[1] Riffle, Jerry W. 1977. Principal Pathologist, Rocky Mountain Forest and Range Experiment Station, Lincoln, Neb., personal communication.

Summary

The need for container grown hardwoods is more limited and specialized than for conifers, and the techniques required to grow them may be a little different, but the basic principles are the same. The greenhouse container nursery must solve specific forestation problems. The nurseryman must know what it takes to grow his particular species. Good management and attention to detail by everyone involved makes the whole forestation system successful.

Literature Cited

1. Fuchigami, L. H.
1977. Ethephon-induced defoliation and delay of spring in growth in *Corpus stolonifera* michx., J. Am. Soc. Hortic. Sci. 102(4):452-454.
2. Fuchigami, L. H., M. Motze, and C. J. Weiser.
1977. The relationship of vegetative maturity to rest development and spring bud-break. J. Am. Soc. Hortic. Sci. 102 (4) :450-452.
3. Hannah, P. W. and W. J. Lowe.
1978. Growth of containerized sweet-gum and shumard oak as affected by planting media. Proc. 5th N. Am. For. Biol. Workshop. [Gainsville, Fla. Mar. 13-15, 1978.]
4. Schopmeyer, C. S. (tech. coord.).
1974. Seeds of woody plants in the United States. U.S. Dep. Agric., Agric. Handb. No. 450, p. 700.
5. Tinus, R. W.
1977. Container seedling production: Information needed and how to get it. Proc. 25th Northeast Tree Improv. Conf. [Orono, Me. July 26-29, 1977, 19 p.].
6. Tinus, R. W.
1976. Greenhouse container nurseries for better trees. *In* Shelterbelts on the Great Plains: Proceedings of the symposium. Great Plains Agric. Counc. Pub .No. 78, p. 137-140.
7. Tinus, R. W.
1974. Large trees for the Rockies and Plains. *In* Tinus, R. W., W. I. Stein, and W. E. Balmer (ed.) Proc. No. Am. Containerized For. Tree Seedling Symp. Great Plains Agric. Counc. Pub. 68. p. 112-118.
8. Tinus, R. W.
1970. Growing seedlings in controlled environment. West. Reforest. Coord. Comm. Proc., West. For. and Conserv. Assoc., Portland, Oreg., p. 34-37.
9. Vogt, A. R.
1970. Effect of gibberellic acid on germination and initial seedling growth of northern red oak. For. Sci. 16(4) :453-459.