PRODUCTION OF CONTAINER GROWN HARDWOODS

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Introduction

There are probably over 100 million container grown seedlings produced annually on this continent, but less than 1% of them are hardwoods. The reason is that container nurseries arose in response to acute regeneration problems of conifers. Only as an afterthought were hardwoods tried in containers. Does this mean that the container nursery is not suited to hardwood production? No! But it does indicate that there may be differences in the justification for growing hardwoods in a container nursery and 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 times to produce a given size of tree. This is one reason why few hardwoods are container grown compared to conifers. Even in the North 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 bare root hardwoods is much easier and early growth much more rapid than that of conifers, so there has not been the same urgency to improve establishment and growth as there has been for conifers. When container hardwoods are used, it is usually (1) because it 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 with bur oak, or (3) it is an unusually valuable tree such as walnut.

Cultural practices in the greenhouse need to be a little different for hardwoods. The broad horizontal leaves 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 the frequency of watering must increase substantially as they grow. With hardwoods it is easier to tell when they are moisture stressed, because wilting of the leaves is more obvious. On the other hand damage to the foliage occurs more quickly, and it is important that wilting be avoided 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 avoid leaf injury when the droplets dry. Conifer needles wash clean easily, but broadleafed hardwoods require more thorough rinsing.

Hardwoods require more protection against insects. Whereas conifers rarely have major problems, anything that can bite or suck will attack hardwoods. Every hardwood nurseryman should familiarize himself with the appearance of aphids, whiteflies, spidermites, and plant bugs, and the damage they cause. The best control is to clean out the house completely between crops, and then fumigate. Second, be vigilant. Insect populations start small and grow rapidly. In my greenhouse we spot spray when they are first noticed. If populations are building, we begin regular weekly spraying and rotate insecticides to catch a wider spectrum of insects and retard the development of resistance.

Another major difference is that most hardwoods are deciduous and normal abscission of the leaves is an important part of the hardening process. Accelerating leaf abscission has not been very successful. A number of investigators (including myself) have sought chemical means to defoliate seedlings without damaging them. So far, I have nothing to recommend. 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 at the <u>beginning</u> of hardening of deciduous species, 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 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 a considerable setback. This 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 tree seedling is basically the same: Get prompt and complete seed germination. Get rapid height growth until the seedling is as tall as desired. 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. We found some major differences between hardwoods and conifers, but that may have been an accident of the order in which we studied them. Let me give you some examples of problems we encountered and how we solved them.

<u>Seed germination</u>

Although germination methods are available for most tree species, the greenhouse container nursery is much more demanding than the outdoor bare root nursery. Initially the problems with bur oak were: (1) The acorns germinated slowly and incompletely, (2) they were infested with weevils, and (3) acorns are large seeds that can only be planted one per cavity. Here is the procedure we developed to overcome these problems:

1. Collect the seed from the ground or shake the tree, but do not pick it green.

2. Immediately float test the seed in water. 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.

This procedure yields prompt germination and insures an almost 100 percent stand.

Green acorns will ripen and germinate, but are a colossal nuisance to pick from the tree. It is far easier to collect them from the ground. (This is one instance where the easiest way is the best way). The float test at time of collection does three things: It eliminates the low viability acorns (0-30% for floaters vs. 80-90% for sinkers), it stops moisture loss, and provides about the right amount of moisture for stratification.

Discovery of the effects of freezing was accidental. We acquired some acorns from the Lincoln-Oakes Nursery in Bismarck, ND and found them to be completely dead. They had been stored in a freezer. It seems remarkable that this would be the case, because surely outdoors in North Dakota, the acorns freeze. Perhaps they would not be killed if they dried before they froze. 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 must escape being killed by the combination of freezing and drying. This kind of storage may be sufficient to perpetuate the species, but it is no 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 here. We examined over 2,800 acorns by X-ray and then germinated them (fig. 2). They were divided into two populations. The nonweeviled germinated 87%, and the weeviled, which comprised 15% of the population, germinated 90%. (This difference is not significant). Now, an acorn is composed of two large fleshy cotyledons and a small embryo axis. It seemed reasonable that the weevils could eat a substantial portion of the cotyledon without killing the seed. Only if it damaged the embryo axis itself, would the seed be killed. So the weeviled acorns were divided into two populations, one in which the embryo was not damaged, and these germinated 92%. Those with damaged embryos comprised only 7% of the weeviled nuts, and the germination of this group was 60%.

Unless an acorn is X-rayed from two directions, there is no way to tell whether the damage and the embryo axis are in the same plane. The damage may be above or below the embryo. Acorns that appeared to have damaged embryos were dissected and only 40% of those judged to be damaged by X-ray actually were damaged. We were not able to germinate the dissected acorns for obvious reasons, but if we assume that the weeviled acorns whose embryos appeared damaged by X-ray, but were not, had the same germination rate as those that appeared not damaged by X-ray, then the calculated germination of the ones with the truly damaged embryos was 14%. In other words a weevil in the embryo axis will destroy the seed, but in our study this amounted to only 13 acorns out of a population of more than 2,800, and that's not worth worrying about.

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 (cf. Schopmeyer 1974). Treatment with gibberellic acid does not accelerate this process (cf. Vogt 1970). However, one can use a minimum amount of stratification, then bring the acorns out into a warm room, keep them moist, and allow them to germinate. The germinants are planted, and the rest are returned to the cooler for continued stratification to be planted in a second batch. This system works nicely with all of the large seeded species we have tried.

Prevention of bud dormancy

Long days prevent dormancy of many woody perennials, in fact all of the conifers we tested responded well. It is not necessary to have continuous light; for most species tested, lights on as little as 3% of the time, provided no dark period is longer than 30 minutes, is effective. Light intensities of 400 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. The apparatus we used to test response to light intensity and duration was in a greenhouse with about a 20° night and 25° day. 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°, and day temperature to 30° to 35°, the oak flushed several times, tripling and even quadrupling in height. This worked not only with bur oak, but also with northern red and black oak.

If neither long photoperiod nor proper temperature maintain growth, perhaps an interaction between several factors is involved. We noticed that black walnut 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 (table 2). When 1200 ppm CO alone were added, there was a 70% 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.

If all else fails, try hormones. Canyon maple (*Acer grandidentatum* Nutt.) from Utah set bud at the two-leaf stage, and even with manipulation of temperature, photoperiod, CO , 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. Several pallets of 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 week to 10 weeks of age and then discontinued. Stem elongation was successfully maintained (fig. 3), but the leaves were abnormally small. The stems are toughening up nicely, but whether a plantable seedling will be produced remains to be seen.

Mycorrhizae

On many previous occasions I have stressed the need for mycorrhizal fungi on the roots of containerized conifers (Tinus 1977, 1976, 1974, 1970). The same is just as true of hardwoods many of which require endomycorrhizae. Unlike the ectomycorrhizal fungi common on conifers, these organisms do not produce airborne spores and, therefore, do not spread rapidly. If container seedlings are to have them, they must be deliberately added.

Three times last winter we attempted to grow big sage (*Artemesia tridentata* Nutt.) in sterilized peat-vermiculite. Each time all of the seedlings damped off and died at the cotyledon stage. In February I brought back from Utah soil collected from under big sage. We mixed about 5% Utah soil with the pot mix and seeded again. This time the seedlings grew rapidly and soon needed thinning. The seedlings that were removed were transplanted bare root into sterilized peat-vermiculite that did not contain soil, and they continued to grow as well as the ones that remained in the original containers. On a limited sample of vigorous sage, Dr. Jerry Riffle found endomycorrhizae.[1/] These observations strongly suggest that the magic ingredient in the Utah soil was a mycorrhizal fungus.

Another example is green ash. This spring we inoculated half of our crop by adding to the pot mix 2% by volume of freshly collected humus layer from under 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). Dr. Jerry Riffle[1/] has found endomycorrhizae in abundance on the large healthy seedlings and none on the stunted ones. The sample was small, and no fungus was isolated either from the humus or the seedlings, but again, the differences are striking. Nurserymen would be well advised to insure that their green ash is mycorrhizal.

[1/] Jerry W. Riffle (1977), Principle Pathologist, Rocky Mountain Forest and Range Experiment Station, Lincoln, Nebraska, 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; and it is good management and attention to detail by everyone involved that makes the whole forestation system successful.

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Table 1.--Interaction of long day and high CO_2 in the growth percent increase over control 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

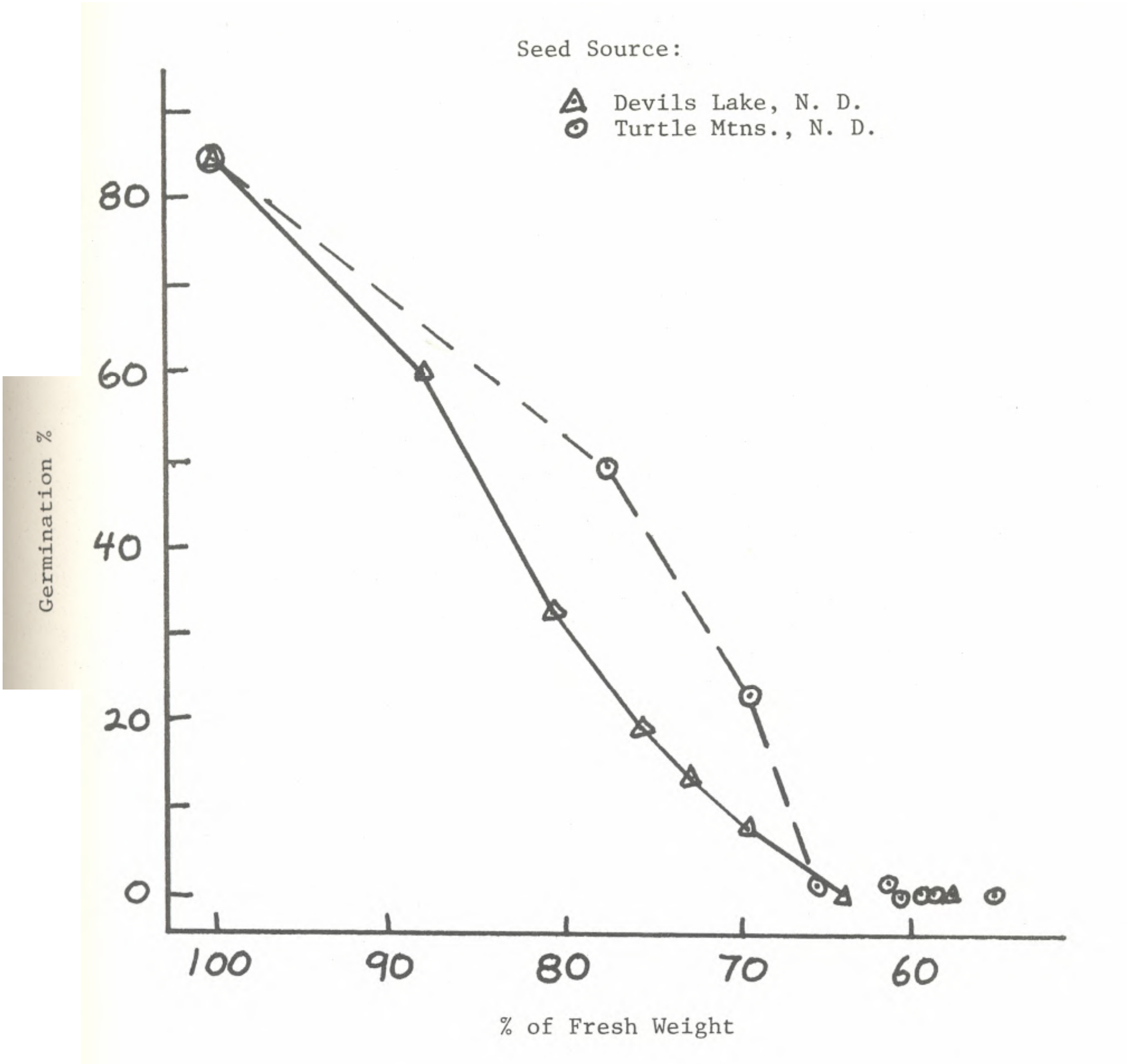

Figure 1.--Germination of *Quercus macrocarpa* acorns as a function of weight loss due to drying.

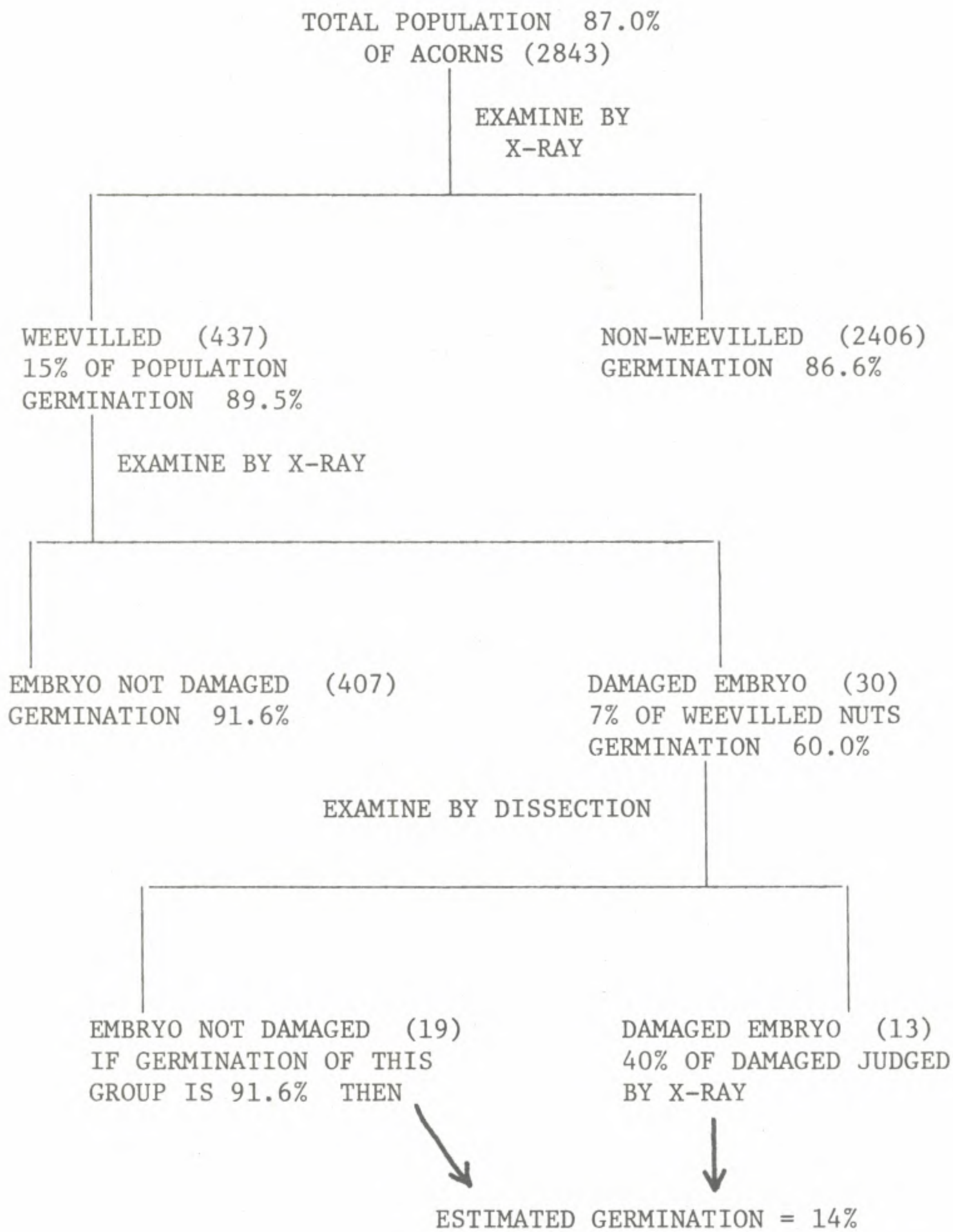

Figure 2.--Effect of weevils on germination of _Quercus macrocarpa_ accorns.

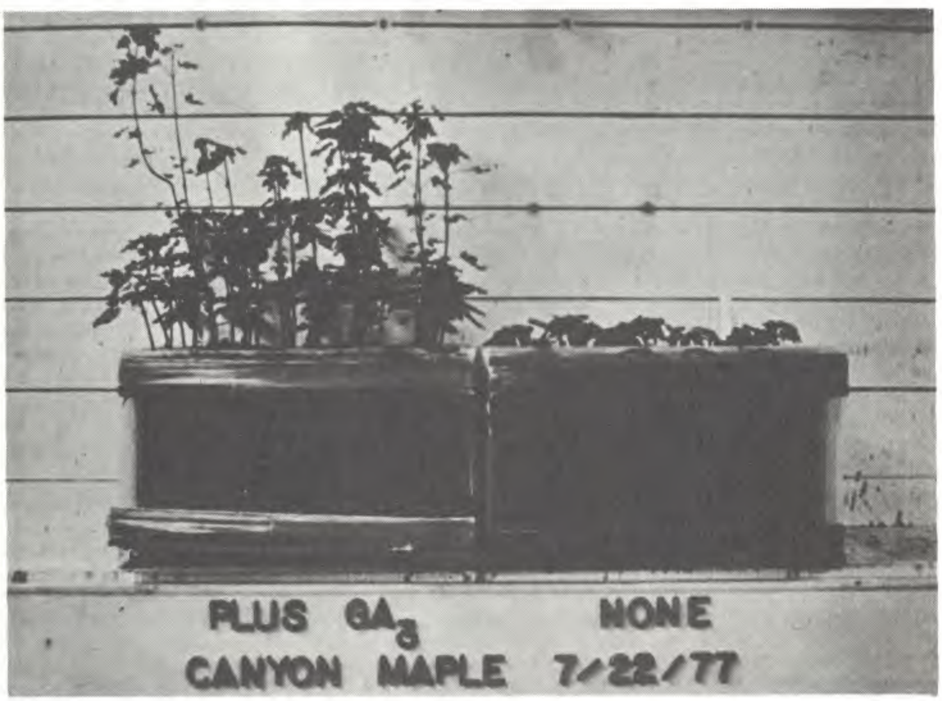

Figure 3.--Canyon maple (*Acer grandidentatum* Nutt.) responded to weekly spraying with 50 ppm GA_3. Background lines are 10 cm apart.

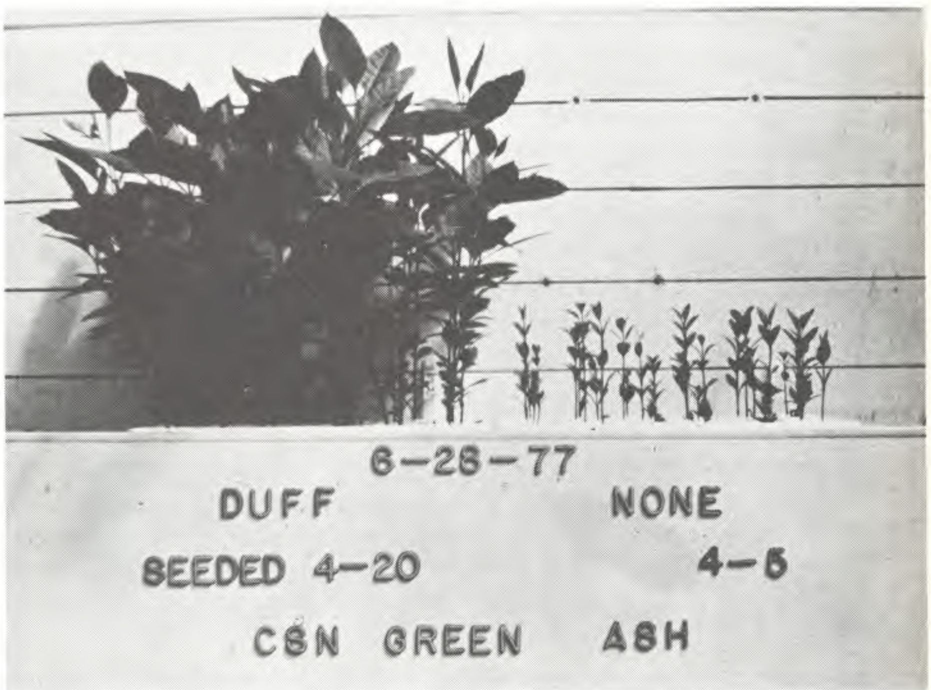

Figure 4.--Green ash (*Fraxinus pennsylvanica* Marsh.) grew vigorously when humus from under green ash was added to the pot mix, but was stunted and chlorotic without it. Background lines are 10 cm apart.