Growing Tree Seedlings in Containers

Bulletin 755 January 1981
Agricultural Experiment Station
Division of Agriculture
Oklahoma State University

Contents

Research reported herein was conducted under Oklahoma Station Project No. **1549**.

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Growing Tree Seedlings in Containers

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Introduction

Tree seedlings have classically been grown in ground beds. A high population of seeds are planted in a small area with some supplemental fertilizer and irrigation and are grown for 1 to 2 growing seasons, depending on the species, then transplanted into the field or containers. This procedure does not provide for modification of the root system other than undercutting of roots at the time the trees are dug for transplanting. Likewise, the crowding reduces the amount of foliage per plant and creates a very suitable environment for various diseases. Stem strength is generally poor because the plants have been grown close together, the lower leaves have dropped due to shading, and flexing of the stem which promotes strong, stout stems is greatly reduced. As a result of these practices, tree seedlings are routinely cut back to 4 to 6 inches in height following transplanting. This pruning forces lateral buds to break and one is selected for the new central leader.

Growing tree seedlings in containers allows for precise control of nutrition, spacing, light and other cultural factors to maximize growth of the seedling at this very critical, early stage. The accelerated growth, as a result of these improved conditions, continues for many years (6). In addition, since the root system is confined to the container, little or no transplant shock and adjustment occurs as is commonly experienced by bareroot seedlings. The production of container tree seedlings is more expensive on a per unit basis than field grown seedlings; however, because the growth rate of container produced trees is accelerated and mortality is lower a great benefit lies in the reduced time for the tree to reach saleable size (Figure 1).

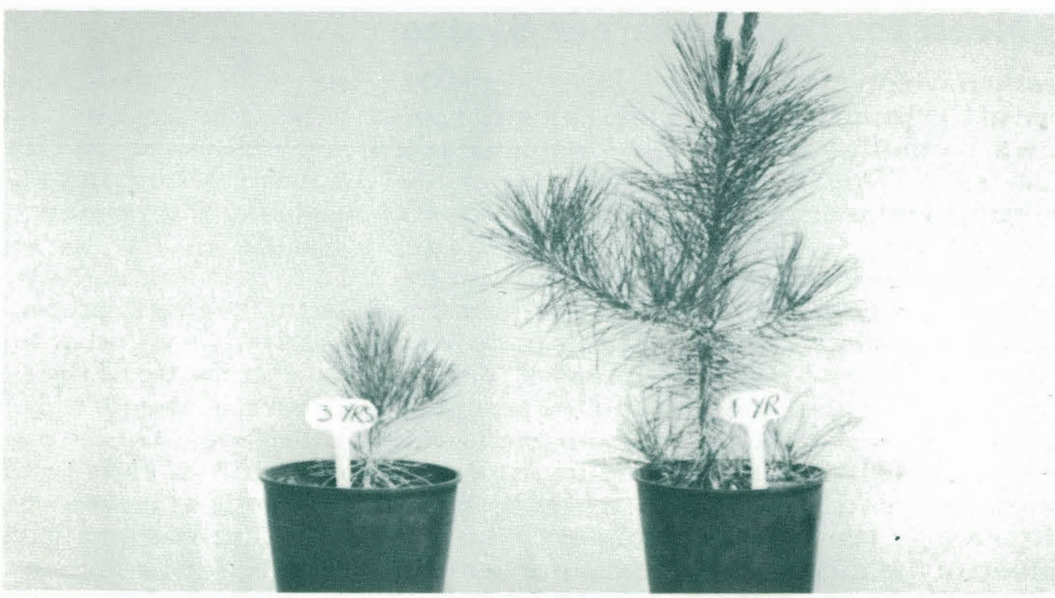


Figure 1. A 3-year old Japanese black pine seedling, left, grown in a ground bed for 3 years before being transplanted into the container, and a 1-year-old air-pruned, container-grown seedling, right.

Figure 2. Root development of Bur oak, *Quercus macrocarpa*, seedlings — at left, in a round container with a bottom and no air root pruning; and at right, in a square bottomless container.

The Need for the Container System

The early development of roots by tree seedlings is the result of the development pattern of the primary root. As this primary root emerges from the seed, it grows downward rapidly with a strong dominance which suppresses the development of lateral roots. This is similar to the dominance of the terminal bud on secondary branch development of the tree top. As soon as the tip of the primary root is destroyed, many secondary branch roots develop (Figure 2). The sequence of growth of a pine seedling, for example, is for the seed to germinate, the primary root begins its downward growth, then the plumule or top begins to grow. As the top and root develop, the top reaches a point where it has only a whorl of seedling or primary leaves and top growth ceases. Very shortly after the tip of the tap root is destroyed by air root pruning and the secondary branch roots begin to develop, the top begins the next flush of growth and develops true leaves. This encouraged investigation of shallower tree seedling containers to provide for early pruning of the primary root. It is not known whether the root tip has direct influence on the development of the top or whether once the root tip is destroyed and secondary branching of the root system begins, nutrient absorption is greatly increased and is the primary factor in the new growth in the top of the plant.

In early studies where tree seedlings were grown in bulk and wooden flats lifted at various intervals to have the tap root manually pruned, a high percentage of the time the tap root would initiate a replacement root, lateral branching back up the root was suppressed and often the root system was deformed (Figure 3).

The need to develop a technique of continually pruning or destroying the tips of the primary roots led to the development of the air root pruning concept. By growing the seedlings in bottomless containers on a wire bench, each time a root tip grows through the bottom of the container and out into the air the tip desiccates and dies. This has the effect of repeated root tip pruning and is very effective in stimulating lateral branches, not only on the primary root but on secondary roots as well (Figure 4).

Container Design

Work on the propagation of woody ornamental plants from cuttings suggested that container size was an important aspect in terms of plant growth and development (1). These observations suggested that tree seedlings would probably respond to increased container volume as well. Davis and Whitcomb (2) studied the effects of 3 container diameters (sizes) and 4 container depths on the growth and development of western soapberry, *Sapindus drummondi,* Japanese black pine, *Pinus thunbergi,* and *Pistacia chinensis,* Chinese pistache. They found that as container diameter increased, growth rate and size of the tree seedlings increased. They also found a detrimental effect of increased depth beyond approximately 9'' on the tree seedling. They concluded that the poor performance of the seedlings

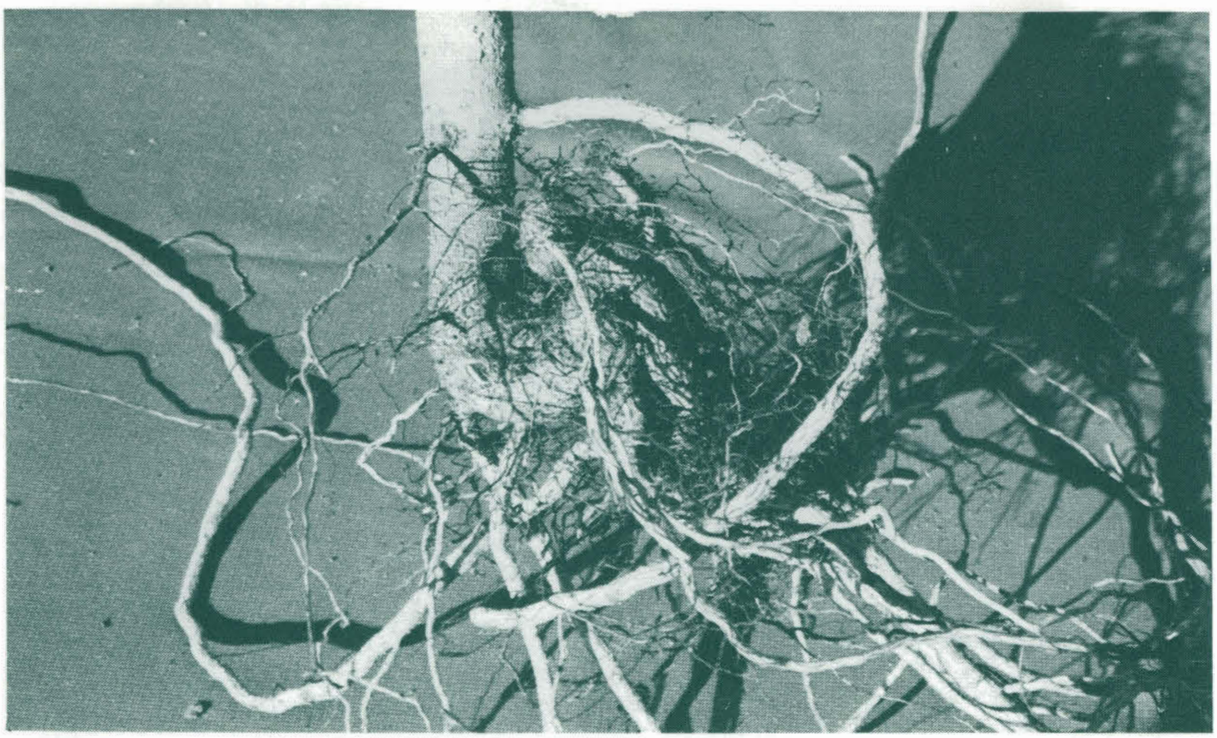


Figure 3. Root system of a Chinese pistache seedling, showing the kinking of the taproot that sometimes develops when bed-grown tree seedlings are planted into containers.

in the 15″ deep containers was due to lack of oxygen in the center of the containers, especially those which were very small in diameter. This led to the use of the half pint milk carton (2¾″ square and 5 ½″ deep) in many subsequent research studies.

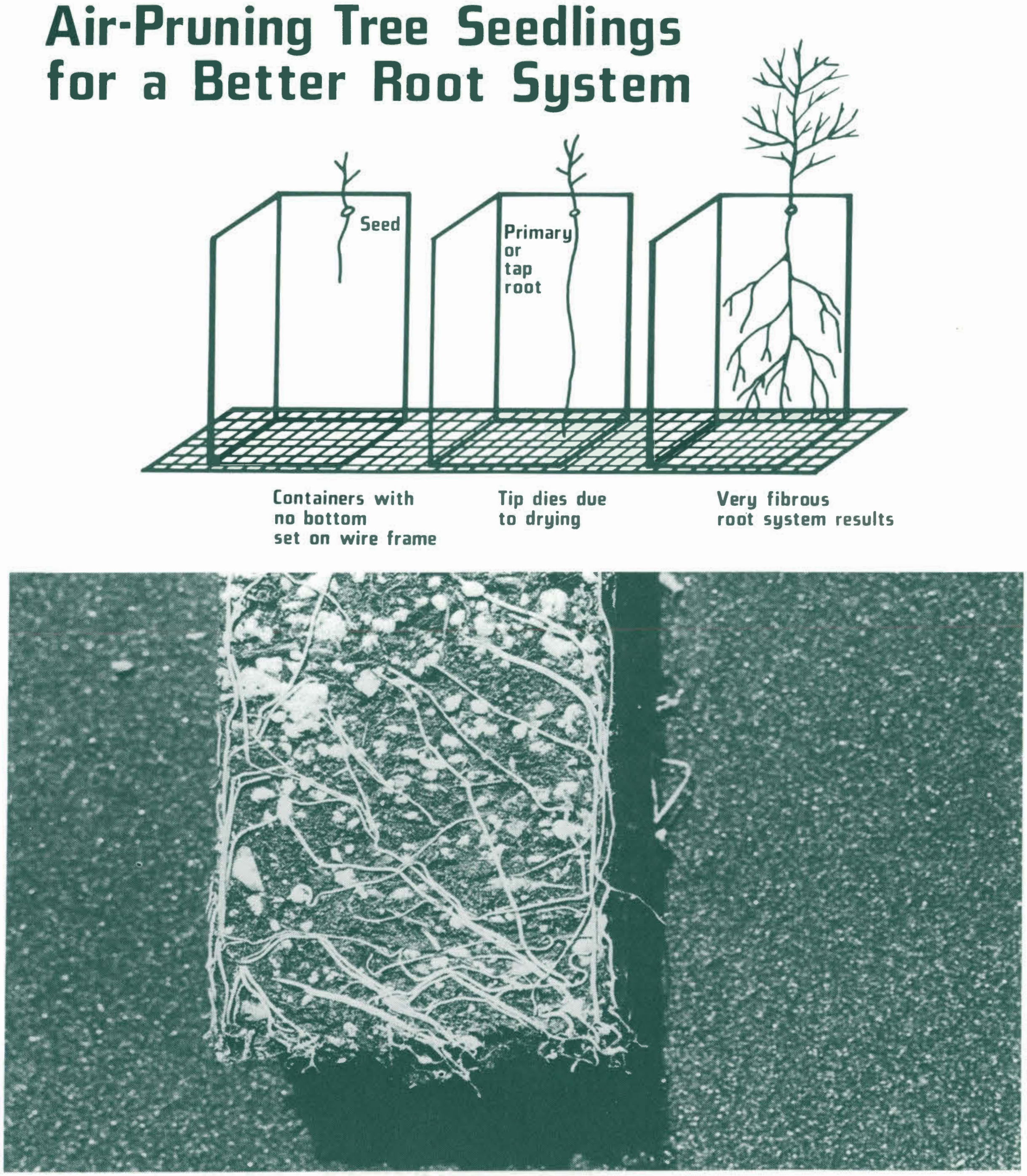


Figure 4. Schematic of the air root pruning system and bottom of a milk carton showing root development stimulated by the air root pruning process.

Figure 5. Effects of transplant date from milk carton to 5-gallon container on growth of black gum—left, July 17; center, August 4; and right, August 22. Photo was taken October 9. Growing medium nutrition and other cultural conditions were the same for all transplant dates.

Gibson and Whitcomb (4) studied the effect of containers 2 ¾'' square, 4'' square and 5 ½'' square (quart, half gallon and gallon milk cartons), all 5 ½'' deep, on the growth of tree seedlings. Tree species were Japanese black pine, Chinese pistache and shumard oak. They found no benefit from the two larger size containers unless the tree seedlings were held in that container for a considerable period of time. If the seedlings were planted after 4 months or earlier, subsequent growth and development was just as good from plants in the small containers as in the larger sizes. However, if the seedlings were held for 12 months prior to planting, the larger size containers were superior. Seedlings survived and performed well the following spring when transplanted into the field during the fall.

Time of transplanting tree seedlings from the initial seedling container into larger nursery production containers can have a striking effect on tree growth (12). Tree species studied were flowering dogwood, *Cornus florida*, monarch birch, *Betula maximowicziana*, Japanese black pine, *Pinus thunbergi*, deodara cedar, *Cedrus deodara*, shumard oak, *Quercus shumardi*, sycamore, *Platanus occidentalis*, Chinese pistache, *Pistachia chinensis* and blackgum, *Nyssa sylvatica*. The seed was planted April 1 and the seedlings were transplanted to larger containers on July 17, August 4 and 22. All seedlings were started in bottomless half pint containers 5 ½'' deep with slow release fertilizers incorporated into the growing medium. Seedlings that were transplanted on July 17 were much larger at the end of the growing season than those transplanted on the later dates (Figure 5). The conifers did not show a benefit from early transplanting at the end of the first growing

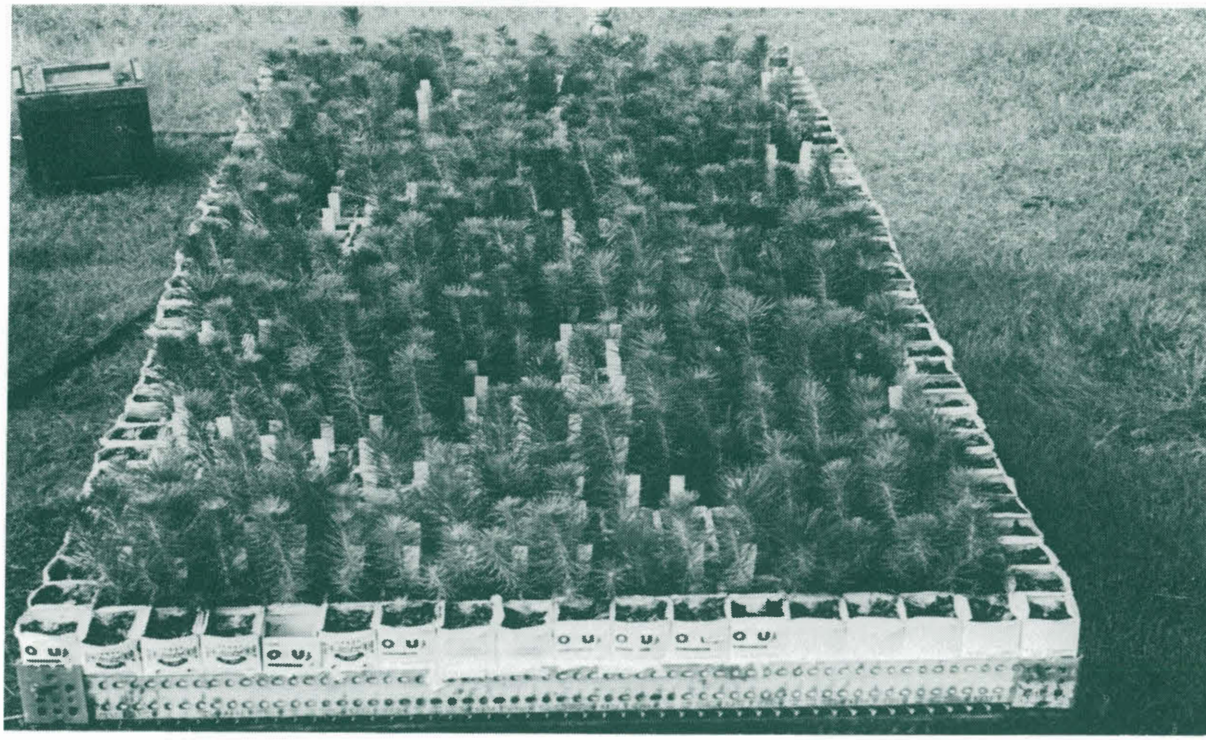


Figure 6. Japanese black pine seedlings in half-pint milk carton 2 ¾ x 2 ¾ inches. After the first true leaves develop, plant foliage is touching in most cases. Closer spacing of seedlings would reduce light absorption by the leaves and flexing of the stems, resulting in weaker plants.

season (approximately November 1). However, following the subsequent spring flush of growth, all conifer seedlings that had been transplanted on the early date were larger than those that had been transplanted on the later dates.

As nutritional conditions improved, the growth rate of the tree seedlings increased. The question then arose as to whether or not improved nutrition could offset the apparent need for a large volume in the containers. Chinese pistache, Japanese black pine, Kentucky coffee tree and bald cypress were grown in containers 1 ¾, 2 ¼ and 2 ¾" square and 3 ½, 5 ½ and 7 ½" deep (13). The growing medium was 2-1-1 ground pine bark, peat and perlite with 1 lb. Micromax[a] micronutrients and 9 lbs. Osmocote 18-6-12 per cubic yard. As the diameter of the container increased, the tree seedling growth increased. Likewise, as container depth increased, tree seedling growth increased although not nearly as pronounced as with the increased diameter. These data suggest that there is an optimum volume of growing media for maximum growth development of tree seedlings in the containers. Similar seedling response can be obtained by using a moderate diameter container with a larger depth or with a short container with a greater diameter to achieve similar growth response.

[a]A micronutrient fertilizer manufactured by Sierra Chemical Company, Milpitas, CA

It has been argued (10) that a smaller diameter container with a greater depth will provide for more seedlings in a smaller amount of space. However, there is an optimum spacing among tree species, especially as related to leaf size, which must also be considered. For example, to place red oak or ash seedlings on 1 ¼" centers in all directions provides no room for development of the enormous leaves and, thus, the shading and eventual dropping of the lower leaves as new growth occurs is a serious restriction of the growth of the plant. On the other hand, to space pine or bald cypress seedlings on 4" centers in all directions is not economical since the growth habit of the plant is not such that it needs as much lateral spacing as a large leaved shorter growing plant such as the northern red oak or ash (Figure 6). A container 2 ¼ to 2 ½" square and 4 to 4 ½" deep appears to be optimum for growth of most tree species unless the seedlings are held in the containers for a long period of time.

Nutrition

In early attempts to grow tree seedlings in containers the seedlings were planted in a well-drained growing medium and after seedling emergence, fertilizer would be applied to stimulate seedling growth and development. It was noted, however, that in most cases the seed would germinate and the seedlings would cease growing until the fertilizer application. This led to studies to determine how soon, relative to seed germination, the fertilizer could be applied. Early work by Bisher and Whitcomb (1) suggested that a slow release fertilizer such as Osmocote could be incorporated into the growing medium prior to sticking of cuttings with no detrimental effects to root initiation but with a stimulating effect on subsequent growth. Based on these experiences and observations, slow release fertilizers were incorporated into the germinating medium for river birch, *Betula nigra*, shumard oak and Japanese black pine at rates up to 24 lbs./cu.yd. Hathaway (5) found that only at the 18 lb./cu.yd. rate of Osmocote were the fertilizers detrimental as long as good water management practices were maintained.

Hathaway and Whitcomb (7) studied the effects of no Osmocote at the time of planting tree seed vs. incorporating a low level of Osmocote 18-6-12 and increasing levels following seed germination. Species used were river birch, shumard oak, Japanese black pine and pecan. River birch seed germinated but did not survive and grow unless some slow release fertilizer was incorporated into the peat and perlite medium. During the first 3 months of growth of the river birch seedlings outdoors, and after transplanting into the field or into larger containers there was no difference among any of the Osmocote levels. At the end of the second growing season, however, the higher the Osmocote level the larger the tree seedlings. A similar growth response was found with the oak, black pine and pecan except that seedling growth was related to the level of Osmocote (Figure 7) and growth rate of the seedling following transplanting from the small container was also related to the level of Osmocote in the container (Figure 8).

Hathaway and Whitcomb (8) also studied the effects of incorporating a micronutrient fertilizer (Perk)[b] and Dolomite into the germinating medium. In all cases, the seedlings were larger when the micronutrients were present as opposed to when they were absent. Dolomite, by contrast, was detrimental to the development of the seedlings with all species at all levels. Subsequent studies also showed that incorporated or surface-applied triple superphosphate (0-46-0) was also detrimental to young tree seedlings.

[b]Manufactured by Kerr McGee Chemical Co., Jacksonville, FL.

Figure 7. Effects of Osmocote in the propagation medium on growth of Japanese black pine seedlings after 3 months — right, 9 lbs. of Osmocote 18-6-12 per cubic yard; center, 6 lbs. per cubic yard; and left, none.

Figure 8. Effects of 9 lbs., left, vs. 3 lbs., right, of Osmocote 18-6-12 incorporated into the propagation medium on growth of shumard oak seedlings. These two seedlings were the same size when transplanted from the milk carton into the 3-gallon containers.

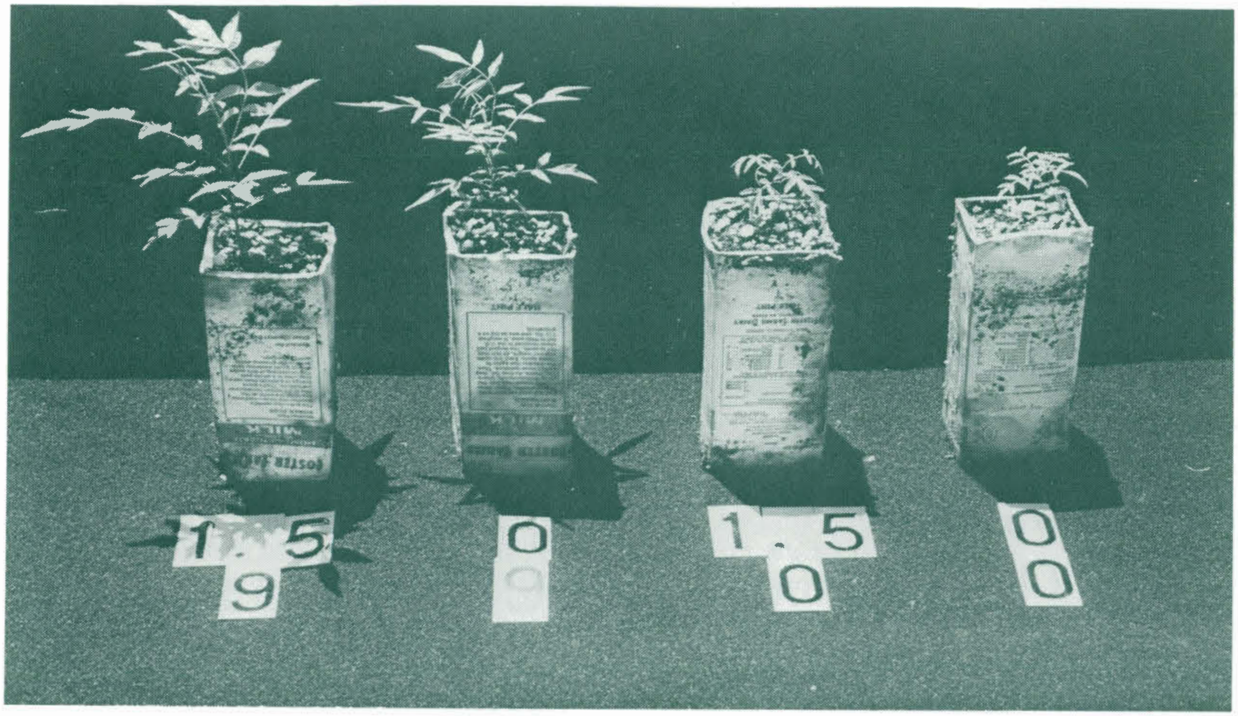


Figure 9. Response of Chinese pistache seedlings to 0 or 1.5 lbs. per cubic yard of Micromax micronutrients and 0 or 9 lbs. of 18-6-12 Osmocote. Note the increase in stem diameter and plant size when both micronutrients and Osmocote were added.

Whitcomb (11) studied the effects of Micromax micronutrients[c] and Osmocote on the development of Chinese pistache, loblolly pine, Russian olive and bald cypress seedlings. He found that 1 lb. of Micromax/cu.yd. of growing medium and 9 lbs. Osmocote 18-6-12 incorporated provided maximum growth among the various treatments tested (Figure 9). The Micromax micronutrient was effective in increasing stem caliper and root development.

By incorporating a slow release N-P-K fertilizer such as Osmocote and Micromax micronutrients into the germinating medium, the seedling can begin absorbing nutrients very early. Only the 18-6-12 formulation of Osmocote (6-9 month formulation) is recommended since it has a slow initial release of nutrients, which coincides well with the developing seedling. Faster release fertilizer sources or even moderate levels of liquid fertilizer may inhibit seedling growth. Osmocote also has the desirable property of increasing nutrient release rate with increasing temperature. When container tree seedlings are started out of doors or in unheated poly structures as is recommended here, the temperature of the medium is low during early stages of seed germination and growth when demand for nutrients is also low, paralleling the nutrient release of the Osmocote. However, as the seedlings develop and temperatures increase, the Osmocote releases more to meet plant demand. This nutritional system is easily managed and removes the possibility of too much or too little liquid or surface dry fertilizer

[c]Manufactured by Sierra Chemical Co., Milpitas, CA.

relative to seedling size and stage of development. Osmocote 18-6-12 should be used at a rate of from 6 to 9 lbs./cu.yd. with the lower rate for slow growing species in very small containers with peat and perlite or a similar growing medium and the high rate for rapid growing species in larger containers or where bark is a component in the growing medium.

Micromax micronutrients should be added at ¾ to 1 lb./cu.yd. for all species in all container sizes. Do not add any calcium, magnesium or phosphate source other than the small amount in the Osmocote to the germinating and seedling growing medium. It is not understood why those materials, which are routinely added to larger containers, are detrimental to the rapidly developing seedling.

Growing Media

The growing medium for tree seedlings in containers must be well aerated and have a moderate water holding capacity. Rapidly developing roots of seedlings with high respiration rates require oxygen levels greater than older plants. When plants are watered excessively, the amount of oxygen diffusing to the root system is decreased. The amount of carbon dioxide on the other hand is increased since the carbon dioxide comes from the living roots and bacteria and fungi. There is evidence to suggest that the carbon dioxide content alone, if it reaches too high a level, can be toxic and cause the deterioration of roots of plants in containers. If the growing medium in the container, "the soil," is made up of materials which create very small pores or air spaces, the growing medium will retain large quantities of water. On the other hand, if the growing medium is a mixture of materials which have some large pores or air spaces, the container retains much less water (Figure 10).

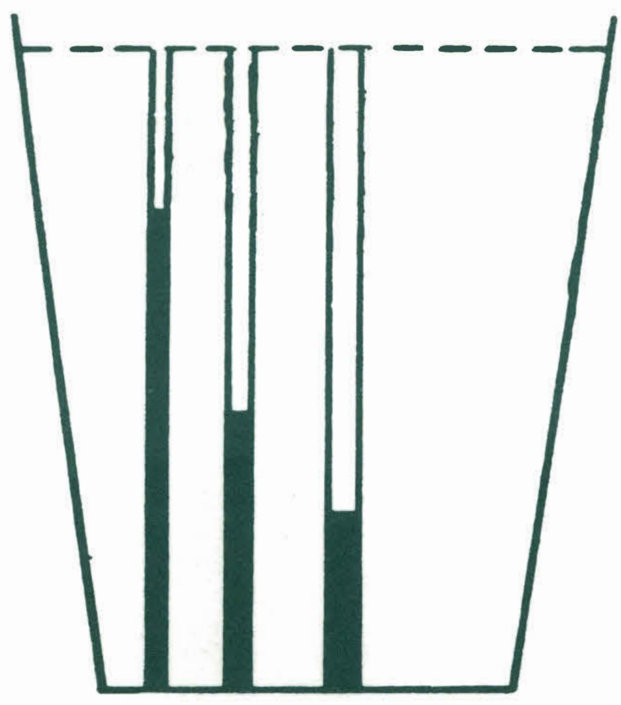


Figure 10. The quantity of water held in a container depends in part on the size of the pores or spaces in the mix — the smaller the pores, the more water held.

Figure 11. When the same growing medium is placed in containers of varying depth, as the container depth decreases the proportion of well-drained growing medium also decreases.

Because the column of growing medium is not continuous as soil is under outdoor conditions, the water collects or accumulates where the "soil" stops, that is, at the bottom of the container. This restriction of downward flow of water occurs in containers with no bottom or wire bottoms as well since the column is broken. Therefore, the more shallow the container, the less growing medium in the top of the container that is well drained and suitable for good root growth (Figure 11). Likewise, the deeper the container, the more growing medium that is going to be well drained and suitable for root growth. Therefore, the more shallow the container, the more porous the growing medium must be. Likewise, the deeper the container, the smaller the pores can be within reasonable limits. The desirable combination is a moderate depth container with a growing medium of moderate texture.

This balance of container depth and texture of the growing medium controls the rate at which oxygen can diffuse into the root zone of the plant. All oxygen must enter through the surface of the pot or through the drain holes (Figure 12). Most plants have the bulk of their roots near the surface and around the sides of the growing medium. Roots grow outward naturally and the concentration of oxygen and thus the best growing conditions for the roots are in these locations. Placing gravel in the bottom of a container has the effect of making the container more shallow and therefore less well drained. By contrast, container diameter has no effect on drainage.

Some water contains considerable amounts of dissolved salts, particularly calcium, magnesium, sodium and bicarbonates. These salts, and salts that enter the container from fertilizers, build up to levels that suppress root and top growth and may cause "burning" of the foliage or stunt plant growth. The most practical way to remove excess salts is by leaching the container. Leaching is a flooding or repeated heavy watering of the container, which carries the salts out of the drain holes, away from the root system of the plant. In order for this approach to be effective, however, the growing medium must be moderately porous to allow water to move rapidly through the container.

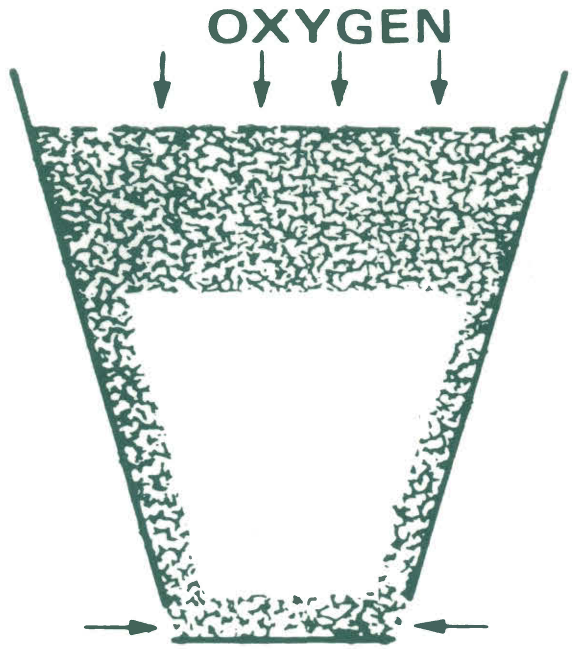


Figure 12. Oxygen must re-enter the container after each watering, primarily from the surface of the growing medium. For best results, use a container as large and as deep as practical. Use a soil mix of a texture that will provide ready movement of water. Do not use gravel in the bottom of containers.

The drainable pore space for tree seedlings should be 25 to 35 %. To determine the water holding capacity and drainable pore space of a growing medium follow these steps:

1) Select 4 or more containers of the *depth* to be used. Remember that in shorter or taller containers the air space will vary with the same growing medium.
2) Place a freezer bag of sufficient size in the container to act as a waterproof liner. An alternative technique is to clean the area around all drain holes and tape the holes shut with duct tape. Be sure not to allow folds in the tape which may leak.
3) Fill the container with the growing medium in question, firm in as though a seedling was being planted.
4) Take a known volume of water and slowly fill the container until the growing medium is fully saturated. Allow the container to sit for one hour or longer.[d] Add additional water as needed since the growing medium may absorb a sizable quantity. Record the total volume of water added. This represents the *total pore space* for the growing medium in this depth container.
5) Suspend the container over a larger water tight container and remove the tape from the drain holes or puncture the freezer bag liner through the drain holes. Allow 5 to 10 minutes for drainage. **Do not** tilt or tip the container as this increases the length of the drainage column (depth) and will give a false reading.

[d]If bark and peat are components of the growing media and they are very dry, additional time may be required.

6) Record the volume of water drained from the container.
7) Divide the volume drained from the container by the total volume of water added. This figure represents the percent drainable pore space and should be 25 to 35%. In general, fresh media with values below 20% are unsuitable for most container tree seedlings. Likewise, values above 35% represent excessive drainage and therefore a limited supply of available water. This means frequent irrigation and probably leaching of nutrients.

It is also advisable to perform a drainage test on growing media that has been in use for some time. Such a test is especially important when new growing medium components are being tested. Compaction and shrinkage of most media occurs with normal settling, watering and decomposition of some of the organic matter particles.

In addition, plant roots fill some of the pores, especially around the sides of the container and at the bottom. In general, values below 20% after 4 months are likely to cause root suffocation if overwatering occurs either from irrigation or rainfall.

Growing media that have worked well in research at OSU are 1-1, peat and perlite; 2-1-1, ground pine bark, peat and perlite; or 2-1-1, ground pine bark, peat and vermiculite.

The Seedling Environment

Many publications suggest a greenhouse environment for container grown tree seedlings. This adds considerable expense while limiting the air movement effect and, thus, affects the stem strength of the tree seedlings. For the horticulture nursery trade, a tree seedling is needed that has a strong stem, capacity for rapid growth and transplants easily from the seedling container to a larger container or field production area. In order to meet these requirements, we first tried growing tree seedlings in the greenhouse. They were tall and slender with large leaves and with the additional cost factor of the greenhouse were too expensive relative to their transplantability, survival and growth rate.

The next step was to grow tree seedlings out of doors. We attempted to plant the seed so that germination would just begin about the time we reached the average frost free date for North Central Oklahoma (approximately April 15). The milk cartons were placed on a wire bench in an area with full sun and good air movement and were filled with a well aerated growing medium and seeded. The seed were covered lightly with growing medium to help assure germination and prevent the seed from drying out in these exposed conditions. The seedlings were strong and well adapted for transplanting with good, stout, straight stems because of the air movement and the flexing of the stem and high light intensity. Work by Neal (9) has shown that in a greenhouse environment the trees are tall and more slender but if flexing of the stem is provided they are shorter and stouter with more secondary branching.

Because of the need to transplant seedlings as soon as possible from the seedling container to prevent stunting and to avoid the occasional pounding from heavy rains, it is suggested that a single layer plastic cover be provided over the tops of the tree seedlings (Figure 13). By providing a cover over the container seedlings very early in the spring, seeding can be done 2 to 4 weeks earlier than if no covering is provided. This earlier seeding provides for earlier transplanting and the seedlings can establish prior to the heat stress of mid-summer. Plastic

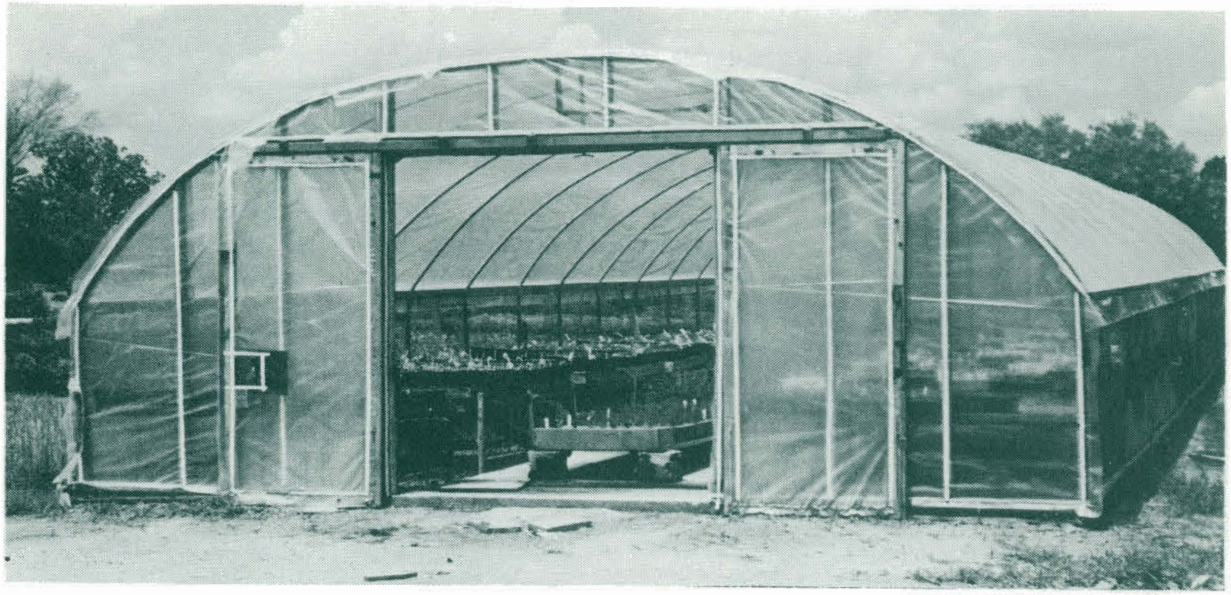


Figure 13. A quonset style covering over tree seedlings in containers. The sides and ends of the structure can be opened to allow air movement for ventilation and flexing of the tree stems to increase stem strength and caliper.

covered structures must be equipped so that the sides can be removed well above the tops of the anticipated height of the tree seedlings as soon as a frost free date is reached. This will allow good air movement and flexing of the young stems to insure good stem development while still preventing the excessive leaching and pounding from occasional heavy spring rains and aids water management of the seedlings. Such a structure would be unheated except for the accumulation of solar energy during the late days of winter when the sun is elevated in the sky. The structure must be rodent and bird proof to prevent substantial losses, especially of large seeded pines, oaks and pecans.

Watering is a critical factor with the young seedling. At the time of germination, temperatures are generally quite cool and evaporation is low and the moisture demand of the germinating seed is quite low. However, as temperatures increase in the spring and the seedlings get larger, there is a need for more frequent watering. It is important to water thoroughly when water is applied to insure wetting of the entire growing medium and a slight leaching of the container system.

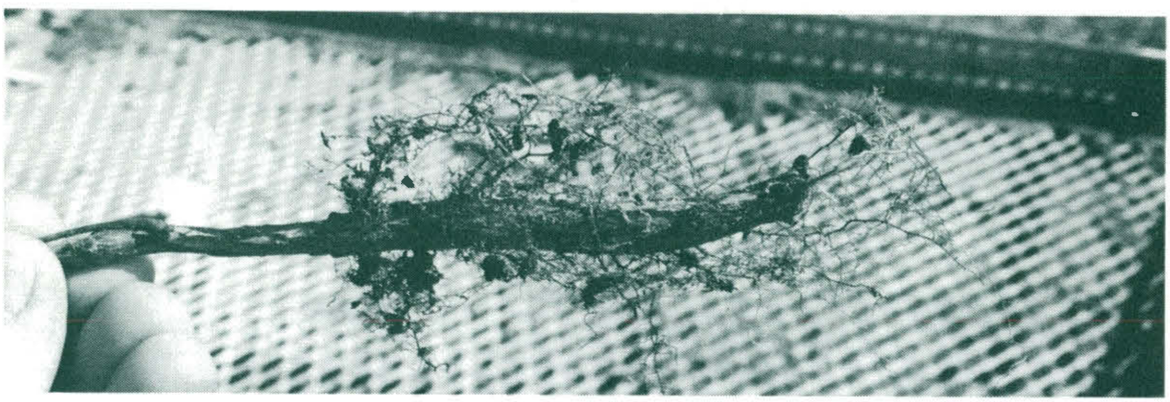
Cutworms may also be a problem in some areas. Other disease and insect control practices have not been required during the many experiments we have conducted.

Post Transplanting Performance

When bareroot bed-grown tree seedlings are transplanted, frequently the deciduous trees are cut back severely to encourage a strong second stem. With the container production system where the root system has not been disturbed in transplanting, this is not necessary and is, in fact, detrimental. With the container system, all the roots go with the top to the new site and, because these roots are container grown and the root tips are actively growing at the time of transplanting, the seedlings establish very quickly.

Dickinson and Whitcomb (3) reported that with sawtooth oak, *Quercus acutissima,* and pecan, the seedlings develop roots 10 to 12 inches into the surrounding soil within 3 weeks after transplanting into the field (Figures 14 and 15). This rapid establishment was also noted by Hathaway and Whitcomb (8) following transplanting of several hundred seedlings each of river birch, pecan, shumard oak and Japanese black pine under weather conditions of near 100°F and low humidity typical of Oklahoma in mid-summer. In this study no seedlings were lost following transplanting.

Because the roots have been forced to branch in the air root pruning process, there are more roots and root surface area near the base of the tree at various subsequent stages of growth and, therefore, they transplant with a greater degree of survival and with less transplant shock than with conventional production (Figure 16). By contrast, trees resulting from seedlings that were bed grown have a relatively sparse root system when dug for later transplanting. The combination of air root pruning, a well aerated germination medium, good nutrition from the time germination begins and early transplanting into larger containers or the field produce rapid growing tree seedlings with good root structures (Figure 17). In studies to date, the accelerated plant growth rate appears to continue indefinitely.



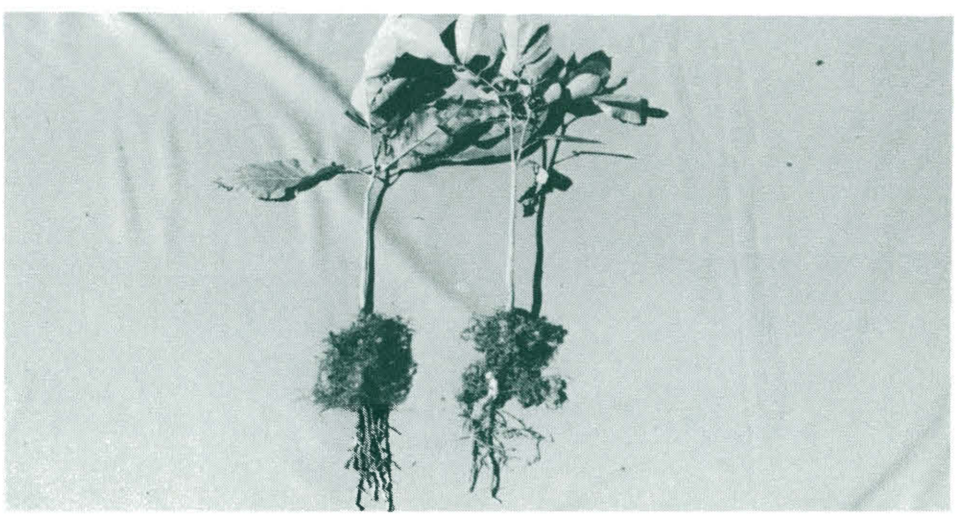


Figure 14. Primary root of pecan with air root pruning effect of stimulating lateral branching, above, and 3 weeks after transplanting into the field, below. The branch roots do not develop further on the pecan seedlings but aid the support of the plant while the tap root branches penetrate downward and establish a multi-branched taproot system.

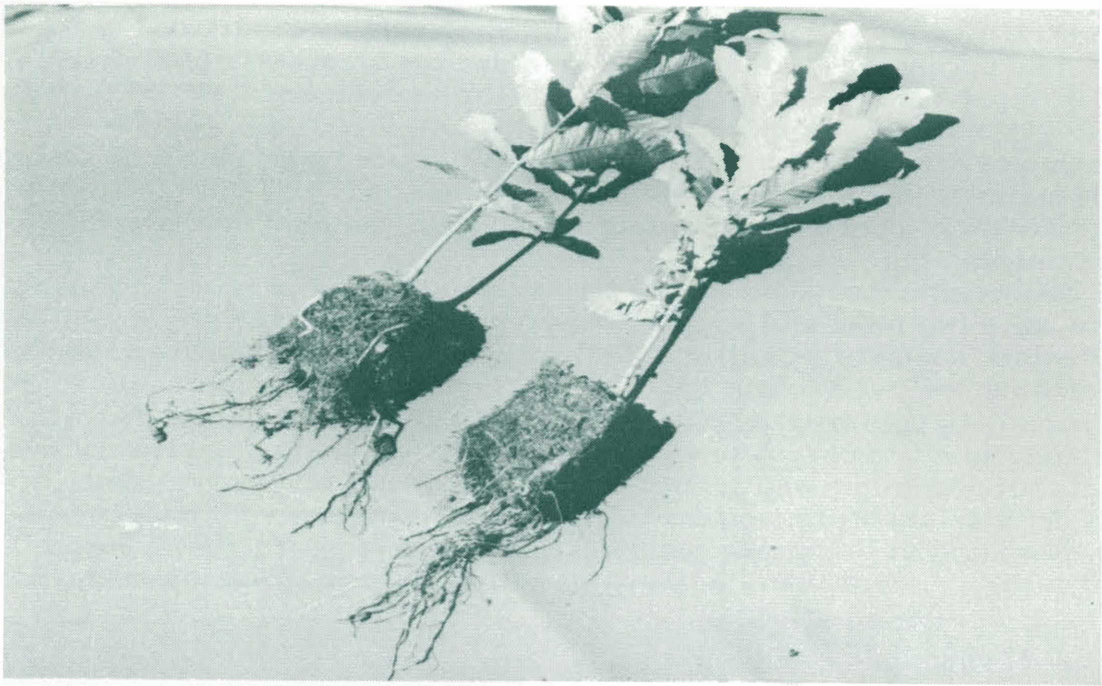


Figure 15. Three month old sawtooth oak seedlings after 3 weeks in the field. Unlike the pecans, the many white root tips of the lateral branch root developed quickly into surrounding soil. This appears to be the typical response of most species.

Figure 16. Root development of a 3½-inch caliper sawtooth oak, which was grown with the air root pruning process and dug balled in burlap after 4 years in the field. Note the distribution of many fine roots.

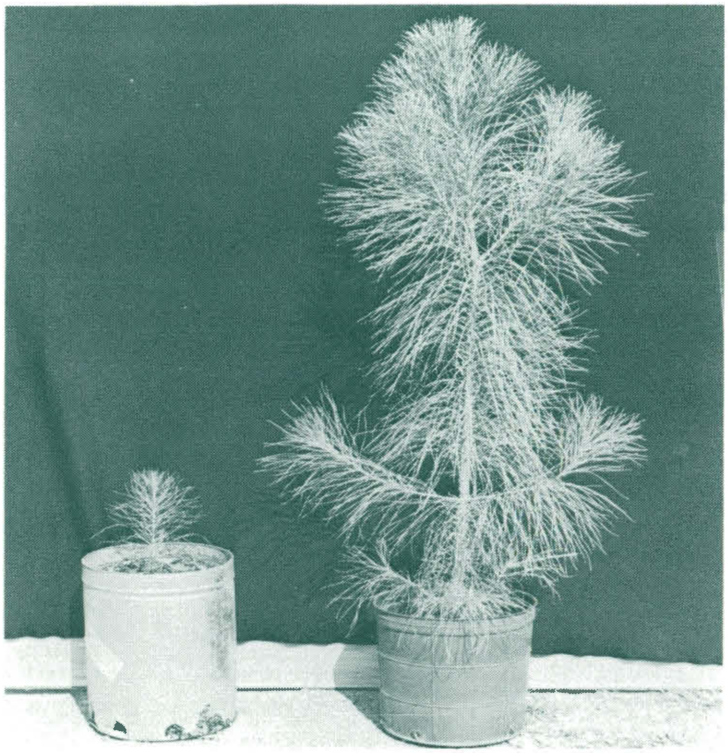


Figure 17. Loblolly pine seedlings, left, 3 months old following transplanting into a 4-gallon container and, right, 15 months old in a 3-gallon container.

Appendix

The specific requirements for seed storage and handling are well documented in the publication *Woody Plant Seed Manual,* USDA Forest Service Publication No. 13, available from Superintendent of Documents, Washington, DC 20002, for $13. This publication covers a wide assortment of species and presents specific requirements of seed storage, handling, germination and other factors. Some of the basic requirements for some of the more commonly grown trees are listed below:

*Acer saccharum
**Acer saccharinum
**Acer rubrum
*Acer ginnala
*Acer palmatum
**Betula papyrifera
**Betula nigra
**Betula maximowicziana
***Castanea mollissima
***Diospyros virginiana
***Elaeagnus angustifolia
***Fraxinus spp.
****Gymnocladus dioica
****Cercis canadensis
***Cornus florida
****Gleditsia triacanthos
***Juglans nigra
****Koelreuteria paniculata
***Liquidambar styraciflua
***Malus spp.
***Nyssa sylvatica
***Maclura pomifera
***Platanus occidentalis
****Sophora japonica
***Taxodium distichum
*****Ulmus parvifolia
***Ziziphus jujuba

*Collect when mature, store in slightly moist peat in refrigeration at 33 to 40°F for 4 to 8 weeks.

**Collect in spring and plant immediately.

***Collect seed when mature, clean and store dry in plastic bags in a refrigerator at 33 to 40°F for 4 to 8 weeks.

****Seed must be treated with concentrated sulfuric acid for 30 minutes in order to partially remove the very hard seed coat which inhibits water absorption. Plant immediately after treating.

*****Mature seed must be collected before a hard freeze in the fall, stored dry or in slightly moist peat at 33 to 40°F and planted in early spring. In addition, we collect seed in mid-November, store in slightly moist peat at 33°F and the seed will begin germinating in the refrigerator if not planted by late March. Seed quality and germination vary greatly among seedling trees, thus it may be necessary to collect seed from several trees until a good, consistent parent is found.

Literature Cited

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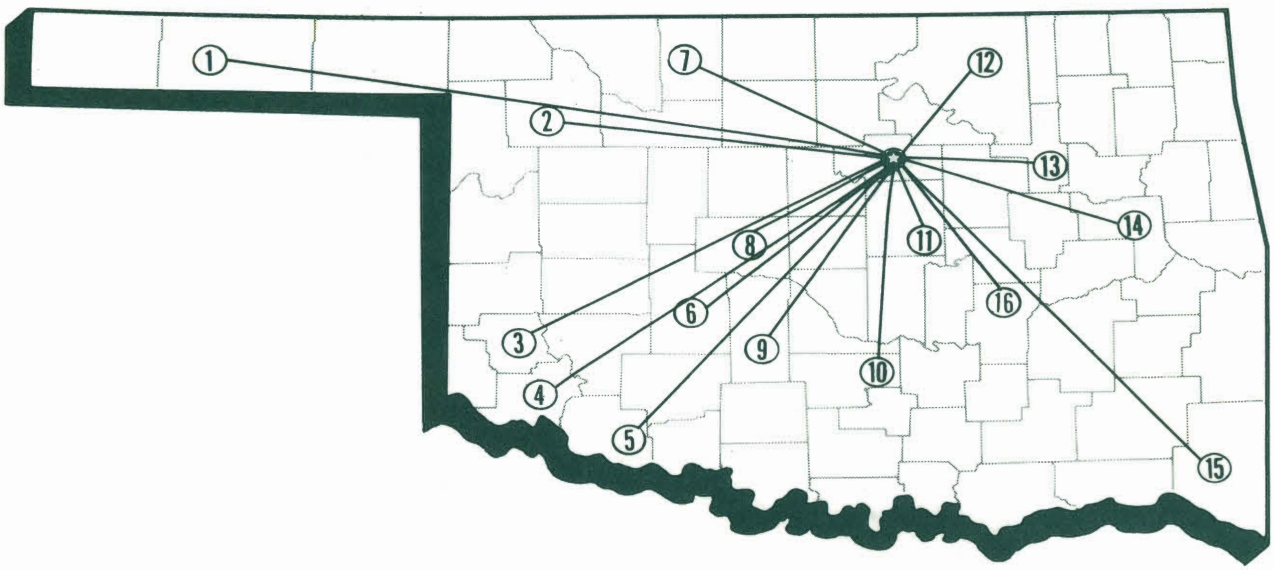
OKLAHOMA

Agricultural Experiment Station

System Covers the State



Main Station — ***Stillwater, Perkins and Lake Carl Blackwell***

1. **Panhandle Research Station** — ***Goodwell***
2. **Southern Great Plains Field Station** — ***Woodward***
3. **Sandyland Research Station** — ***Mangum***
4. **Irrigation Research Station** — ***Altus***
5. **Southwest Agronomy Research Station** — ***Tipton***
6. **Caddo Research Station** — ***Ft. Cobb***
7. **North Central Research Station** — ***Lahoma***
8. **Southwestern Livestock and Forage Research Station** — ***El Reno***
9. **South Central Research Station** — ***Chickasha***
10. **Agronomy Research Station** — ***Stratford***
11. **Pecan Research Station** — ***Sparks***
12. **Veterinary Research Station** — ***Pawhuska***
13. **Vegetable Research Station** — ***Bixby***
14. **Eastern Research Station** — ***Haskell***
15. **Kiamichi Field Station** — ***Idabel***
16. **Sarkeys Research and Demonstration Project** — ***Lamar***