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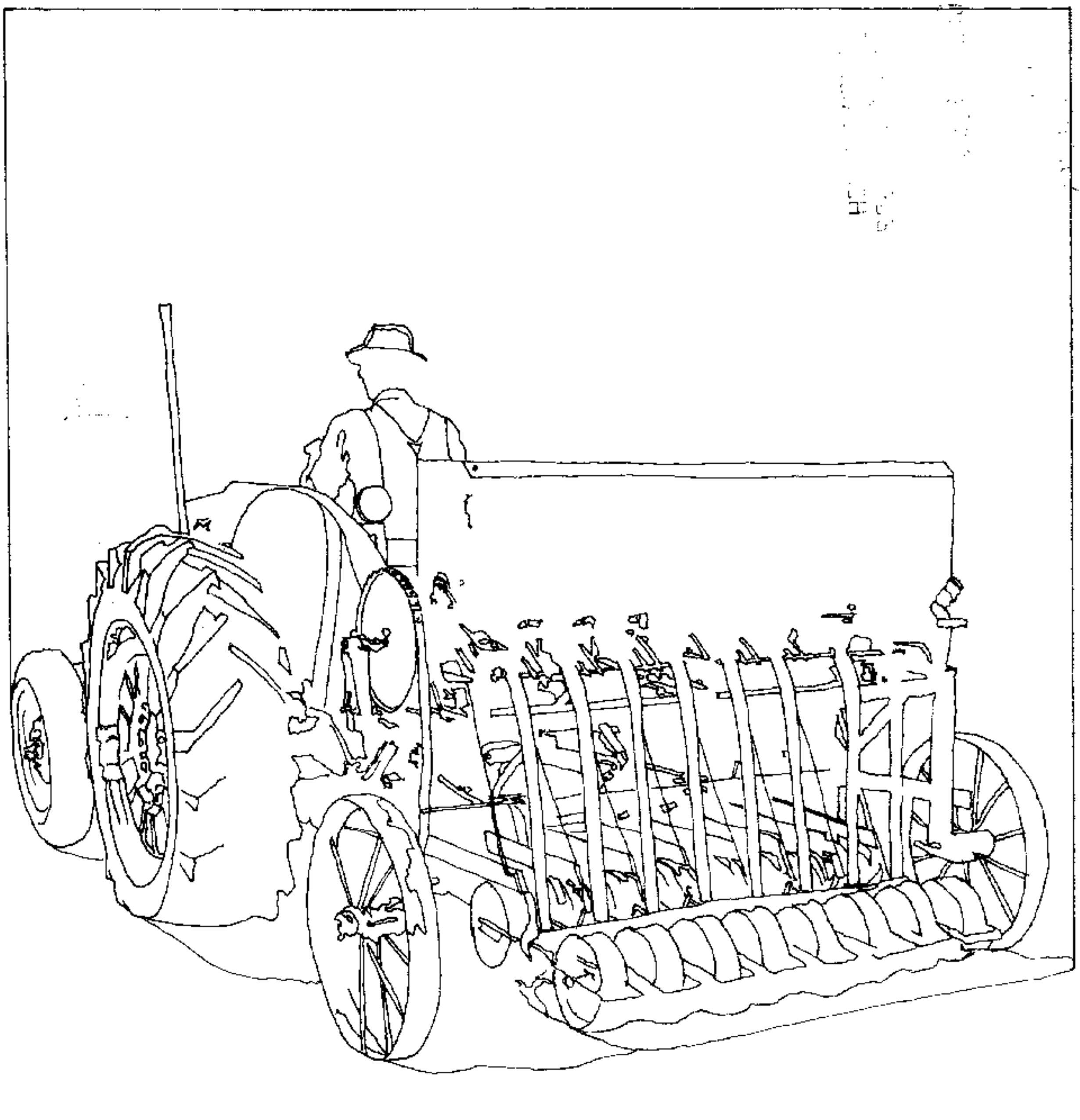
Issued March 1976
Slightly revised
July 1994

Hardwood Nursery Guide



HARDWOOD NURSERY GUIDE

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and

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Agriculture Handbook No. 473

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Forest Service

Williams, Robert D., and Sidney H. Hanks.
March 1976, slightly revisad July 1994. Hardwood nursery guide [formerly Hardwood nurseryman's guide]. U.S, Dep. Agrie., Agric. Handb. 473
78 p., illus.

This illustrated guide provides the information necessary for a nurseryman to produce hardwood seedlings in the eastern half of the United States. Subjects covered are soil management; seed development, collection, extraction, dormancy, testing, and storage; seedbed preparation, sowing, and care; vegetativa propagation; protection from wind, mammals, birds, insects, and diseases; sampling procedure and inventory data processing; and seedling lifting, grading, storage, packing, shipping. Summary tables provide supplementary information.

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Key words: seed collection, seed extraction, seed storage, nursery management, seedbed preparation, vegetative propagation, nursery protection,

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Many nurserymen and researchers have contributed to the information presented in this bulletin. Many people helped by furnishing information, by technical review of the manuscript, or both. Some of the nurserymen and supervisors with State nurseries who viere especially helpful include : Leslie Kahler (deceased), Allan Mickelson, and Hugh Wycoff (Illinois Department of Conservation) ; Delbert Mugford (Missouri Conservation Commission) ; Richard Rambo (retired), Richard McNabb, and Paul Shereda (Indiana Department of Natural Resources) ; E. G. Terrell (New York Department of Environmental Conservation) ; Carl Bailey and Franklin Wood (Ohio Department of Natural Resources) ; and W. H. Brener (Wisconsin Conservation Department).

The authors also gratefully acknowledge the consultation and technical review of Forest Service coworkers.

United States Department of Agriculture
Forest Service
Southern Region

Reply To: 3230 **Date:** June 18, 1994

Subject: Hardwood Nursery Guide (formerly Hardwood Nurseryman's Guide)

To: Reforestation Personnel

The terms "ecosystem management," "biodiversity," and "stewardship" all reflect the current emphasis on nontimber values and the importante of native vegetation. In response to this new emphasis, the demand for hardwood seedlings has rapidly grown.

One of the best sources of information on the propagation and nursery production of hardwood seedlings is USDA Forest Service Agriculture Handbook No. 473 (Robert D. Williams and Sidney H. Hanks, Hardwood Nurseryman's Guide, 1976), which has been out of print for a number of years.

Due to the current high demand for this publication, we decided to reprint now rather than to wait for a revised edition. A revision is in progress, but will Cake some time to complete.

Unfortunately, the Hardwood Nurseryman's Guide was published before the days of concern with terms that convey sex bias. The reader should substitute the term "nursery worker" for "nurseryman" wherever it appears. In anticipation of the revised edition, we have changed the narre to Hardwood Nursery Guide.

Many of the listed procedures are still valid. For example, soil fertility and seed handling guidelines are little changed. The main change has been in the area of pesticides. **Be sure to use currently labeled pesticides only!**

CLARK W. LANTZ
Nursery/Tree Improvement Specialist

ERRATA

Modifications to the Hardwood Nurseryman's Guide are shown below. The reader should keep them in mind when using the Guide.

Insecticides

The following insecticidas are registered (Section 3, FIFRA) for use on nurseries:

acephate
azinphosmethyl
Bacillus thuringiensis (Bt)
carbaryl
chlorpyrifos
diazinon
dimethoate
esfenvalerate
kelthane
malathion
trichlorfon

AH referentes to chlordane, dieldrin, mexacarbate, and mirex should be deleted.

Page 9

Under "Additional Information," for the USDA Forest Service, State and Private Forestry, make the following address changes:

Northeastern Area
5 Radnor Corporate Center, Suite 200
100 Matsonford Rd.
RO. Box 6775
Radnor, Pennsylvania 19087-4585

Southern Region [changed from "Southeastern Area"]:
1720 Peachtree Rd., NW
Atlanta, Georgia 30367-9102

For Forest Experiment Stations, make the following address changes:

North Central
1992 Folwell Ave.
St. Paul, Minnesota 55108

Northeastern
5 Radnor Corporate Center, Suite 200
100 Matsonford Rd.
P.O. Box 6775
Radnor, Pennsylvania 19087-4585

Southern
Room T-10210
U.S. Postal Service Bldg.
701 Loyola Ave.
New Orleans, Louisiana 70113

Southeastern
200 Weaver Blvd.
P.O. Box 2680
Asheville, North Carolina 28802

Page 17

Serafume (mentioned in Table 4, note 3) is a discontinued product. Delete the reference to it.

Errata—Page 36

Replace Table 8 with Table 8A (shown below).

TABLE *8A.—Physical and chemical properties of common soil fumigants*

Chemical name	Trade name (s)	Active ingredients	Formulation/activity	Application methods
Methyl bromide + chloropicrin	Brom-O-Gas® MBC-33® Meta-Brom 98® Namco Pathofume BR® Pic-Brom 33® Terr-O-Gas 67®	Two formulations: 98% methyl bromide + 2% chloropicrin and 67% methyl bromide + 33% chloropicrin	Liquified gas, bottled under pressure. Volitilizes at ambient pressure and temperature.	Injected into the soil, and covered with plastic tarp.
Dazomet	Basamid-Granular®	Tetrahydro-3, 5-dimethyl-2H-1,3,5-thiadiazine-2-thione (Methyl isothio-cyanate)* (Formaldehyde)* (Hydrogen sulfide)* (Monomethylamine)*	Fine crystalline solid. Volitilizes after contacting soil moisture.	Incorporated into the soil, and sealed with roller and/or water.
Metam-sodium	Vapam® Metam® Soil-Prep® Nemasol®	Sodium N-methyl-dithiocarbamate (Methyl isothio-cyanate)*	Liquid. Volitilizes after application to soil.	Injected into irrigation system, or into soil.
Vorlex	Vorlex®	80% Dichloropropene/ dichloropropane 20% Methyl iso-thiocyanate	Liquid. Volitilizes after application to soil.	Injected into soil; may or may not be tarped.

*Breakdown product and active fumigant gas are shown in parentheses.

Source: Landis, Thomas D., and Sally J. Campbell. Proc. IUFRO Working Party S2.07-09, p. 193. Victoria, B.C.: 1990.

Page 45

Replace Table 10 with Table 10A (shown below).

TABLE *10A.—Herbicides for nursery weed control*

Herbicide	Rate	Timing	Remarks
Simazine (Princep 4L®)*	1 lb AI/ac	Before bud break	White pine
	2-4 lb AI/ac	Spring	Walnut
Dimethyl tetrachloro-terepththalate (Dacthal W-75 Turf®)*	14-16 lbs/ac (product) in 50-100 gal water	Early spring	Birch, maple, oak, dogwood
Trifluralin (Treflan MTF®)*	1.25-2.0 pints (product) /ac	Before planting	Walnut
Oxyfluorfen (Goal 1.6E®)*	0.5-2.0 lbs AI/ac in 40+ gal water	Dormant season	Hickory, beech, pecan, walnut, cherry

*Trade names are shown in parentheses.

Errata--Page 55

In the second and fourth paragraphs, delete references to the Bureau of Sport Fisheries and Wildlife. The organization is now called the Fish and Wildlife Service, USDI, and is no longer responsible for disseminating advice and information on animal damage control. The USDA-APHIS-Animal Damage Control office is now responsible, and should be contactad for information. The Cooperative Extension Service is also an excellent source of information on controlling vertebrate pests. It has several very useful publications on animal control, including ones that provide information en trapping techniques and equipment.

In the third paragraph, there is a reference to anthraquinone. Although anthraquinone has been used in the United States as a bird repellent, it is not a registered product, and using it as a pesticida is illegal.

Pages 56-5

Replace the third paragraph on page 56 with the following:

"Pesticida registration changes constantly. Before using any chemical, the user must make cure that the product is registered for the proposed use on the proposed site. The user should be able to determine registration by studying the current label."

Ants

Delete references to chlordane, dieldrin, and mirex. Insert carbaryl, chlorpyrifos, and orthene.

Aphids

Delete references to azinphosmethyl and mexacarbate. Insert esfenvalerate, orthene, and permethrin (24C).

Bagworms

Delete the reference to trichlorfon.

Caterpillars

For the Eastern tent caterpillar, delete references to methoxychlor and mexacarbate, and insert B.t. and dimlin. For the Forest tent caterpillar, delete references to mexacarbate and trichlorfon. For the Fall webworm, insert B.t., carbaryl, and chlorpyrifos.

Willow Leaf Beetles

Delete the reference to chlordane. Insert asana XL, malathion, and orthene.

Cutworms

Delete references to chlordane and mexacarbate. Insert esfenvalerate and malathion.

Lacebugs

Delete the reference to lindane. Insert dimethoate and orthene.

Leafhoppers

Insert asana XL.

Leaf Miners

For the Birch leaf miner, delete the reference to mexacarbate. For the Elm and locust leaf miner, insert cygon 400 and orthene.

Leaf Rollers and Leaf Tiers

Insert malathion.

Mites

Delete the reference to mexacarbate. Note that kelthane is registered for commercial growers only.

White Grubs

Delete the reference to chlordane. Insert chlorpyrifos and diazinon.

Wireworms

Delete the reference to chlordane. Insert chlorpyrifos and diazinon.

Sources of Additional Information

For the USDA Forest Service, State and Private Forestry, make the following address changes:

Northeastern Area
5 Radnor Corporate Center, Suite 200
100 Matsonford Rd.
P.O. Box 6775
Radnor, Pennsylvania 19087-4585

Southern Region [changed from "Southeastern Area"]
Forest Pest Management
1720 Peachtree Rd., NW
Atlanta, Georgia 30367-9102

INTRODUCTION

The demand for hardwood seedlings has continued to increase during the past few years. The number of hardwood seedlings shipped from State, Federal, and industrial nurseries in the eastern half of the United States increased from 23 million in 1965 to 32 million in 1970. More hardwood seedlings are being planted because the demand for hardwood timber has increased and foresters have been able to establish successful hardwood plantations. Successful plantations have been established in open fields and clearcut forest sites, and nursery grown seedlings have been planted after regeneration cuttings to improve the composition of the new stand.

More is known about some species such as cottonwood, black walnut, and sweetgum because they are being thoroughly researched to improve plantation survival, cultural practices, and growth cate. The increased knowledge and successful establishment of these species has encouraged many land managers to plant them. The demand for black walnut seedlings generally exceeds the supply. The demand for hardwood seedlings will continue to increase as other species are more thoroughly studied to learn more about their cultural requirements, and as hardwoods are utilized more for expanded urban and environmental plantings.

Most nurserymen are proficient in growing conifers, and some are experienced in growing some hardwood species ; few, if any, nurserymen have grown all commonly planted hardwood species. Hardwoods as a group are more difficult to grow than conifers because the hardwoods include several botanical families and many species that differ in seeding habits and nursery requirements. Nurserymen, proficient in producing one species, such as cottonwood, might fail when requested to grow walnut or European alder seedlings.

Much scattered information exists that would help nurserymen grow and handle hardwood seedlings. This bulletin summarizes information gleaned from experienced nurserymen and the literature.

SOIL MANAGEMENT

The first factor to consider in the production of hardwood seedlings is the soil. Hardwood seedlings are more exacting in their soil requirements than most conifers. Thus, the best portions of a nursery, in terms of soil texture, surface and internal drainage, and soil *pH*[1], should be used to produce hardwood seedlings. If a new nursery is to be established for raising hardwood seedlings, special attention should be given to selection of the site. Stoeckeler and Jones (1957) cover this topic in detail and this account should be consulted when a new nursery is contemplated.

In established nurseries, most nurserymen find that a large scale soils map is an invaluable aid in locating the best soils for growing hardwood seedlings. If such a map is not available, a soil scientist should be hired to make a detailed soil survey of the nursery property. Stoeckeler (1967) describes an excellent mapping, and soil sampling procedure. The soil mapper should be instructed to delineate areas with similar soil texture in the surface and subsoil, depth to evidence of restricted drain-

[1] Words and symbols in italics are defined in the glossary at the end of the Guide.

age (mottling), and other soil characteristics critical for seedling growth. Soil samples should also be collected from each major soil type delineated on the soil map. These samples should be sent to a soils testing, laboratory for analysis of texture, pH, organic matter content, total and available nitrogen, cation exchange capacity, exchangeable calcium, magnesium, potassium, and extractable phosphorus. Results of these soil analyses furnish the basic information needed for soil management decisions. Much help in planning for the soil survey of the nursery as well as information on soil sampling, soil analyses, and interpretation of soil analyses results can be obtained from local agricultural experiment stations.

The soil management program in a tree nursery will directly affect the yield, size, and quality of the seedlings produced. Soil management practices vary greatly from one nursery to another and even within the same nursery because the effects are influenced by soil texture, previous practices, crops produced, climate, and irrigation water. Nevertheless, there are certain general principies in soil management for raising hardwood seedlings that will apply to most nurseries. Some of these practices are discussed in this bulletin, but many other soil management problems develop that can only be solved by seeking expert advice (see page 59) .

Maintenance of Soil Texture and Soil Structure

Soil texture, the relative amount of sand, silt, and clay particles in a soil, is considered fixed and is not ordinarily changed. However, small changes can be made in the plow layer by deep plowing or by addition, such as mixing sand with a clay sol. Hardwood seedlings, like most other tree seedlings, grow best on sandy loam and loam soils because of the better balance between soil moisture retention and aeration. Soil nutrient levels are also usually much higher in loamy soils than in sandy soils. Whenever problems are encountered in raising hardwood seedlings because of poor texture, the best solution may be to locate a more favorable asea.

Soil structure is the arrangement of individual soil particles and aggregated clusters of sand, silt, and clay. Soil structure can be improved by increasing the quantity of stable soil aggregates. Stable aggregates can be formed in sands and silts when organic or inorganic *colloids* are present. Organic colloids cause a high degree of aggregation and the formation of large aggregates. Aggregation of clays is not adequate without some humus. A continuing supply of decomposing organic matter is necessary to maintain a high level of soil aggregation.

Soil structure may be altered by tillage. Tillage may or may not be beneficial, depending upon the equipment used, the number and types of operations, and the soil moisture content when the soil is worked. Moldboard plows that turra the soil over do not destroy soil aggregates but rotary tillers that pulverize the soil can break up soil aggregates, especially if the tiller is used excessively. Soil should not be overcultivated because the beneficial effects produced by one tillage implement may be destroyed by succeeding operations. Soils should be tilled when the moisture content is optimum for structure formation ; that is, when most of the capillary pores are filled with water and soil particles can stick together. At low soil moisture content, fine dust is produced, and at high moisture content the soil is puddled and dries into hard clods.

Maintenance of Soil Organic Matter

The organic matter in a soil influences the chemical as well as the physical properties. In a forest tree nursery, the depletion of the organic matter is more rapid than for most crops because the entice plant is removed. The lost organic matter must be replaced, but it is not considered advisable to attempt to increase the organic matter content of the soil aboye the equilibrium level. In fact, it is almost impossible to build up the organic matter content of the soil aboye that level, but it can be maintained.

The amount of organic matter that should be maintained in the soil depends upon soil texture, drainage, and climatic factors. Sandy soils should contain from 1.5 to 2.0 percent and heavier soils from 2.0 and 3.0 percent organic matter in the plow layer (May 1964) . If the organic matter content is too low, soil structure and the availability of nutrients may be poor ; if too high, the carbon-nitrogen ratio may become too high and the availability of nitrogen and phosphorus may decrease because of the activities of micro-organisms.

Maintenance of soil organic matter is best accomplished by making small, frequent additions of organic materials that will decay rapidly and benefit one or two crops (Millar 1959) Green manure crops, such as rye, and soil amendments, such as sawdust, are examples of the materials used. Most nurseries follow a crop rotation system. At the George O. White State Tree Nursery in Missouri, the rotation is 2 years in seedling production and 1 year in green manure crop. When soil organic content becomes low and soil structure becomes poor, sawdust may be incorporated before sowing the green manure crop.

Use of Green Manure Crops

Green manuring is the practice of growing and turning under green plant tissue (fig. 1). Green manure crops should grow fast and produce abundant succulent tops. Green manure crops should be plowed under while succulent, when the carbon to nitrogen ratio is low. Mature plant residues have a high ratio, about 50 percent carbon and less than 1 percent nitrogen. Until the carbon to nitrogen ratio is reduced to a range of 15:1 or 10:1, soil nitrogen is utilized by soil micro-organisms and an inadequate supply is available for the seedlings. The addition of nitrogenous fertilizers is usually necessary to hasten decomposition and maintain a favorable carbon-nitrogen ratio. Another reason for plowing under immature green manure crops is to prevent seed formation. Unwanted seed from green manure crops would germinate in nonfumigated seedbeds or even in fumigated seedbeds if the green manure seed is resistant to fumigation.

Various plants are suitable for green manure crops. Some of the legumes that have been used successfully are soybeans, vetch, clover, lupine, serradella, and cow peas. Sudan grass, rye, oats, barley, millet, buckwheat, and corn are some of the nonlegumes that are used.

Green manure crops are used as catch crops for commercial fertilizers (Brener and Wilde 1941) . Inorganic fertilizers are temporarily fixed by the green manure crop as relatively insoluble organic compounds. As the plant tissues decompose, nutrients gradually become available to the seedlings.

Nurserymen in Indiana, Illinois, and Missouri prefer sudan grass as a green manure crop. The seedbeds or units scheduled for renovation are tilled, fertilized, and sown sometime during May to mid-June. At Indiana's Jasper-Pulaski Nursery, which is on a sandy soil with a rather high natural organic matter content, 450 pounds per acre of fertilizer, including 100 pounds of ammonium nitrate, 200 pounds of treble superphosphate, and 150 pounds of muriate of potash are spread when the sudan grass is sown. The sudan grass is plowed clown before the stem hardens, usually in July. No addidonal fertilizer is needed when the sudan grass is turned under.

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Figure 1.—Plowing down green manure helps maintain soil organic matter.

At the Jonesboro Nursery, which is located on a loam soil in southern Illinois, sudan grass is sown in June and moved twice before it is turned under in August. Fifty to 100 pounds per acre of ammonium nitrate or ammonium sulfate are spread when the grass is sown. Additional nitrogen is added if foliage indicates a deficiency. After plowdown, phosphorus, potash, and additional nitrogen are applied as in dicated by soil tests.

At Indiana's Vallonia Nursery, which is located on a sandy soil low in organic matter, soybeans are used as the green manure crop.

Two to 2 1/2 bushels per acre of soybeans are sown in May on soil fertilized with a low nitrogen fertilizer such as 4-16-16 or 5-20-20. The soybean cyst nematode is a risk but is adequately controlled by the fumigation program.

At the Mason State Tree Nursery in Illinois, sudan grass is used. Ammonium nitrate or ammonium sulfate is applied at the rate of 30 to 60 pounds of nitrogen per acre per application to stimulate growth and decompose the green manure crop. Foliage color of the catch crop is a good indicator of nitrogen availability. Before the green manure crop is sown, phosphate and potash are applied on the basis of soil tests and records of previous nursery crops.

One percent organic matter in an 8-inch plow layer of sandy soil is about 12 or 13 tons of dry weight per acre (Stone 1965) . A heavy cover crop, roots and tops, amounts to about 2 to 3 tons of dry weight per acre. When this is plowed down, half or two-thirds is promptly decomposed, leaving only about 1 ton or less of slowly decomposing humus. Such small additions may not balance normal organic matter decomposition during the cropping period so soil amendments such as sawdust are often necessary (Stone 1965).

Other Sources of Organic Matter

Peat moss, sawdust, barnyard manure, compost, and corncobs also have been used to maintain soil organic matter. Sawdust is probably available to any tree nursery and may be used as a compost, a mulch, or incorporated into the soil. It is recommended if certain precautions are observed. Fresh sawdust has an extremely high (500 :1) carbon-nitrogen ratio and will immobilize large quantities of soil nitrogen (Davey 1965).

Sawdust compost may be prepared and added to the soil without losing a year's production of trees, whereas 1 year's tree production is lost if raw sawdust is incorporated. In a suitable container (a large concrete basin) apply 15 pounds of nitrogen in the form of anhydrous ammonia and 5 pounds of 50 percent potassium sulfate per cubic yard of sawdust. After 10 days, neutralize the mixture by adding 2 pounds of 85 percent phosphoric acid per cubic yard. The 2 pounds of acid should be diluted in 8 gallons of water to facilitate a more uniform distribution. After another 10-day period, inoculate the chemically treated sawdust with *Coprinus ephemerus,* a very active cellulose decomposer when sufficient ammonia is present. Under favorable climatic conditions, most of the cellulose can be decomposed and the carbon-nitrogen ratio reduced from 500 :1 to about 20 :1 in about 3 months (Davey 1953) .

Sawdust, new or old, is used at many nurseries to maintain soil organic matter. The rate needed will vary from one nursery to another and so will frequency of application. At the Mason State Tree Nursery, in central Illinois, sawdust is usually spread and incorporated into the soil. Up to 500 cubic yards per acre (4 inches of sawdust) , injected with 1,200 pounds of anhydrous ammonia, has been used. Special equipment is required to use anhydrous ammonia and more risk is involved than with dry fertilizer. Normally, severa] applications of dry nitrogen are applied. The color of the green manure foliage indicates the need for and timing of applications. Phosphate and potash are maintained at high levels.

At the George O. White State Tree Nursery, located on a loam soil in southern Missouri, 400 cubic yards of sawdust per acre (3 inches of sawdust) are incorporated when soil structure deteriorates. The sawdust, along with 1,000 pounds of ammonium nitrate and 500 pounds of superphosphate per acre is broadcast and plowed down in March or April. Sudan grass fertilized with 300 pounds per acre of 8-24-40 is sown in May and plowed under in mid-June as with normal green manure crops.

Sawdust is also used at severa] nurseries to mulch seedbeds. Sawdust and other organic mulches have a minor effect on soil organic matter content. However, sawdust should be treated with ammonium nitrate or other suitable nitrogenous fertilizer before application. At Mason State Tree Nursery mulched hardwoods are topdressed with ammonium sulfate at 125 to 150 pounds per acre as soon as the seedlings are large enough to respond and 2 or 3 applications are made at 2 to 4 week intervals until early August.

Barnyard manure is also well known for its fertilizing qualities and is useful for building soil organic matter. At the Towner Nursery in North Dakota, barnyard manure was applied liberally, 10 to 20 tons per acre, to one tract instead of using green manure crops. During a

10-year period of continuous seedling crops, each new crop was more vigorous than the previous one (Stoeckeler and Slabaugh 1965).

Maintenance of Soil pH

Soil pH for most hardwoods should be maintained near 6, although some species, such as river birch and European alder, grow best when soil pH is near 5. Seedlings may be grown over a wide range of pH if the proper concentrations of essential mineral elements are maintained. Broadfoot *et al.* (1971) list the natural occurrence of southern hardwoods in relation to surface soil pH.

Soil pH regulates, to a great extent, the solubility and availability of many important nutrient elements (Allaway 1957) . Aluminum, iron, manganese, and zinc ions become increasingly soluble as the soil becomes more acid and may become toxic to the seedlings. In contrast, the availability of potassium, phosphorus, calcium, and magnesium is reduced as pH is reduced. The availability of phosphorus can be reduced also if the soil becomes too alkaline, over pH 7.5.

Neutralizing an acid soil usually provides a more favorable environment for the growth of bacteria and other soil micro-organisms. These micro-organisms convert nitrogen, sulfur, and phosphorus from organic compounds not available to plants to inorganic forms usable by plants.

The amount of neutralizing material required to raise or lower the soil pH a given amount will vary with soil texture and organic matter content. Fine textured soils and those high in organic matter have a greater buffering capacity and therefore require more neutralizing material than coarse textured soils or those low in organic matter.

Soil pH may be modified by fertilizers if only slight changes are required. If rather large adjustments are required, lime may be used to increase and sulfur to decrease pH. The chart gives the lime or sulfur requirement for pH adjustment of three soil types (fig. 2) . Lime or sulfur should be applied 2 to 6 months before seeding to allow time for the neutralization reaction.

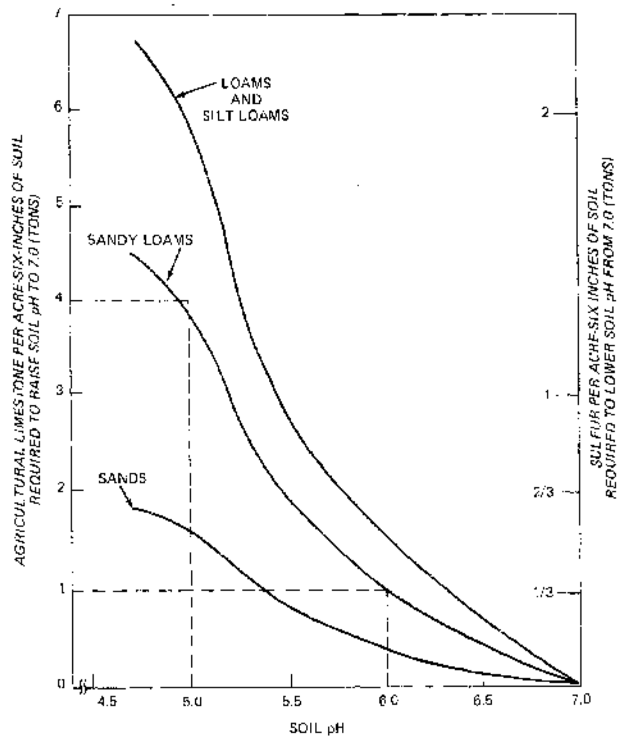


Figure. 2—Amounts of lime or sulfur required to change soil pH on one acre (6-inch surface layer). To raise pH, read the difference in lime requirements on the left vertical axis corresponding to difference between present and desired pH on the appropriate soil curve. To lower pH, read the difference in sulfur requirements on the right vertical axis corresponding to difference between present and desired pH on the appropriate soil curves. *Example:* To raise sandy loara pH from 5.0 to 6.0 requires 3 toas of agricultural limestone per acre—difference between 1 and 4 on left vertical axis.

Use of Fertilizers

All of the nutrient elements needed by hardwood seedlings can be furnished by organic or inorganic fertilizers. With the exception of leguminous green manure crops and barnyard manure, organic fertilizers are expensive to use in the long run because the percent of nutrient is low compared to inorganic fertilizers. The simplest and cheapest way to supply needed nutrients to the seedlings is to apply inorganic fertilizers. Care should be exercised to select the proper fertilizer, and to apply it at the right time in the optimum amount.

Soil fertility must be near optimum and in balance to grow balanced seedlings. Large seedlings produced by heavy applications of fertilizers often have succulent tissues, unbalanced top-root ratio, and other unsatisfactory properties that may adversely affect field survival.

No optimum nutrient ratio is applicable to ll soils and all species. Each soil and species equires individual attention and treatment. ome soil fertility standards for raising hard-ood seedlings are suggested in table 1.

Fertilizers are available in many different rrms and combinations (table 2). The ferti-zer selected should depend upon how much of given element is needed; whether the pH ust be raised or lowered; whether the element to be applied and turned under, used as a top ressing, or used as a side dressing; what kind equipment is available at the nursery; and her soil management or nursery practices iat might affect the availability of the element.

Conversion factors given in table 2 may be ied to determine the weight of an element 'ailable in a given weight of fertilizer. These nversion factors also can be used to compute ie amount of fertilizer required to furnish desired quantity of nutrient (Mony 1952). xamples:

(a) In 500 pounds of 8–16–16, nutrients are 'ailable as follows:

500 × 8 percent = 40.0 pounds of nitrogen

500 × 16 percent = 80 pounds of P_2O_5 × 0.45 = 36.0 pounds of P

500 × 16 percent = 80 pounds of K_2O × 0.83 = 66.4 pounds of K

(b) Thirty-six pounds of phosphorus are needed to fertilize a seedbed. How much 8–16–16 fertilizer is needed to furnish 36 pounds of phosphorus?

$$\frac{36}{.16} \times 2.22 = 500 \text{ pounds of 8–16–16 fertilizer.}$$

Because inorganic fertilizers in large amounts can be toxic to tree seedlings any quantity that exceeds the requirements of the current seedling crop should be applied on a prior crop of green manure or when the green manure is turned under during formation of the seedbeds. However, smaller corrective applications can be made on tree seedlings as top or side dressing throughout the growing season as indicated by foliar deficiency symptoms. Color photographs have been published showing nutrient deficiencies of some hardwood species (Hacskaylo *et al.* 1969).

TABLE 1. Soil fertility standards for raising hardwood seedlings.[1]

Species	pH range	Total N	Available P_2O_5 per acre	Available K_2O per acre	Base exchange capacity	Exchangeable Ca	Exchangeable Mg
		Percent	*Pounds*	*Pounds*	*Me./100 grams*[2]	*Me./100 grams*	
Acer nigrum	5.5-7.3	0.20	100	250	10.0	5.0	2.0
saccharum	5.5-7.3	.20	100	250	10.0	5.0	2.0
Alnus glutinosa	5.0	—	—	—	—	—	—
Betula alleghaniensis	5.0-6.0	.12	70	200	7.0	2.5	1.0
nigra	5.0	—	—	—	—	—	—
Carya illinoensis	5.5-7.3	.20	100	250	10.0	5.0	2.0
Fraxinus americana	5.5-7.3	.20	100	250	10.0	5.0	2.0
Juglans cinerea	5.5-7.3	.20	100	250	10.0	5.0	2.0
nigra	5.5-7.3	.20	100	250	10.0	5.0	2.0
Liriodendron tulipifera	5.5-7.3	.20	100	250	10.0	5.0	2.0
Populus tremuloides	5.0-6.0	.12	70	200	7.0	2.5	1.0
Prunus serotina	5.0-6.0	.12	70	200	7.0	2.5	1.0
Quercus alba	5.5-7.3	.20	100	250	10.0	5.0	2.0
macrocarpa	5.5-7.3	.20	100	250	10.0	5.0	2.0
palustris	5.0-6.0	.12	70	200	7.0	2.5	1.0
rubra	5.0-6.0	.12	70	200	7.0	2.5	1.0
velutina	5.0-6.0	.12	70	200	7.0	2.5	1.0
Tilia americana	5.5-7.3	.20	100	250	10.0	5.0	2.0
Ulmus americana	5.5-7.3	.20	100	250	10.0	5.0	2.0

[1] Source: Wilde, S. A. Forest soils. 537 pp. New York: The Ronald Press Company, 1958.

[2] Milliequivalents per 100 grams.

TABLE 2.—*Some common nitrogen, phosphorus, and potassium fertilizer materials*[1] *and their adaptability for nursery use*

Fertilizer materials	Approximate[2] analyses N	Approximate[2] analyses P_2O_5	Approximate[2] analyses K_2O	Availability	Adaptation for Top dress	Adaptation for Side dress	Adaptation for Plowdown
		Percent					
Ammonia, anhydrous	82	0	0	Rapid	NA	Excellent	Excellent
Ammonia, liquor	21	0	0	Rapid	NA	Excellent	Excellent
Ammonium phosphate (monobasic)	12	61	0	Rapid	Good	Excellent	Excellent
Ammonium phosphate (diabasic)	18	46	0	Rapid	Good	Excellent	Excellent
Ammonium nitrate	33	0	0	Rapid	Good	Excellent	Good
Ammonium sulphate	20	0	0	Rapid	Good	Excellent	Excellent
Ammonium phosphate sulphate	16	20	0	Rapid	Good	Excellent	Excellent
Calcium cyanamide[3]	21	0	0	Medium	Fair	Poor	Excellent
Calcium metaphosphate	0	71	0	Medium	Fair	Fair	Excellent
Phosphate rock	0	Ranges from 28-38	0	Slow	Poor	Poor	Good
Phosphoric acid	0	Ranges from 50-80	0	Rapid	—	—	—
Potassium chloride	0	0	50	Rapid	Fair	Excellent	Excellent
Potassium metaphosphate	0	36	36	Rapid	Excellent	Excellent	Excellent
Potassium nitrate	12	0	44	Rapid	Fair	Excellent	Excellent
Potassium sulphate	0	0	48	Rapid	Fair	Excellent	Excellent
Superphosphate							
Normal (reg. std.)	0	Grades containing up to 22 or less	0	Rapid	Excellent	Excellent	Excellent
Enriched (super)	0	22 to 40	0	Rapid	Excellent	Excellent	Excellent
Concentrated (treble)	0	More than 40	0	Rapid	Fair	Excellent	Excellent
Urea	45	0	0	Rapid	Good	Good	Excellent
Urea-ammonium nitrate-ammonia solution	42	0	0	Rapid	NA	Excellent	Excellent
Urea-formaldehyde	38	0	0	Slow	—	—	—

[1] Commercial (mixed) fertilizers are prepared by mixing materials that are composed of N, P, and K to yield the analyses listed on the label (i.e., percent N—percent P_2O_5—percent K_2O). Conversion factors: Pounds of $P_2O_5 \times 0.45$ = pounds of P; Pounds of P $\times$ 2.22 = pounds of P_2O_5; Pounds of $K_2O \times 0.83$ = pounds of K; Pounds of K $\times$ 1.20 = pounds of K_2O (see text).

[2] Check label for exact content of N, available P_2O_5 and K_2O. Analyses listed are minimum allowable by the American Association of Fertilizer Control Officials (AAFCO) or average minimum content of several analyses. Reference: Berg, G. L., Editor. Farm Chemicals Handbook. Willoughby, Ohio: Meister Publishing Co. 1970.

[3] *Caution:* poisonous, wash from skin.

Specific Nutrient Requirements

Although green plants require 16 essential elements, those most commonly applied and needed in most quantity are the macronutrients nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Lesser amounts of the other elements are generally required.

Nitrogen

Sufficient nitrogen promotes growth of the stem and foliage and gives the leaves a dark green color. Symptoms of an oversupply of nitrogen are very dark green, soft, "sappy" leaves. Such seedlings are susceptible to disease and mature so late in the fall that they often suffer frost damage.

Seedlings receiving insufficient nitrogen are stunted and have yellow to yellowish-green leaves that tend to drop off. If these symptoms are noticed early enough, the deficiency may be corrected by applying nitrogen as a top or side dressing.

Nitrifying bacteria, the soil micro-organisms responsible for the rapid transformation of ammonia nitrogen to the 'nitrate form, are temporarily inhibited when seedbeds are fumigated. This generally increases the ammonium nitrogen and decreases the nitrate nitrogen in the soil (Davidson and Thiegs 1966). Ammonia fertilizers should not be added to recently fumigated seedbeds because ammonia released from them combines with ammonia released from decomposing green manure to become toxic to seedlings (Thiegs 1955). Good aeration of fumigated soil is necessary to allow the fumigant to escape so that the nitrifying bacteria can become re-established and prevent harmful, toxic buildups of ammonia (Davidson and Thiegs 1966) .

Phosphorus

Phosphorus is necessary for cell division, crop maturation, counteracting excess nitrogen, developing roots, particularly lateral and fibrous roots, and developing resistance to certain diseases (Buckman and Brady 1967) .

Most of the total phosphorus in the soil is tied up chemically in forms not usable by the plants. Available soil phosphorus is about 1 percent of the total amount in the soil (Olsen and Fried 1957) . Poor solubility is characteristic of soil phosphorus, but phosphorus is most available to seedlings between pH 6 and pH 7. Phosphorus availability increases with the addition of enganic matter. Availability may drop temporarily during periods of rapid microbial growth because phosphorus becomes bound in organic compounds, especially in crop residues low in phosphorus and high in carbon, such as straw. However, as the organic matter decays, the phosphorus released is available for seedling growth.

A high annual rate of phosphorus fertilization may be necessary for a time, but as phosphorus accumulates in the soil the rate and frequency of application can be reduced. Phosphate fertilizers should be worked finto the soil or placed in the soil in bands close to the seedling roots.

Early stages of phosphorus deficiency may be readily visible. Phosphorus deficiency symptoms are variable. For black walnut the veins of the leaves are light yellow while interveinal aneas are green en reddish brown to purplish red. Sweetgum may have red petioles with light reddish main leaves (Hacskaylo *et al.* 1969) . Root development is peor and the plants often look spindly and stunted. Tree seedlings grow slowly, and have sparse foliage which may be purple or purple tinged. Leaves will often drop early under conditions of phosphorus deficiency (Bingham 1966) .

If a phosphorus deficiency threatens to render the crop below grade, some trees may be salvaged by applying a water soluble, high analysis phosphorus fertilizer as a top dressing during the growing season.

Potassium

Potassium increases crop resistance to certain diseases and has a favorable effect on root development. Plants requise large amounts of potassium but it should be added by frequent, light applications. Excessive potassium is lost by leaching, luxury consumption by the plants, or by fixation in the soil.

A moderate deficiency of potassium may not be noticeable because only a general reduction in growth results. However, when yellowing occurs at the tips and edges of older leaves, the deficiency is more critical but a potassium fertilizer may be used to overcome the damage. As the potassium deficiency becomes worse, the yellowing of the leaf broadens, the margins die, and latee the entire leaf dies.

Magnesium

Visual deficiency symptoms for magnesium generally appear in the older leaves first and become evident in the latter part of the growing season. Loss of green color between the veins followed by chlorosis and/or development of brilliant colors is characteristic. In severe cases the whole leaf may turn yellow or another brilliant color; necrotic areas may develop interveinally or along margins or the tips of leaves. Premature defoliation usually occurs (Embleton 1966) .

Birch leaves turn yellow, with gray-to-brown spotting of the margins spreading over the whole blade until the leaves finally die (Ingestad 1957)

Deficiency symptoms vary in pecan by variety but generally the leaves show bronzing, develop chlorosis and necrosis usually at the margin, and then drop off (Alben *et al.* 1942).

Magnesium deficiency occurs most commonly in acid sandy soils in areas of moderate to high rainfall. The symptoms may not appear during the season of lower rainfall. Crops growing in acid soils containing less than 50 pounds of exchangeable magnesium per acre may show visible deficiency symptoms (Peech 1948) .

Magnesium deficiency in growing crops can be corrected by Epsom sali sprays in the presence of adequate nitrogen levels (Forshey 1959) . Spray applications do not always correct the deficiency symptoms and only a short term response can be expected. Soil applications of a magnesium fertilizer or dolomitic limestone are more reliable.

Calcium

Moderate to acute stages of deficiency are more readily apparent in root response. Root growth is impaired and root rotting frequently occurs. Young leaves of new plants are affected first. They are often distorted, small, and frequently show spotted or necrotic areas. Young leaves of pecan remain small with yellowing, mottling, and bronzing; there may be necrosis of the leaf tips and shorter leaf rachises (Alben *et al.* **1942)** .

Sandy soils subject to high rainfall commonly become acid but should respond to added calcium. On intensively cropped soils, gypsum may be applied to maintain an adequate calcium level without significantly changing pH.

Sulfur

Leaves of sulfur-deficient seedlings are yellow or chlorotic. Leaf yellowing is also characteristic of nitrogen deficiency. Deficiencies of the two elements may be distinguished by the age of the tissue affected. In sulfur-deficient seedlings only the young leaves turn yellow ; in nitrogen-deficient seedlings yellowing can occur on leaves of all ages.

Sulfur deficiencies are not likely to develop if fertilizers containing sulfate are routinely used. Gypsum, used as a source of calcium, will also provide sufficient sulfur for seedling crops.

Micronutrients

Micronutrients must be added to the soil more carefully than the macronutrients. The difference between the amount of a micronutrient (manganese, copper, boron, zinc, molybdenum, sodium, and silicon) required and the amount that is toxic is very small, so micronutrients should be added only when the need is definitely established. When needed, micronutrients may be applied in foliar sprays.

Importance of Soil Micro-organisms

Soil microbiology influences the soil as a medium for plant growth. Bacteria, actinomycetes, and fungi are agents of decay ; they mineralize organic matter and continually recycle chemical elements. Thus, it is important that nurserymen be particularly cautious in using fertilizers, insecticides, herbicides, fumigants, etc., to avoid drastically upsetting the natural balance of the beneficial micro-organisms in the soil.

Mycorrhizal fungi colonize root surfaces and penetrate root cells to form a fungus-root association beneficial to the plant. *Ectomycorrhizae* colonize the root surface and give the seedlings greater absorptive area. Plants with ectomycorrhizae absorb more nutrients than plants without *mycorrhizae* on the roots. This effect remains to be proved for the *endomycorrhizae,* which penetrate the root cells of yellow-poplar and other hardwood species, but endomycorrhizae are necessary for good seedling growth (Clark **1964)** .

Additional Inf ormation

For more information concerning soil management, nurserymen should contact :

State Colleges or Universities, Agronomy or Soils Departments
USDA Soil Conservation Service
State Agricultural Experiment Stations
Cooperative Extension Service
USDA Forest Service
State and Private Forestry:
Northeastern Area
6816 Market St.
Upper Darby, Pennsylvania 19082

Southeastern Area
50 Seventh St., NE
Atlanta, Georgia 30323

Forest Experiment Stations:
North Central
Folwell Ave.
St. Paul, Minnesota 55101

Northeastern
6816 Market St.
Upper Darby, Pennsylvania 19082

Southern
Federal Bldg.
701 Loyola Ave.
New Orleans, Louisiana 70113

Southeastern
Post Office Bldg.
Asheville, North Carolina 28802

This section consists of a brief discussion of topics pertaining to hardwood seeds that are useful to nurserymen. A more comprehensive coverage of these topics and specific data on individual species are included in *Secds of Woody Plants in the United States* (USDA Forest Service 1974) .

Seed Development

A thorough understanding of how and when seed of hardwood tree species is produced is essential for the collection of viable seed.

Flowering

Seed collectors should be especially familiar with the flowering habits of potential seed trees (table 3). The amount of flowering is indicative of the amount of seed that may be produced. Knowing when flowers appear, the seed collector can watch the flowers to determine if weather conditions, such as flower-killing frosts, influence the fruit crop.

Seed collectors should also know whether a species is *monoecious* (male and female flowers separate but on the same tree), *dioecious* (male flowers on one tree and female flowers on a different tree), *perfect* (male and female parts in the same flower), or *polygamous* (perfect and unisexual flowers on the same tree). This information will help him avoid collecting self-pollinated seed, which exhibits low viability, or alert him to check the fruit closely if male and female trees of a dioecious species are too far apart for effective pollination.

Se ed-Bearing Age

The age when a tree bears fruit varíes among and even within species. European alder bears commercial quantities of seed when only 4 or 5 years old, while bur oak does not bear commercial quantities of seed until 35 years of age or older.

Open-grown trees with large, vigorous crowns produce seed at a younger age than woods-grown trees. Young trees put most of their energy, vigor, and nutrients into vegetative growth. Trees produce their best seed crops in the middle years and seed production declines, usually, when the tree reaches old age.

Frequency of Seed Crops

Trees produce seed in cycles but some seed is produced nearly every year by most species (table 3). Some species, such as silver maple, produce good seed crops almost every year. Other species, such as sugar maple, may produce good seed crops only at intervals of 2 to 5 years. These cycles are most apparent for bumper seed- years.

The nurseryman should collect seed from cyclic species during the bumper crops and atore it for use during the poor seed years. In addition to being abundant, seed from bumper crops usually has less insect damage and higher viability than seed from poor crops.

When seed is entirely lacking locally because of frost or some other adverse condition during a critical stage of seed formation, fair to excellent seed crops may be available in other portions of the range.

Seed Ripening and Field Viability Tests

Seed ripening date varíes by species. Seed of red maple and American elm ripens in the spring and mulberry seed ripens in the summer, but the seed of most North American hardwoods ripens in the fall (table 4). Approximate seed ripening dates are known for most species, but specific collection dates cannot be established because the date of seed maturity varies over the range of the species locally with current weather conditions, and between individual trees. Nurserymen, therefore, must determine when seed is ready to collect.

Color change of the fruit is the best way to determine seed maturity once local experience is gained. When the fruit changes color, or in some cases starts to change color, the fruit is either ready or about ready to be collected. Color change is the most important criteria for judging when to collect the seed of basswood, yellow-poplar, mulberry, and many other species.

Before collection, seed from individual trees should be cut or cracked to determine seed maturity and to estimate viability (fig. 3). The kernel of immature seed is soft and milky, while the kernel of mature, viable seed is firm, white or cream colored, and fills the seed cavity.

Field cutting tests will eliminate seed trees that produced excessive blank, rotted, or insect-infested seed. If the seed of an individual tree is not of average quality or better according to the cutting test, seed should not be collected from that tree.

Seed Collection

Seed collection is a significant expense in the production of hardwood seedlings. Thus, it is important that good, viable seed be collected and that no time be lost locating seed trees.

Seed Sources

Most forest tree species probably have developed geographical races adapted to the local climate. For example, seedlings produced from seed collected at a distance from the planting site may break dormancy early in the spring and may be damaged by late spring frosts. Black walnut has exhibited a faster juvenile growth when moved north, but seedlings from seed collected far south of the planting site continue growing later finto the fall and are sometimes injured by early fall frosts.

Usually, but not always, seed from local sources produces seedlings better adapted to local planting sites than imported races. However, if local seed is not available and *provenance tests* have not been made, seed from collection zones similar in climate to the contemplated planting site should be used.

Seed collection zones, based primarily on temperature and precipitation, have been published for some aseas (Limstrom 1965, Rudolf 1957).

The nurseryman should constantly watch for potential seed sources for all species grown or that might be grown at his nursery. He should also look for stands or groups of trees of good vigor and form, and of the optimum age to produce seed. Poorly formed seed trees should be avoided.

Seed should be collected from stands that contain several trees of a species rather than from isolated trees. Pollination of isolated trees

F-521303

Figure 3.—Yellow-poplar seed cones should be cut to determine the number of viable seed per cone. No seed cavities are filled in this view. Unless six or more seed cavities per cone are filled, the tree should not be used as a seed source.

TABLE *3.—Flowering, seed bearing age, and frequency of good crops*

Species	Flowering		Frequency of good seed crops	Remarks
	Habit[1]	Date		
Acer				
negundo	Dioecious	March-May	1	
nigrum	Polygamous	April-May	2-3	Flowers appear when leaves are about ⅓ grown.
rubrum	Polygamous	March-May	1	Flowers tend to be dioecious; precede leaves.
saccharinum	*Polygamo-dioecious*	Feb.-May	1	
saccharum	Polygamous	March-May	3-7	
Albizia julibrissin		June-August		
Alnus glutinosa	Monoecious	March-April	1-2	
Betula				
alleghaniensis	Monoecious	April-May	2	Female flowers appear when tree begins to leaf.
nigra	Monoecious	April-May		
papyrifera	Monoecious	April-June	2	
Carya illinoensis	Monoecious	March-May	1-3	Flowers appear about one week after tree begins to leaf.
Castanea	Polygamous	April-June		
Catalpa				
bignonioides	Perfect	May-June	2-3	
speciosa	Perfect	May-June	2-3	
Celtis				
laevigata	*Polygamo-monoecious*	April-May	1	
occidentalis	Polygamo-monoecious	April-May	1	Flowers appear with leaves.
Cercis canadensis	Perfect	March 1-May 15	2	Flowers precede leaves.
Cornus florida	Perfect	March-May	2	Flowers precede leaves.
Diospyros virginiana	Dioecious	March-June 15	2	Flowers borne after the leaves.
Elaeagnus				
angustifolia	Perfect or polygamous	June	1	
umbellata	Perfect or polygamous	June	1-2	
Eucalyptus	Perfect	Nov.-April	2-5	
Fraxinus				
americana	Dioecious	April-May	3	Flowers appear with or just before the leaves.
nigra	Dioecious	May-June		Flowers appear before the leaves. Rare trees are monoecious.
pennsylvanica	Dioecious	March-May	1	Flowers appear with or just before the leaves.
Gleditsia triacanthos	Polygamous	May-June	1	
Juglans				
cinerea[2]	Monoecious	April-June	2-3	Flowers of both species appear with or shortly after the leaves.
nigra[2]	Monoecious	April-June	2	Both species are dichogamous.
Liquidambar styraciflua	Monoecious	March-May	1-3	Flowers often damaged by frost.
Liriodendron tulipifera[2]	Perfect	April-June	1	Flowers appear after leaves well grown.
Maclura pomifera	Dioecious	April-June	1	

See footnote at end of table.

Table 3 continued on next page

TABLE 3.—*Flowering, seed bearing age, and frequency of good crops (continued)*

Species	Flowering		Frequency of good seed crops	Remarks
	Habit[1]	Date		
Magnolia grandiflora	Perfect	April-Aug.	1	
Morus rubra	Dioecious and Monoecious	April-May		
Nyssa				
aquatica	Perfect or dioecious	March-Apr.	1	Flowers appear as the leaves are developing. Good seed crops occur nearly every year.
sylvatica var. *sylvatica*	Polygamo-dioecious	April-June	Irregular	Flowers appear when leaves are almost grown.
Paulownia tomentosa	Perfect	April-May		Flowers appear before the leaves emerge.
Platanus occidentalis[2]	Monoecious	March-May	1-2	Flowers appear with leaves.
Populus				Differences in flowering time probably depend on current temperatures.
deltoides	Dioecious	Feb.-May	1	Flowers appear before leaves.
tremuloides	Dioecious	March-May	4-5	Flowers appear before leaves.
heterophylla	Dioecious	March-May	1	Flowers usually appear before the leaves.
Prunus serotina	Perfect	April-June	1-5	Flowers appear when leaves are almost full grown.
Quercus				
acutissima	Monoecious		1	
alba[2]	Monoecious	April-May	4-10	Flowers appear with leaves.
falcata var. *pagodaefolia*[2]	Monoecious	March-April	1-3	Flowers appear with leaves.
macrocarpa[2]	Monoecious	April-May	2-3	Flowers appear soon after leaves.
michauxii	Monoecious	April-May	3-5	Flowers appear with the leaves.
nigra	Monoecious	Feb.-May	1-2	Flowers appear shortly before leaves.
nuttallii	Monoecious	March-April	3-4	Flowers appear with leaves.
palustris[2]	Monoecious	April-May	1-2	Flowers appear with or soon after leaves.
phellos	Monoecious	Feb.-May	1	Flowers appear shortly before leaves.
rubra[2]	Monoecious	April-May	3-5	Flowers appear before or with leaves.
shumardii	Monoecious	March-April	2-3	
velutina[2]	Monoecious	April-May	2-3	Flowers appear when leaves are half grown.
virginiana	Monoecious	March-April	1	Flowering later at higher latitude than Florida.
Robinia pseudoacacia	Perfect	May-June	1-2	Flowers appear about 1 month after leaves.
Tilia americana	Perfect	June-July	1	Flowers appear 6 to 8 weeks after leaves develop.
Ulmus				
americana	Perfect	Feb.-March	1	Flowers appear 2 to 3 weeks before leaves.
pumila	Perfect	March-April	1	
rubra	Perfect	Feb.-May	2-4	Flowers appear 10 to 15 days before leaves.

[1] Dioecious = male and female flowers borne on separate trees. Monoecious = male and female flowers borne separately on the same tree. Perfect = male and female parts in the same flower. Polygamous = perfect flowers plus monoecious or dioecious flowers on the same tree.

[2] Some pollination by selfing; most by crossing. Self-pollinated flowers do not yield much viable seed. Avoid isolated trees.

Field cutting tests will eliminate seed trees that produced excessive blank, rotted, or insect-infested seed. If the seed of an individual tree is not of average quality or better according to the cutting test, seed should not be collected from that tree.

Seed Collection

Seed collection is a significant expense in the production of hardwood seedlings. Thus, it is important that good, viable seed be collected and that no time be lost locating seed trees.

Seed Sources

Most forest tree species probably have developed geographical races adapted to the local climate. For example, seedlings produced from seed collected at a distance from the planting site may break dormancy early in the spring and may be damaged by late spring frosts. Black walnut has exhibited a faster juvenile growth when moved north, but seedlings from seed collected far south of the planting site continue growing later finto the fall and are sometimes injured by early fall frosts.

Usually, but not always, seed from local sources produces seedlings better adapted to local planting sites than imported races. However, if local seed is not available and *provenance tests* have not been made, seed from collection zones similar in climate to the contemplated planting site should be used.

Seed collection zones, based primarily on temperature and precipitation, have been published for some aseas (Limstrom 1965, Rudolf 1957).

The nurseryman should constantly watch for potential seed sources for all species grown or that might be grown at his nursery. He should also look for stands or groups of trees of good vigor and form, and of the optimum age to produce seed. Poorly formed seed trees should be avoided.

Seed should be collected from stands that contain several trees of a species rather than from isolated trees. Pollination of isolated trees

F-521303

Figure 3.—Yellow-poplar seed cones should be cut to determine the number of viable seed per cone. No seed cavities are filled in this view. Unless six or more seed cavities per cone are filled, the tree should not be used as a seed source.

TABLE 4.—*Seed ripening, dispersal, and handling (continued)*

Species	Seed ripening date	Dispersal dates	Seed handling: Collection method[1]	Seed handling: Care of fresh seed[2]	Seed handling: Extraction and cleaning method[3]	Remarks
Celtis						
occidentalis	Sept.-Oct.	Sept.-March	3, 2	2	2, 3	Ripe fruit is dark red to purple. Seed may be collected until February. Collection is most efficient after leaves fall. Fermenting the fruits 3 days at room temperature before depulping and stratification gave excellent results.
Cercis canadensis	July-Aug.	Sept.-Feb.	3, 2	2, 4	1	Ripe pods are dark reddish-purple and lustrous. Where insects are a problem, seed soon as possible as the pods collections should be made as are ripe. Seed for fall sowing should be collected while pod is slightly green and seed should not be permitted to dry.
Cornus florida	Sept.-Oct.	Sept.-Nov.	3, 2	2, 3	2, 3	Ripe fruit is dark red. Do not permit fruit to ferment. Fruit from isolated trees is usually empty. Seed can be sown without extracting.
Diospyros virginiana	Sept.-Nov.	Sept.-Feb.	1, 2, 3	1	2	Ripe fruit is brownish-orange.
Elaeagnus						
angustifolia	Aug.-Oct.	All winter	2 or 3	1, 2 or 6	2	Ripe fruit is silver-gray. Do not allow fruit to heat. Fruit may be macerated with water, sown fresh, or allowed to dry and sown without cleaning.
umbellata	Aug.-Oct.	Sept.-Nov.	2 or 3	1, 2 or 6	2	Ripe fruit is red-pink. Do not allow fruit to heat. Fruit may be macerated with water, sown fresh, or allowed to dry and sown without cleaning.
Eucalyptus	Oct.-March	Oct.-March		2	1, 3	Seed is dark black. Collect only well-developed, closed capsules. Dry 5 days at 70° F.
Fraxinus						Ripe fruit of these 3 species is yellow-brown to brown.
americana	Oct.-Nov.	Sept.-Dec.	2, 3, 4	2	1, 3	
nigra	June-Sept.	July-Oct.	2, 3, 4	2	1, 3	A good index of maturity for all ash seed is a firm, crisp, white, fully-elongated seed within the samara.
pennsylvanica	Sept.-Oct.	Oct.-May	2, 3, 4	2	1, 3	
Gleditsia triacanthos	Sept.-Oct.	Sept.-Late winter	1, 2	2	1, 3	
Juglans						
cinerea	Sept.-Oct.	Sept.-Oct.	1, 3	1, 2		Ripe fruit is greenish-brown.
nigra	Sept.-Oct.	Oct.-Nov.	1, 3	1, 2	4, 5	Ripe fruit is yellowish-green.
Liquidambar styraciflua	Sept.-Nov.	Sept.-Nov.	2	2, 4	1	Collect seed balls when seed ball starts to turn yellowish. Fruit heads picked prematurely may be ripened by storing them moist at 40° F. for about a month (Bonner 1970).

See footnote at end of table.

Table 4 continued on next page.

TABLE 4.--*Seed ripening, dispersal, and handling (continued)*

Species	Seed ripening date	Dispersal dates	Seed handling: Collection method[1]	Care of fresh seed[2]	Extraction and cleaning method[3]	Remarks
Liriodendron tulipifera	Aug.-Oct.	Oct.-Jan.	2, 3, 6	2	1	The best seed is in the upper ⅔ of the crown. Fruit is ripe when it turns yellow. When cut cones show endosperm to be firm, seed is ready to collect.
Maclura pomifera	Sept.-Oct.	Sept.-Oct.	1	5, 7	6, 2	Ripe fruit is yellow-green.
Magnolia grandiflora	Late July-Oct.	Aug.-Oct.	2	2	1	Ripe fruit is red or rusty-brown; 40 to 60 seed per fruit.
Morus rubra	June-Aug.	June-Aug.	3	3	7, 6	Ripe fruit is purple. Must beat birds and animals to the seed. A 1-percent lye solution aids extraction.
Nyssa						
aquatica	Sept.-Oct.	Oct.-Nov.	1, 3	3	2	Ripe fruit is dark purple.
sylvatica var. *sylvatica*	Sept.-Oct.	Sept.-Nov.	1, 2, 3, 5	3	2	Ripe fruit is blue-black.
Paulownia tomentosa	Fall	—	2, 6			Ripe fruit is brown. Fruit persists on tree through winter.
Platanus occidentalis	Sept.-Nov.	Feb.-April	2	6	1, 6	Collect seed from stands after fruiting heads turn brown. Collect from several trees and mix seed. Collect after leaves fall. Do not breathe fine hairs which abound during extraction--wear dust masks.
Populus						
deltoides	April-Aug.	April-Aug.	2	6	4	Short collection period. Collect seed when capsules are green. Seed cream colored when ripe.
tremuloides	May-June	May-June	2	6	4	Short collection period. Collect seed when capsules are green.
heterophylla	April-July	April-July	2	6	4	Short collection period.
Prunus serotina	June-Sept.	July-Sept.	3, 2	1	2	Fruits should be collected when fully mature. Do not allow fruits to ferment. Ripe fruit is black. Hammermills should be worn or rounded hammers and be run at low speed (Mugford 1969).
Quercus						
acutissima			1, 3, 4			
alba	Sept.-Oct.	Sept.-Oct.	3, 1, 4	3, 8	3, 5	Ripe acorns are brown. Acorns of white oaks ripen in one year, while those of the red oaks require two. Collect soon after acorns fall to retard early germination.
falcata var. *pagodaefolia*	Sept.-Oct.	Sept.-Nov.	3, 1, 4	3, 8	3, 5	Sound acorns have a light, almost lemon-colored cup scar--that of defective acorns is dull brown (Lotti 1960).
macrocarpa	Aug.-Sept.	Aug.-Sept.	3, 1, 4	3, 8	3, 5	
michauxii	Sept.-Oct.	Sept.-Oct.	1, 3, 4	3, 8	3, 5	

See footnote at end of table.

Table 4 continued on next page.

TABLE 4.—*Seed ripening, dispersal, and handling (continued)*

Species	Seed ripening date	Dispersal dates	Seed handling: Collection method[1]	Care of fresh seed[2]	Extraction and cleaning method[3]	Remarks
Quercus						
nigra	Aug.-Oct.	Aug.-Oct.	1, 3, 4	3, 8	3, 5	
nuttallii	Sept.-Oct.	Sept.-Feb.	1, 3, 4	3, 8	3, 5	
palustris	Sept.-Oct.	Sept.-Nov.	1, 3, 4	3, 8	3, 5	Ripe acorns are black.
phellos	Aug.-Oct.	Aug.-Oct.	1, 3, 4	3, 8	3, 5	
rubra	Sept.-Oct.	Sept.-Oct.	1, 3, 4	3, 8	3, 5	
shumardii	Sept.-Oct.	Sept.-Oct.	1, 3, 4	3, 8	3, 5	Sound acorns have a light, almost lemon-colored cup scar—that of defective acorns is dull brown (Lotti 1960).
velutina	Sept.-Oct.	Sept.-Nov.	1, 3, 4	3, 8	3, 5	
virginiana	September	Oct.-Nov.	1, 3, 4			
Robinia pseudoacacia	Sept.-Oct.	Sept.-April	3, 2	2	1, 5	Ripe fruits are brown and open on the tree. Collect before pods open.
Tilia americana	Sept.-Oct.	Oct.-March	2, 3	3	3	Ripe fruits are greenish-brown. Seed collection should start when fruit starts turning brown and be concluded before seedcoat turns dry and hard. Extraction method "2" if seed is to be stored.
Ulmus						
americana	March-June	March-June	4, 3, 5	2	3	Ripe fruit is greenish-brown. Seed is ripe when leaves are about half open.
pumila	April-May	April-May	1, 2 or 3	2	3	
rubra	April-June	April-June	4, 3, 5	2	3	Ripe fruit is green. Seed is ripe when leaves are about half open.

(1) Pick from ground after natural seed fall. If seed is mature shake tree or jar limbs to remove fruit. (2) Hand pick or strip into collecting bag seed from standing trees or from tops after felling. (3) Flail, strip or shake onto canvas tarp or collection net. (4) Sweep or rake from streets, parking lots, or lawns after natural seedfall. (5) Skim from water in eddies and along bank. (6) Cut or break fruits from tree.

[2] (1) Extract from fruit immediately. (2) Spread to dry. Do not allow to heat, mold, or ferment. (3) Keep in cold moist storage until sown or extracted. (4) Dry in kiln at low temperature (80°-100° F.). (5) Place fruits in cool moist place and allow fermentation. (6) Spread fruits to dry in well aerated trays. (7) Pile fruit in a place protected from animals and birds overwinter and extract in the spring shortly before sowing. (8) Fumigate te kill insect larvae.

[3] (1) Macerate dry then fan or screen out debris; or tumble followed by fanning and/or screening. (2) Run wet through macerator with water. Float off or screen out pulp. Can clean by crushing pulp and washing the mass on a screen under water pressure. The screen allows the pulp to pass but retains the seed. Surface dry followed by fanning or screening to remove more debris. (3) Screen out or fan out leaves, twigs, and other trash. (4) Run "green" nuts through huller. (5) Float in tub. Discard floaters. (Fumigate oak acorns with Serafume. Put about 50 pounds of acorns in loosely woven cloth bags. Place sacks in a 55 gallon drum with an empty coffee can (or equivalent) on top of the bags. Pour 3/4 inch of Serafume into can. Cover drum with burlap bag and place in a slight draft. After 24 hours, remove bags and let them aerate for about 2 hours. If seed is not sown immediately, spread seed on wire trays (not over 6 inches deep) and place in chi)]. room. Store in drums with heavy polyethylene liners at 38° F.) (6) Rub through a screen. (7) Mash and soak berries in water 48 hours to allow slight fermentation. Macerate wet in hammermill or macerator. Pulp is floated off in tilted tub or drum using hose to create swirling motion.

[4] One day after collection run dry through macerator. Rub through a No. 8 screen. Rerun debris through macerator and screen as many as four times to extract the maximum amount of seed. Seed passed through the No. 8 screen is rubbed through a No. 12 sereen to separate seed and debris making seed 90 percent pure. One bushel of capsules yields about 4 pounds of seed.

may be poor and the seed from isolated trees, although numerous, may not be viable. Where severa' trees of the same species are present, adequate pollination of flowers is more likely, which results in a higher percentage of sound seed.

Potential collection arcas should be marked on a fairly large-scale map and a record kept of the area showing species, number of trees, amount of seed that may be expected, and frequency of good seed crops. After seed is collected from the area the records should then include seed quality and quality of progeny.

Valuable seed collecting arcas may be found un private lands. If so, the nurseryman should secure the landowner's permission to collect seed.

Seed orchards and seed production areas are being developed at some nurseries to provide high quality seed (fig. 4).

F-521304

Figure 4.—A young black walnut seed orchard established at Indiana's Vallonia Nursery with progeny from selected mother trees.

Seed Collection Period

It is helpful to know how long the seed collecting period will last for the various species. Ripeness of some species (cottonwood is our best example) must be forecast because the seed capsules upen and the cottony, wind-borne seed is dispersed in a very short time. Fortunately, seed maturity can be predicted for cottonwood by cutting branches bearing seed capsules from potential seed trees and putting them in water at room temperature. The seed capsules will open 2 or 3 days before those on the tree. Individual trees in a stand will ripen and disperse their seed at different times. If the entice local seed crup is lost, seed may be gathered from trees at a more northern locality. However, don't collect seed more than 100 miles north of the potential planting sites.

The collecting period for heavy seeds such as walnuts is not usually critical. However, seed collection should not be delayed too long because squirrels and other animals, including man, may gather or destroy the seed. Seed collection of these species should usually be delayed until after the first frost or until a large portion of the seed has fallen because the first fruits to fall are often wormy, aborted, or inferior in some other way.

Species such as sycamore, black locust, and hackberry retain their seed on the tree well into the winter and even until the following spring. Seed collection can thus be delayed until winter when other chores are not pressing. Also, after the leaves fall the seed is more visible and less trash is collected with the seed.

Seed Collection Equipment and Techniques

The equipment used for collecting seed varíes according to species, but usually includes knives ; wire cutters or hammers for cutting tests ; hook cutters for detaching fruits; ladders ; containers including buckets, bags, baskets and tubs; bamboo or fiberglass potes for cutting hooks or for flailing; safety belts; and tarps, nets, or burlap sheets to catch seed.

Specialized heavy equipment such as "cherry pickers," mechanical tree shakers, and Alpar's (1963) hydraulic ladder are available for picking seed from standing trees. Specialized equipment will be more economical as seed orchards and seed production areas begin producing more seed.

Heavy seeds, such as acorns and walnuts, fall close to the seed tree and can be picked off the ground. After normal seed fall has started, the tree or individual branches may be shaken or flailed to dislodge the fruit.

Light, wind-dispersed seed, as from elm, maple, and birch, can be gathered by placing a canvas under the tree (preferably on a calm day) and flailing the branches to dislodge the seed. If the seed is already dispersed, it can be swept from streets and lawns. However, sweeping up seed may be questionable because disease organisms may be collected with the seed and the debris may be excessive. Seed of some light-seeded species, as well as "heavy-seeded" species that float (black gum is an example), may sometimes be collected from water surfaces. The best places to find seed in the water are in eddies and along the shore.

Most tree seed must be picked from standing trees or from felled trees. Seed such as dogwood must be picked from the tree because it is too small to pick off the ground economically after it falls naturally. Seed of yellow-poplar, cottonwood, sweetgum, and other species can be picked either from standing trees or from felled trees. Care should be taken to make sure that seed collected on logged aseas is mature before the trees are cut.

Cave of Fresh Seed

Freshly collected fruits of practically all deciduous species will hect if piled or sacked and left undisturbed for any appreciable length of time. Heating destroys seed viability. All pulpy-fruited species and most dry-fruited species require adequate aeration or cold storage. Fruits of most species should be stored in a shady, dry place with adequate aeration until the seed is extracted. Some seed, such as basswood, should be sown immediately after collection. Black walnuts should be hulled immediately, while the hull is firm, if a mechanical huller is used. If the seed of fieshy-fruited species such as black cherry cannot be extracted immediately, the fruits should be kept in cold storage until the seed is extracted. Seed of most species should be extracted as soon as possible after collection and put in cold storage until sown or until prepared for long-term storage.

Freshly collected fruits of most species (acorns are examples of seed that should not be dried) should be spread to dry. Seed dries best in screen-bottomed trays because air circulation is better. Fruits of species such as yellow-poplar and sweetgum can be dried on tarps or the (loor of a dry, well-ventilated building. Drying seed should be stirred daily (fig. 5).

Seed Extraction

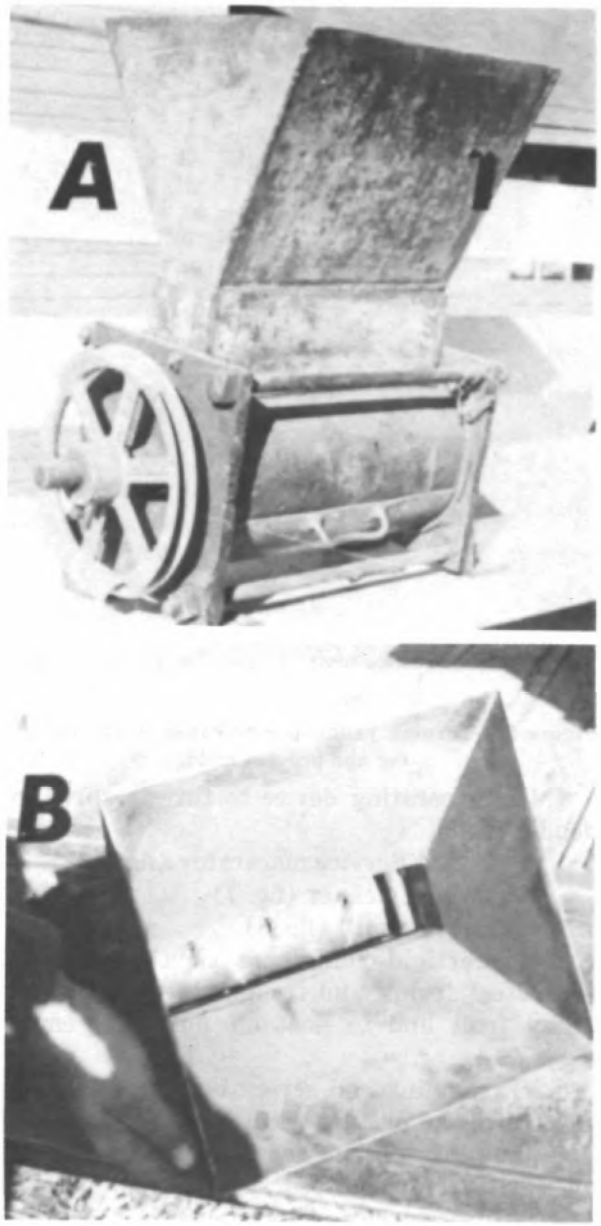
Seed is extracted (separated from the fruit) to prevent seed spoilage, prepare the seed for sowing, or reduce the bulk and weight of the seed for storage. Seeds of most species should be extracted immediately (some fruits must dry a short time) after collection.

Extraction equipment necessary for clearing hardwood seed includes:

Figure 5.—Turning yellow-poplar cones to hasten drying and prevent mold.

1. A macerating device to thresh, shred, or depulp fruits.
   a. Forest Service macerator (fig. 6.).
   b. Dybvig cleaner (fig. 7).
   c. Hammermill (fig. 8).
2. Watertight containers such as buckets, tubs, steel drums, and troughs to wash or soak fleshy fruit and to float off pulp and empty seeds.
3. Tarpaulins and screen-bottomed trays to dry fruits and cleaned seeds.
4. Fanning mili to separate debris and unfilled seed from good seed.
5. Air screen cleaner.
6. Gravity separator to separate empty from filled seed.
7. Assortment of screens of various sizes to separate seed and debris.
8. Tumblers to separate individual seeds of species such as yellow-poplar and sweetgum from their cones.

The primary objective in all fruit handling and extraction is to obtain as much viable seed as possible (high extraction factor) while preserving the germinative capacity of the seed. The extraction factor is the yield of clean seed expressed as a percent of rough fruit (table 5). Considerable weight loss occurs by removing pulp, pods, husks, twigs, and other debris. The



F-521340, 521341

Figure 6.—The Forest Service macerator is used to clean certain dry and pulpy hardwood fruits: A, Side view; B, top view. Note teeth on the shaft.

extraction factor is used to determine the amount of rough fruit to coilect to obtain a given weight of dry, clean seed.

Hardwood seed is much more variable than conifer seed so extraction methods are more variable. Extraction methods vary by the type of fruit being processed. Hardwood seed, for the purpose of extraction, is divided finto three main classes: (1) dry fruits, (2) fleshy or pulpy fruits, and (3) nuts.

F-521306

Figure 7.—Depulping autumn olive seed in the Dybvig cleaner.

Dry Fruits

Seed of most of the dry fruits must be separated from the pod or capsule in which it develops. Dry fruits are usually dried, threshed, tumbled, and fanned to extract the seed.

For efficient drying, the fruits should be spread on a screen to allow free air circulation around each fruit. To prevent mold and loss of seed viability, the drying area should be protected from the elements.

Dried fruits may be threshed or shredded in a macerator or a hammermill. If seeds are extracted in a hammermill, the proper screen must be selected to allow free seed passage, thus preventing seed cracking and damage. The discharge opening of the macerator must be regulated to prevent damage to the seed. Sometimes it is necessary to remove all screens.

A fanning mill or air screen cleaner may be used to separate filled seed from debris and empty seed (Harmond *et al.* 1968).

Yellow-poplar seed is best separated using a tumbler. Small seedlots of dry fruits may be extractad by hand shucking, treading underfoot, or by screening. Bonner and Switzer (1971) adapted yellow-poplar seed for drill


F-521307

Figure 8.—Shedding yellow-poplar cones.

sowing by clipping the winds in a clipper-debearder. Then, with a gravity separator, they upgraded the wingless seed.

Seeds can be cleaned efficiently by sifting them through various sized screens, one on top of the other or in sequence. A large mesh screen holds the leaf and branch debris and allows the seed and small trash to pass. A second screen catches the seed but allows smaller debris to pass through. Further cleaning can be done by a fanning mili. An efficient technique which utilizes a vacuum cleaner, compressed air and screens has been devised for cleaning aspen and other cottony seed (Roe and McCain 1962).

Large lots of sycamore seed can be cleaned efficiently in fertilizer spreaders (Briscoe 1969) and smaller lots can be cleaned using screens in combination with a window fan (Webb and Porterfield 1969).

Fleshy Fruits

Seed of fleshy fruits, such as cherry, autumn olive, mulberry, and osage-orange, is best extracted by macerating in water (fig. 7). Fleshy fruits should first be soaked in water to soften the pulp before being run through the macerator, but the water should be changed as necessary to prevent fermentation. As the fruits are run through a macerator, the pulp is floated off in water. The speed and agitator clearance of macerating and cleaning machines must be adj usted to prevent damage to the seed. Fleshy fruited seed also may be cleaned by washing the pulp and seed under water pressure on a screen that allows the pulp to pass but retains the seed.

Another method used for mulberry is to place crushed or softened fruits in a tub or pail and direct a stream of water into the mass, washing the pulp from the seed. The pulp and empty seed float and may be skimmed off, or a skillful operator can cause the debris to overflow by creating a swirling-separation motion in the container with the water jet. After maceration and extraction, the dried seed can be cleaned further by running it through a fanning mili.

Nuts

Acorns can be cleaned satisfactorily by floating them in water. The seed should be stirred to allow trapped debris and empty seeds to float so they can be skimmed off the surface. When acorns are in short supply, cave and sow the floaters.

The next step in processing acorns is to kill any insect larvae not thrown out with the floaters. Probably the best method for killing these seed weevils is to use a Serafume fumigant (see footnote in table 4).

Black walnuts may be hulled by various methods but specially built mechanical hullers are most efficient for large quantities. Hullers built to handle large volumes are available from severa' sources.[2] The Wycoff huller works best if the nuts are hulled before the hulls become mushy (fig. 9) . Soft hulls clog the grating, which may be kept clean by directing water into the hulIing chamber. Walnuts should be hulled as soon as possible because soft hulls may heat and damage the seed. Walnuts have been cracked in some mechanical hullers, so a machine should be tested before it is purchased or used to hull a large quantity.

HuIled walnut seed are floated to separate the filled from the unfilled. The bad seed floats and may be skimmed off. The seed should be stirred while in the water to allow trapped floaters to surface.

F-521308

Figure 9.—Wycoff's walnut huller with top up to show grating, chain, paddles and gauging wheel.

A gravity separator is used to separate good seed from unfilled seed and debris of some small seeded species (Bonner and Switzer 1971) (fig. 10).

F-521309

Figure 10.—Separating filled redbud *seed* from unfilled seed and debris on a gravity separator.

[2] Hugh Wycoff, Topeka, Illinois; Hammons Products Company, Stockton, Missouri; Churchwell (1964).

Some extraction and cleaning methods that have proved satisfactory in practice are shown in table 4.

Seed Dormancy

Seed dormancy is common among hardwood species, but with few exceptions satisfactory seed treatments to stimulate germination are known (table 5).

Seed dormancy has two main causes:

1. Seedcoat dormancy caused by an impermeable or hard seedcoat that prevents water or oxygen from reaching the embryo, or prevents the embryo from breaking out of the seedcoat even though water and oxygen passed in.
2. Internal dormancy which may be caused by an immature embryo or endosperm.

Usually only one type of dormancy is present but some seeds exhibit double dormancy, a combination of seedcoat and internal dormancy.

Treatment of Seedcoat Dormancy

Any one of four treatments can be used to overcome seedcoat dormancy of black locust and other seed with impermeable seedcoats (1) mechanical scarification—tumble seed in a drum (some nurserymen use a concrete mixer) lined with sandpaper, or blow them against a curved surface lined with sandpaper ; (2) acid soak—immerse in concentrated sulphuric acid for a specific period (optimum soak time for each seedlot of black locust should always be determined experimentally by timed acid soak periods ; a swelling test is used to indicate the best soak period; (3) pour boiling water over the seed and allow them to soak in the gradually cooling water for about 12 to 24 hours ; or (4) warm, moist stratification (constant or alternating temperatures) for a given duration. These seedcoat dormancy treatments are described in detail (USDA Forest Serv. 1974).

Seed varies in the treatment required to break dormancy. Some seed, such as basswood, should be collected and fall sown immediately after the pulpy seedcoat starts turning from green to brown (Bailey 1961) . If the seeds are allowed to dry out before fall sowing, they become dormant and fewer will germinate without long-term stratification. Seed of other species, such as Russian-olive, germinates better if allowed to ripen longer on the tree before collection and sowing.

Internal Dormancy

Internal dormancy is common among most of the hardwood species described in this bulletin. Seed of these species require a period of after-ripening. Treatments required to break internal dormancy also vary by species.

Four common methods for overcoming internal dormancy are: (1) cold stratification at constant temperature, (2) stratification at fluctuating temperatures (fig. 11) , (3) overwinter stratification in outside pits of fall-collected seed for spring sowing, and (4) warm followed by cold stratification. Although not a dormancy treatment, sowing immediately after collection will ensure germination of most hardwood seed. Immediate sowing is especially important for fall-ripening and for spring-ripening seed that becomes dormant when allowed to dry.

If fall-collected seed is to be held overwinter for spring sowing, methods (1) and (3) aboye will be of greatest value to nurserymen. A higher percentage of seeds will germinate if treatment number 2 is used, but it is a time-consuming treatment. Treatment number 2 would be most useful for seed specialists determining *germinative capacity* and for workers who require a high percentage of the viable seed to germinate. The stratification methods found to be best for the different species covered in this bulletin are given in table 5.

Seed Storage

Seed of many hardwood species should be sown immediately after collection and extraetion. However, surplus seed from bumper seed crops should be stored to furnish adequate seed for poor seed years.

Some seed ripens too late in the spring or summer to be sown immediately after collection.

In Indiana, red maple seed ripens too late to produce plantable *1-0 seedlings* if sown fresh, and the *2-0 seedlings* are too large. In Iowa and North Dakota, this is true of cottonwood seed. So 1-year storage of the seed from these species is desirable and necessary in some localities.

Hardwood seed is more difficult to store than that of most conifers. However, interim storage methods have been developed for most of the hardwoods.

TABLE 5.—*Seed yield, dormancy, and recommended treatments*

Species	Extraction factor	Seed Yield: Average number of clean seed per pound	Average laboratory germination: Energy	Average laboratory germination: Capacity	Dormancy type	Dormancy: Pregermination treatment: Medium	Warm period: Temp.	Warm period: Duration	Cold period: Temp.	Cold period: Duration	Remarks
	Percent	*Number*	*Percent*				*°F.*	*Days*	*°F.*	*Days*	
Acer											
negundo	81-100	18,400	14-67 in 14 to 48 days	24-96	Internal	Moist sand	—	—	41	60-90	Dormancy common. Mechanical rupture of the pericarp is recommended before stratification. Alternate treatment —soak seed 2 weeks in cold running water.
nigrum	81-100	4,200	—	—	—	—					
rubrum	81-100	22,860	75 to 89 in 2-6 days	85-91	None	—	—	—	—	—	Some lots are dormant. Freeze at 32° F. for 3-5 days, then water soak 24 hours before sowing. An alternate treatment is to soak 5 days in cold running water.
saccharinum	—	17,800	72-91 in 3-13 days	94-97	None	—	None required				
saccharum	41-100	7,030	80 in 75 days	95	Internal	Moist sand	—	—	33-41	40-90	Soak in water 24 hours before stratifying. One of pair of samaras is always empty. Empty samaras will float in n-pentane (Carl and Yawney 1969).
Albizia julibrissin	—	11,500	—	—	Seedcoat						Scarify until breaks appear in seedcoat or soak in sulfuric acid 10 to 15 minutes then soak in water 15 minutes.
Alnus glutinosa	—	110,000	—	—	—						Germination of some lots is benefitted by stratification.
Betula											
alleghaniensis	21-40	450,000	59 in 10 days	27	Internal	Moist sand or peat	—	—	41	30-60	
nigra		375,000	70 in 10 days	34	—	None					Germinates soon after it falls. The percent of viable seed can be estimated by examining the seeds under transmitted light (Patterson and Bruce 1931).
papyrifera	11-20	1,380,000	54 in 9 days	47	Internal	Moist sand or peat	—	—	41	60-75	
Carya illinoensis	41-60	100-162	80 in 30 days	50-91	Internal	Moist					Dormancy of some horticultural varieties may be broken by various acids and hydroxides. Prior to cold treatment nuts should be soaked 2 to 4 days in water at room temperature with 1 or 2 water changes per day (Eliason 1965). The number of seed per pound varied by location and germination varied by test medium.
Castanea	100		92 in 28 days	100	Internal	Moist			33-40	Overwinter	Do not allow nuts to dry out.
Catalpa											
bignonioides	—	20,000		90+	None	—	—	—	—	—	In Louisiana germination starts about 12 days after March sowing and germination is about 80 percent.
speciosa	21-40	21,000		90+	None	—	—	—	—	—	
Celtis											
laevigata	—	6,000	30-50 25-30 days	55	Internal	Moist sand			41	60-90	
occidentalis	40-75	4,300	39 in 37 days	47	Internal	Moist sand	—	—	41	60-90	Seedcoat may also cause dormancy. Clean seeds respond more quickly to stratification.
Cercis canadensis	20-35	18,000	70-80 in 8-14 days	76-85	Seedcoat-Internal	Moist sand	—	—	35-41	35-60	Not all lots have embryo dormancy. Best treatment (run test on small sample) is to soak seeds 25 to 60 minutes in concentrated sulfuric acid followed by stratification.

Table 5 continued on next page

TABLE 5.—*Seed yield, dormancy, and recommended treatments* (continued)

Species	Extraction factor	Seed yield Average number of clean seed per pound	Average laboratory germination: Energy	Average laboratory germination: Capacity	Dormancy type	Dormancy Pregermination treatment: Medium	Warm period: Temp.	Warm period: Duration	Cold period: Temp.	Cold period: Duration	Remarks
	Percent	*Number*	*Percent*				*°F.*	*Days*	*°F.*	*Days*	
Cornus florida	37	4,500	14-45 in 15-20 days	35	Internal	Moist sand	—	—	41	120[1]	Seed collected somewhat "green" and sown immediately will germinate the following spring. Seeds typically double celled.
Diospyros virginiana	10-30	1,200	54-94 in 20-34 days	62-100	Seedcoat	Moist sand	—	—	37-50	60-90	A layer of cells cap the radicle. These impermeable cells can be removed by hand.
Elaeagnus angustifolia	15 60	2,900[2] 5,160[3]		7-90	Internal	Sand or peat	—	—	34-50	60-90	Seedcoat dormancy of some lots may be overcome by 30 to 60 minutes soak in sulfuric acid. Run tests on small samples.
umbellata	5-10	27,600		93	Internal	Sand or peat	—	—	—	60-90	
Eucalyptus		40,000		2-80	Variable						Not all seedlots are dormant, but to ensure germination stratification for 3 to 4 weeks at 38° to 41° F. is recommended. 12,800 seedlings from 1 lb. of seed.
Fraxinus americana	—	13,120	49 in 24 days	54	Internal	Moist sand or peat	68-86	30	41	60-90	An alternative is to water soak 2 to 10 days.
nigra	—	8,100	7 in 18 days	20	Internal	Moist sand or peat	68-86	60	41	90	
pennsylvanica	75	17,260	70 in 20 days	76	Internal	Moist sand or peat	68	60	32-41	60-210	Old seedlots contain a higher proportion of dormant seeds than fresh seedlots. If seed dries, soak 3-5 days before stratification; 60 to 90 days is enough stratification in the South, but 150 days is needed in the North (Eliason 1965).
Gleditsia triacanthos	20-35	2,800	45-99 in 9 to 20 days	75	Seedcoat	—	—	—	—	—	Soak 1-2 hours in concentrated sulfuric acid. Check soaking time for each seedlot.
Juglans cinerea	20-30	30	54 in 58 days	65	Seedcoat-Internal	Moist sand or peat		—	34-41	90-120	
nigra	30-65	17	60 in 24 days	50	Seedcoat-Internal	Moist sand or peat	—	—	34-41	90-120	Best pregermination treatment known is alternate daily temperatures of 37° F. one day, 52° F. the next. Outside pit stratification from December to March is satisfactory.
Liquidambar styraciflua	(12 oz./bu.)	82,000	86 in 14 days	95	Internal	In plastic bags	—	—	38-40	30	Germination excellent after this treatment.
Liriodendron tulipifera	30-80	14,000	81 in 40 days		Internal	Moist	—	—	35	45-90	Outside pit stratification is satisfactory. Spring-sown seed must be stratified at least 45 days. Alternating weekly temperatures 32° and 50° F.
Maclura pomifera	(2¼ lbs./bu.)	14,000	20 to 79 in 14-34 days		Seedcoat-Internal	Moist sand or peat	—	—	32-50	30	An alternative is to soak in cold water 48 hours. Fruit stored overwinter in piles outdoors are easily cleaned in the spring and the seed germinates promptly.
Magnolia grandiflora	—	6,450		43 to 90	Internal	Peat	—	—	32-41	90-180	Fall sowing provides natural stratification.
Morus rubra	2-3	360,000		20-92	Seedcoat-Internal	Moist sand	—	—	33-41	30-90	Sow immediately after cleaning. Seed becomes dormant with storage. Stored seed should be stratified at least 30 days before spring sowing.

Table 5 continued on next page

TABLE 5.—*Seed yield, dormancy, and recommended treatments* (continued)

Species	Extraction factor	Seed yield: Average number of clean seed per pound	Average laboratory germination: *Energy*	Average laboratory germination: *Capacity*	Dormancy type	Pregermination treatment: Medium	Warm period: Temp.	Warm period: Duration	Cold period: Temp.	Cold period: Duration	Remarks
	Percent	*Number*	*Percent*				*°F.*	*Days*	*°F.*	*Days*	
Nyssa											
aquatica	—	450	87 in 18 days	97	Internal	Moist sand or plastic bags	—	—	33-41	30-120	
sylvatica var. *sylvatica*	25	8,300		71	Internal	Moist sand or plastic bags	—	—	32-50	30-120	
Paulownia tomentosa	—	2,820,000	86 in 9 days	90 in 19 days	None	—	—	—	—	—	Light is necessary for germination.
Platanus occidentalis	7	193,270		80[4]	None	—	—	—	—	—	Collect soon after leaf fall. A large percent of sound seed usually germinates but great variation in number of sound seeds per lot result in germinative capacities from 1 to 81 percent (Briscoe 1969).
Populus											
deltoides	(2-4 lbs./bu.)	350,000			None	—			—	—	Extraction factor depends on extraction methods.
tremuloides		3,600,000			None	—			—	—	
heterophylla	—	152,000	—	—	—						No information available. Probably similar to other *Populus*.
Prunus serotina	20-40	4,800		86	Internal	Moist sand	68-86	11-60	33-41	120	Soak 48 hours in 0.1 percent citric acid solution followed by 120 day stratification period (Jones 1963).
Quercus[5]											
acutissima	—	102	—	98							Sow oaks in the fall or hold in cold, moist stratification for spring sowing.
alba	60-90	120	39-93 in 10-41 days	50-99	None						
falcata var. *pagodaefolia*		580	85-90 in 21-38 days	86-98	Internal	Moist sand			41	60	Begin germinating if in stratification more than 30 to 45 days.
macrocarpa	65-75	75	28-85 in 25-45 days	45-99	None		—	—			
michauxii	—	85	30-86 in 22 to 39 days	40-98			—	—			
nigra	—	395	54 to 80 in 31 to 73 days	60-94		Moist sand			33-41	60	
nuttallii	—	95	—	64-82		Moist sand	—	—	33-41	60	
palustris	50-70	410	—	68	Internal	Moist sand	—	—	33-41	60	
phellos	—	462	79-83 in 34 to 47 days	89-91		Moist sand	—		33-41	60	
rubra	70-80	125	39-85 in 13-42 days	58-100	Internal	Moist sand	—	—	33-41	60	
shumardii	—	100	53 to 66 in 21 to 34 days	67-82		Moist sand	—	—	33-41	60	
velutina	40	245		7-88	Internal	Moist sand	—	—	41	60	May be stratified overwinter in well-drained outside pits.
virginiana	—	352	92 in 8 days	97		Moist sand	—	—	33-41	60	
Robinia pseudoacacia[6]	4-33	24,000		10-98[7]	Seedcoat	Moist sand	—	—	—	—	Scarification—mechanical; soak in concentrated sulfuric acid, and soaking in hot water (see text).

Table 5 continued on next page

TABLE 5.—Seed yield, *dormancy, and recommended treatments* (continued)

Species	Extraction factor	Seed yield: Average number of clean seed per pound	Average laboratory germination: Energy	Average laboratory germination: Capacity	Dormancy type	Medium	Warm period: Temp.	Warm period: Duration	Cold period: Temp.	Cold period: Duration	Remarks
	Percent	*Number*	*Percent*				*°F.*	*Days*	*°F.*	*Days*	
Tilia americana	75	5,000		31	Seedcoat-Internal	Moist sand (see remarks	—	—	—	—	Seed yield data based on dry seed. Remove pericarp and etch seedcoat in concentrated sulfuric acid before stratification.
Ulmus											
americana	50	70,900	55 in 7 days	64	Variable	Moist sand			41	60	Seed in some lots remain dormant until second season.
pumila	50	72,000	55 in 10 days	76	None	—	—	—	—	—	
rubra	·	41,000	21 in 10 days	23	Variable	Moist sand			41	60	Some seedlots are dormant.

1 Seed should be depulped bef ore stratification.

2 Seed with pulp.

3 Cleaned seed.

4 Percentages are based on sound seed only.

5 Do not allow acorns to dry. Acorns of any species 1 isted may be fall sown.

6 Dormancy much more preconoced in some lots than others. Dormancy may be overcome by abrasive action of pebbles and seed in a concrete mixer.

7 Germinative capacity governed primarily by effectiv eness of scarification without damaging the embryo.

F-521310

Figure 11.—Yellow-poplar seed stratified under protective screen and 6-inch layer of straw.

Storage of hardwood seed varies with species : (1) cold dry storage (fig. 12), (2) cold moist storage, and (3) outside stratification pits (fig. 13). The best seed storage techniques known for the species covered in this bulletin are shown in table 6, but better methods are needed for some species.

Seed Testing

Seed testing is necessary to determine: (1) the potential percent germination of a seedlot, (2) the amount of seed required to produce a given number of plantable seedlings, and (3) the sowing rate to produce a desirable seedbed density.

Normally some nurserymen and seed dealers buy and sell seed on the oasis of the percent of good seed as determined by a seed testing laboratory such as the Eastern Tree Seed Laboratory. For example, if black locust seed is listed at $5 per pound and the laboratory's test shows that 75 percent of the seed germinates normally, the purchaser gays the dealer 75 percent of $5, or $3.75 per pound.

F-521311

Figure 12.—Sealed containers are used to maintain a stable moisture content under cold storage.

F-521312

Figure 13.—Black walnut seed can be stored successfully for as long as 4 years in outside stratification pits.

Selection of Seed Samples

Economy in seed sampling is important because seed counting, cutting, drying, and germinating are time consuming, and actual viability tests destroy the seed. Samples must be selected with great care to be truly representative of a seedlot. If the seed is stored in more than one container, it is important to sample each one (Bonner 1974) . To get a representative sample, subsamples should be taken from several creas within each container. If the several subsamples result in a combined sample that is too large, it may be divided satisfactorily by pouring into one cone-shaped pile, then pressing a straight edge through the pile from top to bottom to divide the sample into two halves. Subsequent dividing in the same man ner may be necessary until the sample size is satisfactory.

Sample Size and Care

Sample size will vary by species and intended use of the seedlot. If all seed in the lot is *thoroughly mixed*, one composite sample is adequate; but if seed has been stored in separate containers, there may be considerable variation in germination of seed among containers. Results of a composite test, with seed taken from individual containers, cannot safely be applied to the seed in the individual containers. The size of the actual sample to be drawn for testing as recommended by the Eastern Tree Seed Laboratory is shown in table 7.

If moisture content of a seed sample is to be determined by a testing laboratory, the sample should be shipped in a moisture-proof container. If the seed sample is being taken from cold storage, the sample should be placed in the moisture-proof container before its removal from cold storage. This prevents condensation from forming on the cold seed which would raise apparent moisture content.

Tests for Viability

It is important to test viability of seed immediately after extraction and again before sowing, if the seed has been stored for any length of time.

Seed samples may be sent to the Eastern Tree Seed Laboratory for germination tests.[3] The Laboratory is operated under a cooperative agreement involving the USDA Forest Service, the Georgia Forestry Commission, and the Georgia Forest Research Council. Tests of tree seed are made at cost for anyone desiring the service. The Laboratory also conducts investigations of tree seed to determine the best methods of testing, handling, extraction, and storage.

When there is not sufficient time for germination tests (this is normal for those hardwood seeds that are sown immediately after collection) , viability may be estimated locally by cutting test. For better estimates of seed viability, however, representative seed samples should be sent to a recognized seed testing laboratory" with a request for quick test analyses. Most seed testing laboratories have the facilities and expertise to estimate viability by : (1) growth of excised embryos, (2) tetrazolium staining of the embryos, (3) X-ray radiographs, or **(4)** hydrogen peroxide stimulation (Bonner 1974). These four tests require skilled, experienced personnel and ordinarily should not be tried locally.

In a cutting test several seed should be cut or cracked to determine visually the percent of filled seed. Good seed are filled with firm, white or cream-colored kernels.

Seed size and color offer some indication of seed quality and condition but are more a measure of ripeness than viability.

Flotation is another method than can be employed locally to separate good from bad seed. Empty seeds of many heavy seeded species float in water while sound ones sink. However, if seeds are allowed to dry, many sound ones will also float. It is necessary too, to stir the sunken seed to allow trapped floaters to surface. Walnut seed must be hulled before the float test is employed.

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[3] Eastern Tree Seed Laboratory, P.O.Box 819, Macon, Ga. 31202.

[4] In addition to the Eastern Tree Seed Laboratory some States maintain recognized seed testing laboratories.

TABLE 6.--*Seed storage*

Species	Period	Seed storage: Seed: Condition	Seed storage: Seed: Moisture content	Seed storage: Container	Seed storage: Temperature degrees F	Remarks
	Years		*Percent*			
Acer						
negundo	1½	Moist	——	——	33-40	Moisture content not known (USDA Forest Service 1974).
nigrum	——	——	——	——	——	No information available. Probably identical to sugar maple.
rubrum	1¾	Moist	——	Sealed	33-40	USDA Forest Service (1974).
saccharinum	1+	Moist	——	——	33-40	Normally sown immediately after collection. Moisture content must not fall below 34 percent.
saccharum	4+	Dry	10-17	Sealed	14	Yawney (1968).
Albizia julibrissin	5	——	——	——	——	No definite information — 90 percent of seed kept in loosely corked bottles in a laboratory germinated after 5 years.
Alnus glutinosa	1½	Dry	7-10	Sealed	33-40	Storage below 32°F. may be better.
Betula						
alleghaniensis	4+	Dry	1-3	Sealed	33-40	Clausen (1965).
nigra	1½+	Dry	1-3	Sealed	33-40	USDA Forest Service (1948).
papyrifera	4+	Dry	12	Sealed	33-40	Clausen (1965).
Carya illinoensis	3-4	Moist	90	Closed	41	Maintain relative humidity at least 90 percent (USDA Forest Service 1948).
Castanea	Overwinter	Moist	40-45	Closed	33-40	Maintain at 70 percent humidity. May be kept overwinter in stratification pits (USDA Forest Service 1948).
Catalpa						
bignonioides	Overwinter	Dry	——	——	33-40	Long term storage has not been studied. Seed has been stored successfully 2 years (USDA Forest Service 1974).
speciosa	Overwinter	Dry	——	——	33-40	Long term storage has not been studied.
Celtis						
laevigata	——	Dry	——	Sealed	41	
occidentalis	5½	Dry	——	Sealed	41	For short periods seed may be kept in moist sand at low temperature (USDA Forest Service 1948).
Cercis canadensis	——	Dry	Air dried	Sealed	33-40	Seed with low moisture content may be stored in freezer.
Cornus florida	2-4	Dry	Air dried	Sealed	33-40	In Missouri seed is held in cold, dry storage one "year" and sown in August.
Diospyros virginiana	——	Dry	——	Sealed	33-40	Thorough air drying required.
Elaeagnus						
angustifolia	3	Dry	6-14	Sealed	33-40	
umbellata	——	Dry	6-14	Sealed	33-40	

Table 6 continued on next page

TABLE 6.—Seed storage (continued)

Species	Seed Storage: Period	Seed: Condition	Seed: Moisture content	Container	Temperature degrees F	Remarks
	Years		*Percent*			
Eucalyptus	10	Dry	4-6	Sealed	33-40	Seed stored 30 years at room temperature germinated although germination was poor.
Fraxinus						
americana	3+	Dry	——	Sealed	33-40	Although not proven, techniques worked out for *pennsylvanica* probably apply to entire genus.
nigra	——	——	——	——	——	Techniques found suitable for *pennsylvanica* probably apply.
pennsylvanica	7+	Dry	7-10	Sealed	33-40	Seed with low moisture content may keep better at temperature below 32° F.
Gleditsia triacanthos	Several	Dry	——	Sealed	33-40	USDA Forest Service (1948).
Juglans						
cinerea	4-5			Sealed	33-40	Store hulled or unhulled (USDA Forest Service 1948).
nigra	4	Moist		Open	Outside pit	Williams (1971).
Liquidambar						
styraciflua	4	Dry	10-15	Sealed bags	33-40	
Liriodendron						
tulipifera	5+	Dry	——	Sealed cans or plastic bags	33-40	Also seed stratified in moist, well-drained, outdoor pits retained viability 5 years (Williams and Mony 1962).
Maclura pomifera	3+	Dry	Air dried	Sealed	33-40	Seed should be clean (USDA Forest Service 1948).
Magnolia grandiflora	Several	Dry	——	Sealed	32-41	Seed can be stored clean or in the dried pulp (USDA Forest Service 1974).
Morus rubra	——	Dry	——	Sealed	−10 to 0	Seed tends to become dormant if stored. Another species was held 3 years in cold, dry storage.
Nyssa						
aquatica	Overwinter	Moist	——	——	33-40	Removal of pulp probably not essential for storage or stratification.
sylvatica var. *sylvatica*	Overwinter	Moist	——	——	33-40	No information available for long term storage. Seed may be stored overwinter in cold, moist stratification.
Paulownia tomentosa	——	——	——	——	——	
Platanus occidentalis	4	Dry	10-15	4-mil polyethylene bags	20-38	Seed to be sown soon after collection may be stored in a cool, well-ventilated place in open mesh bags or spread out on shelves (Briscoe 1969).
Populus						
deltoides	2-3	Dry	6	Sealed	33-40	Seed can be stored 1 year at 25 percent relative humidity and 10° F. (Bonner 1966, McComb and Lovestead 1954).
tremuloides	1+	Dry	5-8	Sealed	33-40	Seed dried 3 days and stored at 41° F. germinated 97 percent after 1 year (USDA Forest Service 1974).

Table 6 continued on next page

TABLE 6.—*Seed storage* (continued)

Species	Seed Storage: Period	Seed: Condition	Seed: Moisture content	Container	Temperature degrees F	Remarks
	Years		*Percent*			
Populus						
heterophylla	——	——	——	——	——	No specific information but storage should be possible. Reduce moisture content to less than 10 percent and store at 33 to 40° F.
Prunus serotina	3	Dry	4-6	Sealed	33-40	Seed moisture content must be lower than 12 percent for subfreezing storage (Huntzinger 1971).
Quercus						White oak acorns may be held overwinter. Most red oak acorns should be held overwinter in an open moist medium, but for longer storage would be sealed with extra space in the container at 33 to 34° F. (Jones 1962).
acutissima	——	——	——	——	——	
alba	Overwinter	Moist	30-40	4-mil polyethylene bags	33-40	Same as above.
falcata var. *pagodaefolia*	——	Moist	30-40	4-mil polyethylene bags	33-40	Same as above.
macrocarpa	Overwinter	Moist	30-40	4-mil polyethylene bags	33-40	Same as above.
michauxii	Overwinter			4-mil polyethylene bags	33-40	Same as above.
nigra	——					Same as above.
nuttallii	——					Same as above.
palustris	——	Moist	30-40	4-mil polyethylene bags	33-40	Same as above.
phellos	——					Same as above.
rubra	——	Moist	30-40	4-mil polyethylene bags	33-40	Same as above.
shumardii	——					Same as above.
velutina	——	Moist	30-40	4-mil polyethylene bags	33-40	If sealed leave extra space in container. Do not freeze (Jones 1964).
virginiana	——					Same as above.
Robinia pseudoacacia	10+	Dry	——	Sealed	33-40	USDA Forest Service (1974).
Tilia americana	4+	Dry	——	Sealed	33-40	Storage below 32° F. is probably better. Stored seed should be fall sown. If spring sown, follow recommended dormancy treatment.
Ulmus						
americana	15	Dry	3-4	Sealed	25	USDA Forest Service (1974).
pumila	8	Dry	3-8	Sealed	33-40	Storage below 32° is probably better if seed moisture content is low.
rubra		Dry			33-40	Storage below 32° F. is probably better if moisture content is low.

TABLE 7.—A *method of determining sample size*[1]

Number of seeds per gram[2]	Sample size	Seeds per ounce	Sample size
	Grams	*Number*	*Ounces*
5 to 9	510	140 to 250	18.0
10	430	250 to 300	15.0
11 to 29	200	301 to 800	7.0
30 to 34	140	801 to 940	5.0
35 to 43	115	941 to 1,200	4.0
44 to 75	85	1,201 to 2,100	3.0
76 to 125	45	2,101 to 3,490	1.5
126 to 250	25	3,491 to 7,000	1.0
251 to 430	15	7,001 to 12,000	.5
431 to 643	10	12,001 to 18,000	.3
644 to 1,800	6	18,001 to 50,000	.2

[1] For species having less than 5 seeds per gram (140 seeds per ounce) or more than 1,800 seeds per gram (50,000 per ounce), write to the Eastern Tree Seed Laboratory, P.O. Box 819, Macon, Georgia 31202 for sample size information.

[2] See table 5 for the average number of seeds per pound for most species listed.

To convert seeds per pound to number of seeds per gram or ounce, use one of these formulas:

$$\text{(a) Number of seeds per gram} = \frac{\text{number of seeds per pound}}{454}$$

$$\text{(b) Number of seeds per ounce} = \frac{\text{number of seeds per pound}}{16}$$

SEEDBED PREPARATION, SOWING, AND CARE

Crop rotation and lifting time govern the time and type of seedbed preparation. If seedbed preparation follows a green manure crop, the green manure should be plowed clown at least 30 to 45 days before the beds are formed. If seedbed preparation follows a seedling crop, the seedbeds will be prepared in late fall after the seedlings are lifted. Or seedbeds may be prepared in the spring after late fall lifting or spring lifting. When possible, it is more efficient to prepare seedbeds in the fall.

Soil should be plowed to a depth of 8 or 9 inches to permit good root development. After plowing, the soil should be disced and samples taken to determine fertilizer needs.

Nurserymen differ in their preferred sequence of jobs to get the seedbed ready for sowing. Some believe that fertilizers may be added before or after soil fumigation, but before beds are formed in either case. Others believe that the proper sequence is to form beds, rotary-till, fumigate, then fertilize. Evidence from several nurseries indicates that fumigation renders phosphorus unavailable causing a phosphorus deficiency in the seedlings. This condition is most apt to occur when son pH is less than 5 or when available phosphorus is less than 30 pounds per acre. It appears then that fertilization should be delayed until after fumigation.

When seedbed preparation follows a green manure crop, the various jobs required could be done in the following order :

1. Plow under green manure crop in mid-June or July. Incorporate a complete fertilizer with the green manure to hasten decomposition.
2. Allow 30 to 45 days for green manure to decompose.
3. Disc.
4. Take soil samples for analyses.
5. Ridge bed with two-row lister plow.
6. Rotary-till bed.
7. Fumigate.
8. Aerate (see quick-test instructions in Appendix) .
9. Fertilize based an analyses of soil samples.
10. Form seedbed with bedformer.

If green manure is not used, plowing would replace steps 1 and 2 above. The other jobs would follow in order.

Seedbed Formation

Seedbeds are raised aboye the general land level to improve soil aeration and drainage. Raised seedbeds generally are not required in very sandy soils that have good internal drainage, but are necessary in heavy soil, soil with poor subsoil drainage, soil with a high water table, and soil in poorly drained, extremely level areas.

Raised seedbeds are formed with special equipment. Severa] devices, or equipment combinations, are used, and the equipment that produces the best results varíes from one nursery to another. In a rather heavy soil, a two-row lister plow may be used tu throw soil toward the middle of the bed being formed (fig. 14). Then a rotary-tiller, first with the hood up, then down and weighted, may be run over the partially formed bed to pulverize the soil and level the seedbed (fig. 15) . In a lighter, sandy loara soil, a bedformer such as the Planet or Whitfield would work satisfactorily after the area has been plowed and disced (fig. 16). If the soil is heavy and drainage is a problem, the seedbeds should be formed convex in shape. Otherwise, they should be flat to facilitate sowing. If beds are prepared but not sown in the fall, a Gin pulverizer may be used to renovate the seedbeds for spring seeding (fig. 17).

F–521314

Figure 14.—Ridging a seedbed to improve drainage and aeration with a two-row lister plow.

F–521315

Figure 15.—Rotary-tilling with hood up to break up and loosen the soil. Another pass is made over the bed with the hood turned down to shape the seedbed.

F–521316

Figure 16.—Forming the seedbed with a Planet bedformer.

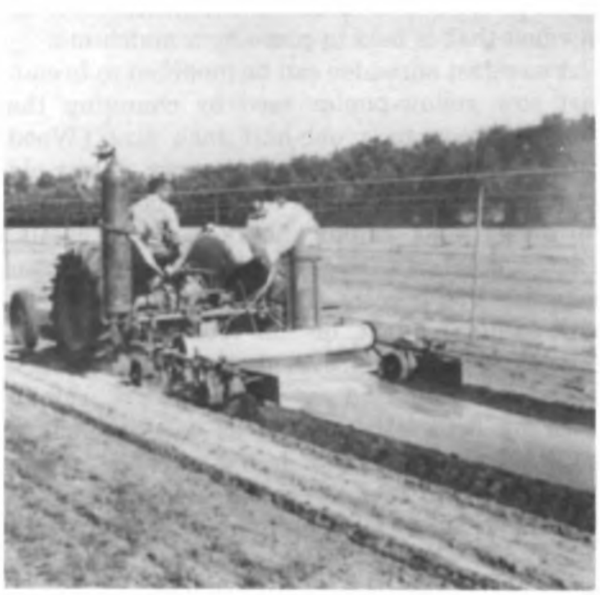
Seedbed Fumigation

Fumigation can control soil-borne insects, nematodes, fungi, diseases, and weeds in one

F-521317

Fig. 17.—Renovating a previously prepared seedbed with a Gill pulver izer.

operation, thus eliminating many nursery problems (fig. 18) . But weed control alone often will justify the cost of fumigation. Another benefit of fumigation is growth stimulation for some species such as yellow-poplar.



F-506020

Figure 18.—Laying tarp and shooting fumigant mechanically.

The beneficial effects of fumigation decrease with time because fumigated areas become contaminated from outside sources. To obtain the maximum benefit, seed sowing should follow fumigation as soon after the required aeration period as possible. To minimize contarnination of fumigated arcas, it is advisable to shape beds and complete all soil movement involved before fumigation.

A number of effective soil fumigants are are available (table 8) . The application of fumigants in forest nurseries is exacting. Howe (1965) stressed that :

1. Fumigants should be applied when the soil is rnoist.
2. The soil should be loose.
3. The soil temperature should be 50° F. or aboye for most fumigants, but some may be used at temperatures of 30° F. (table 8) .
4. Sandy or sandy loam soils are the ideal soil types to fumigate.
5. Organic matter will absorb and break down soil fumigants but absorption by organic matter is less if soil moisture is at a satisfactory level.
6. Nematodes are protected in undecomposed organic matter .
7. Fumigants should be applied at the recommended registered rate.
8. All fumigants inhibit nitrifying bacteria. The organisms that convert nitrates to ammonia are not as easily killed, so ammonia may build up to toxic levels.
9. Fumigated soils must be properly aerated and aeration time depends on soil temperature and soil moisture. Aeration is slower during cold weather. Also, if tarps are taken off and a heavy raro occurs on the area before it is thoroughly aerated, it usually is necessary to wait about another week to give the fumigant time to dissipate. This is also true for liquid fumigants.

Because fumigants temporarily inhibit the nitrifying bacteria (thus delaying transformation of ammonia nitrogen to nitrate nitrogen) nitrate fertilizers should be used for fumigated soils, especially for acid soils low in nitrates (Thiegs 1955). Poor growth and injury to some plants may result from high ammonia levels. The problem is most apparent when ammonia is released from decomposing manure or other organic fertilizers.

TABLE 8.—*Fumigants for preplanting control of nursery pests*

Common fumigants	Some common trade names	Pests controlled
CP-chloropicrin	Larvacide, Picfume	Nematodes, root rots, insects
DD, dichloropropene + dichloropropane	Vidden D, Nemex, D-D Mixture	Nematodes, fungi
DD + methyl isothiocynate	Vorlex	Root rots, damping-off
DMTT-dimethylltetradro-thiadiazinethione	Mylone, Cragfungicide 974, Dazomet	Root rots, damping-off
EDB-ethylene dibromide	Dowfume W-85, Soilbrom, Soilfume	Nematodes, fungi
MBR-methyl bromide	Bedfume, Brom-O-Gas, Pest-master, Weedfume, Meth-O-Gas	Bacteria, nematodes, fungi, weed seeds
MBR-chloropicrin	Brozone, Dowfume MC-2	Bacteria, nematodes, fungi, weed seeds
dichloropropene + chloropicrin	Telone	Nematodes, root rots, damping-off
SMDC-sodium *N*-methyldithiocarbamate	Chem-vape, Vapam, Trimaton, VPM, Mycoban	Root rots, nematodes, herbicide

Phosphorus absorption is also inhibited by fumigation. It has been found beneficia', even necessary, to apply phosphorus fertilizer after fumigation to prevent phosphorus deficiency from developing in the seedling crop (Martin *et al.* 1963) . In New York classic phosphorus deficiency symptoms were found in white spruce after fumigation even though soil analysis indicated adequate amounts of phosphorus were present. Deficiency symptoms were corrected when phosphorus was banded below and to one side of the seed placement zone after fumigation but before sowing.

Seed Sowing

Methods

Hardwood seeds may be broadcast (figs. 19 and 20), drilled (figs. 21 and 22), or sown in drill marks (fig. 23) (table 9). Because seed size and chape vary so much among species, mechanical sowing equipment has been developed or adapted for only a few species. Thus, most hardwood seeds are broadcast or sown in drill marks. Hand sowing is slow and expensive, so mechanical sowing equipment is being developed.

Broadcast sowing distributes the seed uniformly over the entire seedbed. The resulting seedlings should develop better root systems than seedlings growing in rows because the seedbed is more evenly occupied. Seed may be broadcast by hand or by mechanical methods. Manually operated laven seeders have been used successfully at the Nekoosa-Edwards Paper Company Nursery, Port Edwards, Wis. (Stoeckeler and Jones 1957). At the George O. White State Tree Nursery unhulled black walnut seeds are sown with a manure spreader. The shredder and beater mechanism is de-activated allowing only the platform elevator to function. Unhulled walnut are spread upon a well roto-tilled secdbed to produce 10 plantable' seedlings per square foot. After a slight amount of raking and hand distribution, the seed is pressed finto the soft seedbed with a 300 pound roller. The rolled-in seed is covered with a 3-inch layer of sawdust that is held in place by a mulch-net.

A sawdust spreader can be modified to broadcast sow yellow-poplar seed by changing the shaker screen to a one-half inch size (Wood 1967) . The modified spreader sows 3-year -old stratified seed (the wings would be decomposed) uniformly and rapidly. Labor requirements, when compartid with the old hand method, can be reduced 90 percent. The seed may be covered with sand, sawdust, or soil from the paths.

Although some hardwood seed, such as black locust, red gum, and osage-orange, are usually sown by drill, others such as oak and silver maple are sown by hand in drill marks. The space between rows or the number of rows per bed varies by species and the experience and preference of the nurseryman, although five drill rows are commonly used.

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[5] A plantable seedling has a 5/32-inch stem diameter or larger measured 1 inch above the root collar.

F–521318

Figure 19.—Spacing broadcast walnut **seeds.**

Seeding Rate

Most nurserymen in the Central States strive to produce a given number of plantable hardwood seedlings per square foot. To determine the amount of seed to sow, the seed germination percent and the number of seeds per pound are required. With this information, and the desired density per unit of area, the amount of seed to sow to produce a given number of seedlings may be computed by the following formula, taken from Stoeckeler and Jones (1957) :

$$P = \frac{A \times D}{G \times S \times Y}$$

in which the term A x D equals the total number of seedlings desired ; when A = area in square feet; D = density (desired number of seedlings per square foot) ; P pounds of seed; G = germination percent of the seed, expressed as a decimal ; S = number of seeds per pound as they come from the container ; and Y = survival factor, variable by species, is an experience factor based on the percentage of viable seed that will produce plantable seedlings at the end of the growing season, expressed as a decimal.

The number of seeds per pound may be determined by weighing a small sample of uncleaned seeds (debris included) on a sensitive balance (grams), then counting the number of whole seeds in the sample. The Stoeckeler and Jones (1957) formula to compute the number of seeds per pound is :

$$\text{Whole seeds per pound of unclean seeds} = \frac{\text{Number of whole seeds in the sample} \times 454}{\text{Weight (grams) of unclean seeds in sample}}$$

In this formula, 454 is the number of grams per pound.

F–521319

Figure 20.—Covering broadcast walnut *seed.*

F–521342

Figure 21.—Wind River seed drill suitable for sowing small-seeded hardwood species.

For example, suppose that the nurseryman wishes to produce 100,000 yellow-poplar seedlings. Yellow-poplar should be grown at a density of 10 plantable trees per square foot, so 10,000 square feet of seedbed will be required. The germinative capacity of the seed is 8 percent, there are 14,000 seeds per pound, and the survival factor is 50 percent. The formula becomes

$$P = \frac{10{,}000 \times 10}{.08 \times 14{,}000 \times .50}$$

$$P = \frac{100{,}000}{560} = 178.57 \text{ pounds.}$$

The number of seeds to sow per linear foot of drill can be computed also. The formula is :

$$N = \frac{D}{GY}$$

when N = number of seed to sow per linear foot ; D = desired number of seedlings per linear foot; G germination percentage of the seed, expressed as a decimal; and Y = survival factor, based on the percentage of viable seed that will produce plantable seedlings at the end of the growing season, expressed as a decimal.

To facilitate even distribution for hand sowing, small quantities of seed must be sown on small areas of the seedbed. In nurseries that have an overhead irrigation system, it is relatively easy to divide the seedbed finto small equal-sized areas. Seedbeds are 4 feet wide and pipe supports for the irrigation pipe range from

F–521344

Figure 22.—Sowing European alder with a Whitfield seed drill.

12 to 15 feet apart. Thus, the seedbed area between pipe supports is easy to calculate. For hand sowing in drill marks or broadcast, sufficient seed should be sown to produce the desired density in the 48 to 60 square feet (4 X 12 or 4 x 15 feet) of seedbed between pipe supports.

F-521337

Figure 23.—Preparing seedbed to sow hardwood seed with a five-row layoff plow.

Use of History Plots

It has been customary to rely on the experience of the nurseryman to determine sowing rate for a given yield of plantable trees at the end of the first year. Although this often gives satisfactory results, it is desirable to establish permanent "history plots" in the nursery (Belcher 1964). These provide accurate records of what was done and the effect in terms of germination, size of seedlings, etc., and will enable the nurseryman to determine sowing rates for producing the desired number of seedlings. History plot records, or complete nursery records by beds or areas, enable the nurseryman to produce a higher percentage of plantable stock.

Even when adequate germination data are available, optimum sowing rates may be determined more accurately when the *survival factor* is known. This is defined as the number of plantable trees that survive to be lifted. The survival factor should be determined for various species at specific locations in the nursery. History plots are employed to get this information and should be established at sowing time. The exact number of seed (of known quality) sown in a history plot should be recorded. Intermittent counts should be made to get germination, early survival, and survival at lifting time. A *cull factor* can and should be determined for the sowing. The cull factor will vary with seed quality, seeding rate, soil treatments, cultural practices, weather, etc.

Predator damage can be evaluated separately from loss of germination or mortality caused by disease, insects, or heat damage by randomly covering some plots in each area with hardware cloth to exclude animals.

Time of Sowing

Time or season of sowing is determined by seed availability, seed characteristics, need for seed stratification or other pretreatment, and seasonal work load at the particular nursery and nursery location. In northern nurseries, both dormant and nondormant seed lots are often sown in the fall after temperatures drop below the minimum conducive to germination. Fall sowing provides natural overwinter stratification in the seedbed for dormant seed, and prompt uniform germination generally occurs the following spring. In southern nurseries, nondormant seed lots cannot be sown in the fall because germination could occur throughout the winter period and result in the loss of an entire crop. Dormant seed lots may be sown from February through April at locations where temperatures will provide suitable stratification in the seedbed and premature germination is not a hazard.

In northern locations fall sown seed germinates promptly and 1-0 seedlings produced from fall sown seed are generally larger simply because they make full use of the entire growing season. Properly timed spring sown seed could attain similar size. However, the vagaries of weather and spring work load usually prevent the northern nurseryman from properly timing his spring sowing. Southern nurserymen do not have the same concern since they enjoy a longer

TABLE 9.—*Seedbed preparation, sowing , and care during germination*

Species	Season of sowing	Sowing Method[1]	Sowing depth[2]	Desirable seedbed density seedlings/sq. ft.	Remarks
			Inches		
Acer					
negundo	Spring or fall[3]	1 or 2	¼	10-20	Mulch fall sown seed.
nigrum	Spring or fall[3]	1 or 2	¼	10-20	Mulch fall sown seed.
rubrum	Spring[4]	1 or 2	¼	10	Light mulch desirable.
saccharinum	Spring[4]	1 or 2	¼	15	Light mulch desirable.
saccharum	Spring or fall[3]	1 or 2	¼	15	Mulch fall sown seed.
Albizia julibrissin	Spring or fall	3 or 4	¼	15-20	Scarification of seedcoat necessary for spring sowing.
Alnus glutinosa	Spring or fall	3 or 4	Surface to 1/16	10-15	
Betula					
alleghaniensis	Spring or fall[3]	3 or 4	1/16 to 3/16	10-20	Mulch fall sown seed.
nigra	Spring or fall[3]	3 or 4	1/16 to 3/16	10-20	Mulch fall sown seed.
papyrifera	Spring or fall[3]	3 or 4	1/16 to 3/16	10	Mulch fall sown seed.
Carya illinoensis	Spring or fall[3]	1, 2 or 4	¾ to 1½[5]	10	Mulch fall sown seed.
Castanea	Spring or fall[3]	1, 2 or 4	¾ to 1½[5]	10-15	Mulch fall sown seed.
Catalpa					
bignonioides	Spring	1, 3 or 4	Surface to ⅛	10-20	Light mulch beneficial.
speciosa	Spring	1, 3 or 4	Surface to ⅛	10-20	Light mulch beneficial.
Celtis					
laevigata	Spring or fall[3]	3 or 4	¼–½	15-20	Light mulch beneficial.
occidentalis	Spring or fall[3]	3 or 4	¼–½	15-20	Light mulch beneficial.
Cercis canadensis	Spring or fall[3]	3 or 4	Surface to ¼	15-20	Light mulch beneficial.
Cornus florida	Spring or fall[3]	3 or 4	¼–½	10-20	Light mulch beneficial.
Diospyros virginiana	Fall or spring[3]	3 or 4	½–¾	10	Mulch fall sown seed.
Elaeagnus					
angustifolia	Spring or fall[3]	1, 2, 3 or 4	½	15-25	Mulch fall sown seed.
umbellata	Spring or fall[3]	3 or 4	½	15-25	Mulch fall sown seed.
Eucalyptus	——	——	—	15-20	For detailed information see USDA Forest Service (1974).
Fraxinus					
americana	Fall or spring[3]	1, 2 or 4	¾	10-20	Mulch fall sown seed.
nigra	Fall or spring[3]	1, 2 or 4	¾	10-20	Mulch fall sown seed.
pennsylvanica	Fall or spring[3]	1, 2 or 4	¾	10-20	Mulch fall sown seed.
Gleditsia triacanthos	Spring	3 or 4	½–¾	15-20	Scarification of seedcoat or hot water treatment is necessary.
Juglans					
cinerea	Spring or fall[3]	1, 2 or 4	1½–2[5]	5-10	Mulch fall sown seed.
nigra	Spring or fall[3]	1, 2 or 4	1½–2[5]	5-10	Mulch fall sown seed.
Liquidambar styraciflua	Spring or fall[3]	1 or 4	Surface to ⅛	15-25	Mix aluminum powder (4 tablespoons per 100 pounds of seed) with wet stratified seed to achieve easy flow in the seeder. Mulch fall sown seed.
Liriodendron tulipifera	Spring or fall[3]	1, 2, 3 or 4	¼	10	Seed can be dewinged in a debearder, then empty seed and trash can be removed by gravity separator (Bonner and Switzer 1971). Mulch fall sown seed.
Maclura pomifera	Spring	3 or 4	¼–½	10-15	
Magnolia grandiflora	Spring or fall[3]	1, 3 or 4	¼	15-20	Half-shade is reported to be beneficial. Mulch fall sown seed only.

Table 9 continued on next page

TABLE 9.—*Seedbed preparation, sowing, and care during germination* (continued)

Species	Season of sowing	Sowing Method[1]	Sowing depth[2]	Desirable seedbed density seedlings/sq. ft.	Remarks
			Inches		
Morus rubra	Spring[3]	3 or 4[6]	Surface to ⅛	12	Half-shade is reported to be beneficial. A 100-hour soak in cold water is beneficial for fall sowing (see USDA Forest Service 1974). Mulch fall sown seed only.
Nyssa					
aquatica	Fall or spring[3]	1, 3 or 4	½–1	10-15	Mulch fall sown seed.
sylvatica var. *sylvatica*	Fall or spring[3]	3 or 4	¼–½	10-15	Mulch fall sown seed.
Paulownia tomentosa	Spring or fall[3]	1, 3 or 4	Surface to ⅛	10	Mulch fall sown seed.
Platanus occidentalis	Spring[3]	1, 3 or 4[6]	Surface to ⅛	10-15	Frequent watering may be used lieu of light mulch.
Populus					
deltoides	Spring[4]	1 or 2	Surface[7]	10	
tremuloides	Spring[4]	1 or 2	Surface[7]	15-20	Use sideboards, sow seed in acid sand, and cover bed with plastic to prevent erosion by raindrops (Einspahr 1959).
heterophylla	Spring[4]	1 or 2	Surface[7]	10-15	
Prunus serotina	Spring or fall[3]	1, 2, 3 or 4	½	5-11	Mulch fall sown seed.
Quercus					
acutissima	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
alba	Fall or spring[4]	1, 2 or 4	¼–1[5]	10-15	Stratification not usually required. Mulch fall sown seed.
falcata var. *pagodaefolia*	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
macrocarpa	Fall or spring[4]	1, 2 or 4	¼–1[5]	10-15	Stratification not usually required. Mulch fall sown seed.
michauxii	Spring or fall[5]	1, 2 or 4	¼–1[5]	10-15	
nigra	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Moist storage necessary if sowing is delayed until spring. Mulch fall sown seed.
nuttallii	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
palustris	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
phellos	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
rubra	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
shumardii	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
velutina	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
virginiana	Spring or fall[3]	1, 2 or 4	¼–1[5]	10-15	Mulch fall sown seed.
Robinia pseudoacacia	Spring	3 or 4	⅛–¼	15-20	Hot water soaking hastens germination.
Tilia americana	Fall[8]	1, 3 or 4	¼ to ½	15-20	See tables 4 and 5. Mulch.
Ulmus					
americana	Spring[4]	2 or 4	¼	10-20	
pumila	Spring[4]	2 or 4	¼	10-20	
rubra	Spring[4]	2 or 4	¼	10-20	

[1] (1) Hand broadcast; (2) hand, drill marks; (3) mechanical drill; (4) mechanical broadcast.

[2] If more exact information is lacking, cover seed to a depth 1½ times diameter of seed.

[3] Spring sown seed should be stratified.

[4] Immediately after collection.

[5] Protect seed from rodents.

[6] In Missouri, seed is broadcast onto a rolled seedbed with a Gandy spreader and covered with light coat of sand.

[7] Create small ridges in bed and wet surface before broadcasting seed. Do not cover but irrigate immediately after sowing and as often as 3 times per day for 7 days. Germination starts 24 hours after sowing so sparse spots may be reseeded within 48 hours to bring density to desired level.

[8] Good results have been obtained by early collection when the seedcoat is greenish brown and immediately sown (Bailey 1961). Mulch is important to prevent prolonged freezing and inhibition of the stratification action (Heit 1967).

growing season. Hardwood seedlings nearly always attain plantable size in one season. The concern with sowing date in the south is pointed toward the onset of hot, humid weather which can contribute to heat and disease problems in the seedbed. Their objective then is to arrive at a sowing date which ensures that all germination is complete prior to the onset of weather conditions unfavorable for germination.

Seed ripening and storability also affect sowing date. Species from the genera *Populus* and *Acer* that ripen in the spring develop best if sown shortly after collection.

Added costs associated with fall sowing are mulching and the necessity to protect fan sown seedbeds from rodents over a longer period of time. These factors should be evaluated by the nursery manager and a decision about sowing date based upon his experience in his nursery situation.

Depth of Sowing

Optimum seeding depth will vary with the size of seed, season of sowing, and soil texture. Large seeds may be sown deeper (about 1 1/2 times seed diameter) than small seeds. Fall sown seeds should be sown slightly deeper than spring sown seeds to compensate for erosion and to combat frost heaving. Seeding depth can be about one-third greater in light sandy soils than in heavier loamy soils because of the comparatively greater ease of emergente.

Mulching

Fall sown seedbeds should be mulched overwinter. Materials used are sawdust *(figs.* 24 and 25), burlap, light woven cotton cloth, crushed corncobs, straw, and marsh hay (fig. 26). Mulching material such as rye straw and marsh hay should be fumigated to kill seed. Baled straw can be fumigated by placing it under the tarps when the seedbeds are fumigated. Hydromulching is a relatively new development in which wood fiber is sprayed on the beds in a water slurry (fig. 27) . Hydromulch is free of weed seed and is applied mechanically. Where the mulch material may be rolled from the seedbeds by high intensity winds, mulch net staked across the ends of seedbeds would minimize losses.

F-521320

Figure 24.—A front-discharge spreader covering European alder seed with sawdust.

F-521321

Figure 25.—Laying mulch net to hold sawdust in place.

Mulches prevent erosion and frost heaving and may be left in place to delay early spring germination 10 to 14 days until danger of spring frost is less. Corncob, sawdust, and hydromulches may be left on the seedbeds through the growing season, but straw and marsh hay mulches are usually removed when germination begins in the spring (figs. 28 and 29). Sawdust mulch is usually held in place by mulch net, screen wire, or bed frames.

F-521322

Figure 26.—Fall sown black walnut seedbeds mulched with marsh grass for overwinter protection.

Irrigation

Irrigation is extremely important during the germination period. The soil must be kepí moist while the seed is germinating. Some small seeded species are extremely sensitive to lack of moisture. For cottonwood, it is necessary to dampen the seedbed immediately before and immediately after the seed is sown. During the germination period seedbeds should be watered at least once a day to moisten the surface one-half inch of soil. It may be necessary to irrigate every 3 to 4 hours during daylight hours because the surface of seedbeds dries out rapidly.

Seedbeds must remain moist through the germination period, thereby providing a haven for damping-off fungi. Damping-off has been controlled in recent years by fumigating the seedbeds, but if it does occur, water should be withheld for a time then used sparingly until the seedlings are past the danger stage. During the germination period seedbeds should be watered early in the day to reduce incidente of damping-off.

Water is necessary throughout the growing season. Irrigation is required to supplement rainfall in producing quality planting stock. Many nurserymen compute their irrigation requirements by assuming that nursery stock requires 1 or more inches of water per week. When rainfall does not supply this requirement, the seedbeds are irrigated to maintain this standard. Every soil has a maximum water-holding capacity, or field capacity. The field capacity of loamy sand soils containing 15 to 20 percent of silt-plus-clay is usually from 12 to 15 percent (Stoeckeler and Jones 1957) . Seedbeds should be irrigated to bring the soil moisture content of the surface 8 inches to field capacity.

The amount of water to be supplied by the irrigation system is dependent on (1) rainfall, (2) temperature, (3) percolation, and (4) seedbed density. Indiscriminate irrigation may cause serious damage to soil fertility. Excessive watering causes the leaching of nutrients and encourages the development of fungus diseases.

A record of the amount and frequency of rainfall is useful for determining the need for irrigation. Light, frequent watering is not as effective as heavy, infrequent watering. However, where there is danger of *denitrification* only a small amount of water should be applied at a time. Denitrification and other reduction processes may occur in soils if watering lowers aeration below 20 percent by volume for an extended time. This means that soils having 50 percent porosity may contain 30 percent water, while soils having a porosity of 40 percent can tolerate only 20 percent in water (Wilde 1958) . The aeration of coarse sandy soils practically never drops to an undesirable level.

Daytime watering in the hot sun can decrease soil and air temperature (a desirable practice during germination) but much water is lost by evaporation. The most effective time to water is in the evening or early morning hours (3 a.m. to 5 a.m.). This allows water to percolate to 8 or 9 inches. If the irrigation water is "hard," daytime watering during periods of high evaporation will cause a trust of calcium and magnesium carbonates to form.

Water often is warmer than air, so irrigation may be used to protect seedlings from frost damage. Frost protection by irrigation during

F–519684

Figure 27.—The hydromulcher sprays wood fiber onto the seedbed in a water slurry. (Photo courtesy Saratoga Nursery, New York State Conservation Department.)

F–519685

Figure 28.—The mulch pickup developed at the Bessey Nursery in Nebraska picks up straw mulch from seedbed.

the spring germination period can be accomplished by irrigating the nursery stock before sunrise when frost hazard is present.

Weeding

Weeds are a problem in hardwood seedbeds. A seedbed will support only a certain amount of vegetative growth. If some of the space, nutrients, and water are used by weeds, then the seedling crop suffers.

Some fumigants (table 8) help control weeds but more complete control often is needed. Some pre-emergence weed control chemicals are used on hardwood seedbeds (table 10). Because many hardwood seedlings are killed by contact herbicidas, there use is often limited to noncrop aneas in the nursery such as roads, paths, and

F–519686

figure 29.—A closeup of **the** mulch pickup shows the working parts of the machine.

under irrigation fines. Weeds have been controlled with such herbicides when shields were used to protect the seedlings, much as in row crop production.

Some pre-emergence herbicides can be used safely on hardwood seedlings. Rate of application must be governed by the tolerante of the seedlings, the texture of the nursery soil, and the registered application rates. In general, rather high rates of herbicide are necessary in heavy soils. Rates lower than those recommended on the label should be used in Iighter textured soils because the herbicide is more easily carried to the root zone where it may kill the seedlings. However, if lower rates are applied, the user must be assured that the goal of reducing target weeds will be achieved.

The pre-emergence herbicides Usted in Cable 10 are in use in tree nurseries in the northeastern United States on the species indicated. This list and pre-emergence herbicide usage will grow as screening and registration of agricultura] herbicides for nursery use continues.

There is no substitute for *following the herbicide manufacturer's safety recommendation, calibrating* the sprayer properly, and *cleaning* the sprayer thoroughly between applications of different spray materials (see Appendix) Unfamiliar chemicals and techniques should be tried in small-scale tests with each species. Chemicals and the techniques for using them should be registered for the specific use.

Hand weeding is expensive and will become even more so as labor costs continue to rise. But hand weeding has been mechanized to some extent. Workers ride on a low slung vehicle that is either tractor drawn or self-propelled over the length of the seedbed at the correct height and speed for the workers to pull weeds. Weeds are easier to pull right after a raro or irrigation.

A mechanical, rotary hoe developed by Mony (1954) can be used in hardwood seedbeds if the seedlings are grown in romos. The rotary hoe blades are powered by a self-contained motor and the machine is carefully guided along the

TABLE *10.—Herbicides for nursery weed control (Anon. 1967)*

Herbicide	Concentration	Soil type	Rate	Timing	Remarks
2-Chloro-4, 6-bis (ethylamino)-5-triazine Simazine*	80W[1]	Sandy loam	1 lb AIA[2] in 35 gal water	July 15	Black locust
Dimethyl Tetrachloro-terephthalate DCPA Dachtal*	50W or 75W	Sandy loam	6 lbs AIA with 50 gal water	Spring and Fall	Yellow birch, red oak, hard maple; best results on freshly disturbed soil
Trifluralin Treflan*	1 lb per quart	Silt loam	2 gal per acre	Spring	Black walnut, spring application prior to sowing.

[1] 80W = 80 percent wettable powder.
[2] AIA = Active ingredients per acre.
*Trade names.

seedbed by two men (fig. 30). A row and path cultivator adaptable to row-sown hardwoods has been developed in Oregon (Baker 1962).

Many nurseries employ a combination of materials and methods. An example is preplanting treatment with a fumigant (table 8), followed by one or more herbicides and some mechanical weed control. This combination of practices coupled with weed control in fallow fields and idle arcas does a good job of protecting the seedling croe from losses due to weeds.

Seedbed Pruning

Seedlings of some species can be pruned in the seedbeds. Seedlings are top pruned and root pruned to control size, stimulate fibrous root growth, and develop uniformity. Top and root pruning can also be used to slow down the growth of surplus 1-0 stock to be held for sale as 2-0 seedlings.

Top Pruning

Seedlings are sometimes top pruned one or several times during the growing season to produce more uniform seedlings. Each pruning clips the tops off the tallest seedlin-s without touching the shorter ones. Opposite budded species such as the maples and ashes should not be top pruned. Early pruning promotes the development of large branches on the lower stem, while stems pruned during the domará season are clean (Briscoe 1969).

Root Pruning

Roots are pruned to increase seedling uniformity and to stimulate lateral root development. Severing the taproot of some species such as oak and walnut stimulates lateral root development. Roots of black walnut seedlings pruned to a 5-inch depth in early June were branched and more fibrous than those of unpruned seedlings.

Several effective lateral root pruners have been described (Wycoff 1959, Lanquist 1965) . The seedlings must be grown in rows to allow passage of 18-inch rolling coulters mounter on a cultivator frame. The coulters are staggered to lessen soil compression and lifting action,

F–521323

Figure 30.—Weeding and cultivating a drilled seedbed with a mechanical cultivator. Seedlings must be in rows.

and are on swivels to reduce the strain. The beds can also be undercut with a horizontal blade to sever taproots.

Fertilization

Nutrient deficiencies should be corrected when noticed (fig. 31). However, it is better to start with a good nutrient level than to try to correct deficientes during the growing season. Deficiencies are difficult to correct on short notice and proper corrective treatment are not easily prescribed.

F-521324

Figure 31.—Top dressing a seedbed with supplemental fertilizer.

If basic nutrient levels are attained before seeding, nitrogen is the only element that is apt to become deficient. Nitrogen deficiency is especially common when a high C/N ratio mulch is left on the seedbed. Top dressing with 100 to 150 pounds of ammonium sulfate per acre at 3 week intervals usually will maintain satisfactory nitrogen levels on a fine textured soil.

VEGETATIVE PROPAGATION

Most hardwood nursery stock is produced from seed, but under special circumstances it may be desirable, necessary, or more efficient to reproduce some species by vegetative methods. Vegetative reproduction is used to mass-produce trees with desirable characteristics that cannot be retained with assurance through seed production. Hardwood tree improvement and genetics programs often depend on vegetative propagation for establishment of breeding collections and seed orchards. In the future, nurserymen may be required to produce genetically superior seedlings in quantity once superior trees have been selected.

Vegetative propagation can be separated finto three general categories : rooting of cuttings, layering, and grafting (McAlpine 1965). The method selected will be governed by the objectives of propagation, the species being propagated, and the age and vigor of the tree being propagated.

Age is often a critica] factor in the rooting and survival of stem cuttings, especially in species difficult to root. Cuttings taken from young trees, or young material (such as sprouts from old trees), usually root with far less difficulty than cuttings from old trees (figs. 32 and 33). Success of grafting, however, is more closely correlated with the vigor of the parent tree from which the scion wood is taken than it is with age.

Rooting of Cuttings

Some species, such as cottonwood and sycamore, are reproduced by stem cuttings; others, such as aspen, sweetgum, and black locust, are reproduced by root suckers or root cuttings (fig. 34, table 11). Rooting of cuttings is probably the most economical way *clones* of forest trees can be mass produced (fig. 35). Mist chambers and rooting auxins, such as indolebutyric acid, sometimes increase success with species that are difficult to root.

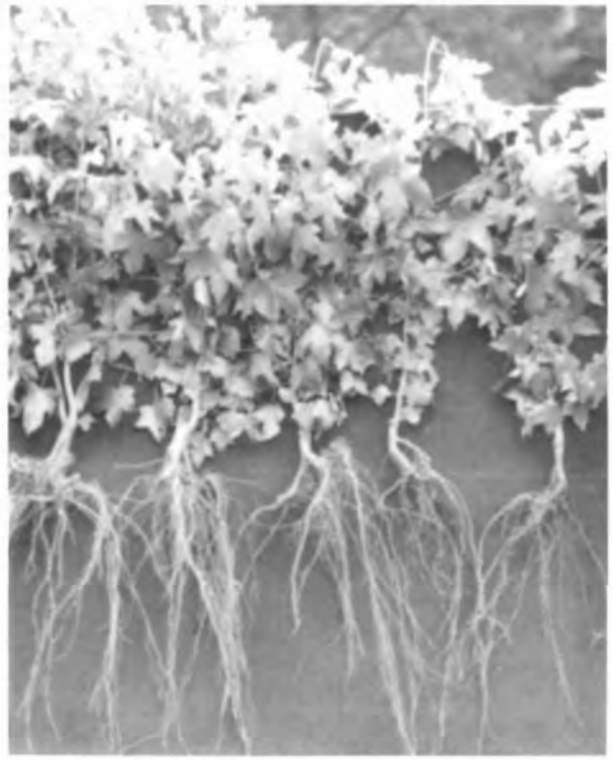
Greenwood (succulent) cuttings root more easily than hardwood (dormant) cuttings. Greenwood cuttings can be taken from relatively young (less than 5 years old is best) trees or from recent sprouts of older trees. When greenwood cuttings from young trees are required but not available, older trees may be induced to sprout by wounding. Young material may also be obtained by grafting branch material from older trees, then cutting back the scion to cause it to sprout (fig. 36). In some species, the time of year in which the cuttings

F–521301

Figure 32.—Rooted yellow-poplar cuttings taken from stump sprouts.

F–521302

Figure 33.—Rooted yellow-poplar clones from stump sprouts 2 years after transplanting from nursery bed. These clones are ready to be cut back to 1-foot stumps to provide cuttings for further multiplication.



F–521300

Figure 34.—One-year-old sweetgum root cuttings.

are taken can have a striking influence on the success of rooting. Hardwood cuttings are taken during the dormant season. Leafy or semihard cuttings should be taken during the early or midgrowing season. Semihardwood cuttings are usually rooted under intermittent mist sprays so that water loss is held to a minimum. Greenwood cuttings are prepared from soft, succulent, new spring growth with leaves attached, and root best under mist (fig. 37).

Butt cuttings of most species root easier than cuttings taken closer to the tip of a whip, but tip cuttings are required for the normal development of some species.

Cuttings make up a substantial share of cottonwood and sycamore planting stock. The procedure, for both species, is to plant nurse trees about 1 foot apart in rows 3 to 4 feet apart to facilitate cultivation. With adequate fertilization and irrigation, each plant should provide 4 to 6 cuttings when the cuttings are taken during the dormant season. In the north cottonwood whips should be cut in the fall, TABLE *11.—Vegetative reproduction*

Species	Method[1]
Acer	
negundo	Grafting or budding
nigrum	Grafting or budding
rubrum	Difficult to root by cuttings but results improved by treating with 200 mg./l of IBA for 3 hours (USDA 1965).
saccharinum	Stem cuttings
saccharum	Stem cuttings can be rooted but are difficult to keep alive after they strike roots (USDA 1965).
Albizia julibrissin	Root cuttings several inches long and ½ inch or more in diameter planted in early spring (Hartman and Kester 1968).
Alnus glutinosa	Stem cuttings or layering
Betula	Cuttings difficult to propagate. Leafy cuttings will root in summer under glass if treated 24 hours with 50 p/m indolebutyric acid (Hartman and Kester 1968).
alleghaniensis	Grafting
nigra	Grafting
papyrifera	Stem cuttings. Treat with IBA.
Carya illinoensis	Budding or grafting best. Leafy softwood cuttings and root cuttings are possible.
Castanea	Grafting or budding
Catalpa	
bignonioides	Softwood cuttings rooted under glass (Hartman and Kester 1968).
speciosa	Root cuttings. Softwood cuttings rooted under glass.
Celtis	
laevigata	Stem cuttings (USDA 1965); also grafting and budding.
occidentalis	Stem cuttings or layering (USDA 1965); also grafting and budding.
Cercis canadensis	Stem cuttings or layering
Cornus florida	Late spring stem cuttings from new growth after flowering rooted under mist. High concentrations (20,000 p/m) indolebutyric acid helps root cuttings (Hartman and Kester 1968).
Diospyros virginiana	Budding or grafting, also root cuttings.
Elaeagnus	
angustifolia	Stem or root cuttings; layering or grafting
umbellata	Stem or root cuttings; layering or grafting
Eucalyptus	Stem cuttings, grafting
Fraxinus	
americana	Budding, grafting or layering
nigra	———
pennsylvanica	Budding, layering: stem cuttings from young trees root easily under greenhouse conditions (USDA 1965).
Gleditsia triacanthos	Grafting, budding, stem cuttings and root cuttings (USDA 1965).
Juglans	
cinerea	Budding or grafting
nigra	Budding or grafting. Stem cuttings (Shreve 1972).
Liquidambar styraciflua	Root cuttings, layering, grafting. Leafy softwood cuttings rooted under mist in mid-summer. Naphthalene acetic acid helpful (Hartman and Kester 1968).
Liriodendron tulipifera	Stem cuttings 10 to 20 mg/ml IBA (Enright 1957); also budding.
Maclura pomifera	Stem cuttings
Magnolia grandiflora	Stem cuttings, grafting and layering. Leafy cuttings in late spring or early summer, wounded and treated with 20,000 p/m IBA root easily under mist (Hartman and Kester 1968).
Morus rubra	Stem cuttings, budding
Nyssa	
aquatica	Layering but results not encouraging (USDA 1965).
sylvatica var. *sylvatica*	Layering (USDA 1965).
Paulowna tomentosa	———
Platanus occidentalis	Stem cuttings
Populus	Most species (except aspens) propagated by stem or root cuttings
deltoides	Stem cuttings
tremuloides	Root cuttings. Stem cuttings from 1-year-old sprouts will root if treated with IBA (USDA 1965).

See footnote at end of table.

Table 11 continued on next page

TABLE 11.—*Vegetative reproduction* (continued)

Species	Method[1]
Populus	
heterophylla	Cuttings root less easily than eastern cottonwood; as difficult to root as American aspens (USDA 1965).
Prunus serotina	Grafting or budding
Quercus	
acutissima	Grafting
alba	Grafting
falcata var. *pagodaefolia*	Grafting
macrocarpa	Grafting
michauxii	Grafting
nigra	Grafting
nuttallii	Grafting
palustris	Grafting
phellos	Grafting
rubra	Grafting
shumardii	Grafting
velutina	Grafting
virginiana	Grafting
Robinia pseudoacacia	Root cuttings or grafting
Tilia americana	Layering. Suckers cut back to the ground have been mound layered.
Ulmus	Spring softwood cuttings rooted under mist. Budding.
americana	Stem cuttings, root cuttings
pumila	———
rubra	Layering

[1] Rooting of most stem cuttings may be improved by use of IBA or naphthalene acetic acid (NAA).

F–519683

Figure 35.—A hardwood cuttings planter developed in Saskatchewan, Canada.

tied into bundles, and protected from drying while they are transported to a shelter. They should be cut into optimum lengths, then stored overwinter and planted in the spring. In the south cottonwood cuttings cut and planted in October, November, and December survived best (Briscoe 1963). In one study root formaton and survival of cuttings viere not affected by cutting diameter, but increased as length of the cutting increased from 6 to 18 inches, and decreased with increasing age and decreasing vigor of the parent tree (Alien and McComb 1958).

Sycamore cuttings generally should be 16 to 20 inches long and at least 0.3 inch and preferably 0.5 inch in diameter at the top (Briscoe 1969) . Further, there is no known biological limit to maximum diameter of cuttings but planting techniques usually restrict diameter to 1.5 inches.

Root-inducing chemicals such as indolebutyric acid (IBA) do not cause plants to root that will not root without them (Avery *et al.* 1947). Nor will chemicals substitute for light, moisture, and temperature conditions required for the successful rooting of cuttings.

Root inducing auxins are usually applied by soaking the base of the cutting in a prepared auxin solution or by wetting it first with water and then dipping it into an auxin powder. Cuttings may be immersed in an auxin solution from a few seconds to as long as 48 hours, depending on the concentration of the solution. Concentrations may vary from 10 p/m to 10,000 p/m or more. Optimum concentrations will vary with species and whether greenwood or hardwood cuttings are being treated. Greenwood cuttings are usually treated with the low strength solutions. Normally, the stronger solutions are required for the hardwood cuttings. For some species, a quick dip finto high concentrations of IBA is suggested (Humphrey 1966). If powder is used, the hormone is mixed in a carrier, usually talc, but other material such as charcoal and bentonite have been used. Trade preparations of hormone powder in talc usually contain from 1 to 8 milligrams of indolebutyric acid per gram of carrier.

Indolebutyric acid, naphthaleneacetic acid, and indoleacetic asid and their potassium salts and esters are the three most common compounds used to promote rooting. Some species respond better to one of these compounds than to the others. Other species produce more roots if a combination of chemicals is used. Rooting of some species is further improved if fungicides or minteral nutrients are used with the growth substances (Kramer and Kozlowski 1960).

For optimum rooting conditions in some species, soft, succulent plant tissue, and warm, humid conditions are needed. Fungicides have been used with hormones to overcome the disease problem. Captan and thiram generally have been superior when used with hormones to produce rooting (Snyder 1966).

F-521298

Figure 36.—Grafted yellow-poplar topped to provide sprouts for rooting.

F-521299

Figure 37.—Greenwood yellow-poplar cuttings being rooted in an outside mist bed. The media is a 6-inch deep, half and hall mixture of sand and peat. The mist is applied for about 5 seconds at 1-minute intervals from sunrise to sunset.

Layering

Layering is the development of roots on a stem while it is still attached to the parent plant. After roots develop, the rooted stem is cut from the parent plant and transplanted.

Layered stems produced roots more successfully than stem cutting because the stem continues to receive moisture and nutrients from the parent plant. Most methods of layering are relatively simple to perform and can be practiced outside. If only a small number of plants are needed, layering of some species is easier than rooting cuttings because it requires less skill, effort, and equipment. However, layering is expensive and is not generally used for large scale production.

Simple Layering

Simple layering is done by bending a branch to the ground, pinning the bent stem firmly to the soil, and covering the stem with 3 to 6 inches of soil. A sharp bend that causes the terminal to stand upright may help induce rooting. Also, wounding by twisting the branch to loosen the bark or cutting and notching the underside of the stem, helps to induce rooting.

Layering is usually done in the early spring using dormant 1-year-oid shoots. Stems Iayered in the spring will usually be adequately rooted by the end of the growing season and may be lifted in the fall or the next spring .

Stool Layering

Stool layers are made by cutting the parent plant back to the ground during the dormant season. When sprouts forra in the spring, soil or other rooting medium is mounded around the sprouts to encourage roots to form on them. As the shoots increase in height, the rooting medium is mounded higher around the stems until in midsummer the third and final mounding is done. After the rooted layers are cut, the mother plant remains exponed until new shoots again reach a height of 3 to 5 inches and the process is started again. Rooted shoots are cut as close to their base as possible to keep the height of the stool plant low.

Air Layering

Air layering induces roots to form on stems or branches too high to be rooted by simple layering (figs. 38 and 39). The stem is girdled or slit at an angle, a rooting hormone is brushed onto the wound which is then enclosed in a moist rooting medium and wrapped in polyethylene film to keep it moist. Aluminum foil is sometimes wrapped around the polyethylene film to prevent excessive heat. Splints are often used to help prevent breakage.

F–521296

Figure 38.—Air-layered cottonwood after 3 weeks. Aluminum foil is usually pressed around the plastic film to reduce heat buildup.

Grafting and Budding

Grafting and budding can be used to propagate species such as black walnut that are difficuIt to root. These techniques are sometimes essential to the success of tree improvement work.

Five important requirements (Hartmann and Kester 1968) for any successful grafting operation are:

1. The stock and scion must be compatible.
2. The cambial region of the scion must be in intimate contact with that of the stock.
3. The grafting must be done when the stock and scion are in the proper physiological stage. Usually this means that scion buds are dormant, so for deciduous plants, dormant scion wood is often collected during the winter and kept inactive by storing it at low temperature.

4. Immediately after the grafting operation is completed, all cut surfaces must be carefully protected from desiccation.

5. The grafts must be tended for a period of time after grafting. Shoots from the root stock must be pruned off or they will prevent growth and development of the scion.

Grafting is sometimes done before the growing season using dormant scions and dormant rootstocks. In this case if it is done inside using potted rootstocks it is sometimes called "bench" grafting. Bark inlay and whip or tongue grafts are particularly useful for small diameter material and are the most common dormant season grafts.

Grafting of dormant scions on active rootstocks is probably the most common type of grafting. Scion wood is generally collected during the dormant season and refrigerated until grafting time. Whip, or cleft grafts are often used. Nut growers prefer using bark inlay grafts in May. Because grafted scions are susceptible to wind breakage during the first year, new shoots should be staked the first year or cut back to about half their height.

Grafting a single bud onto a stock plant is called budding. Budding can be done anytime that buds are fully developed and the bark of the stock will slip, but most budding is done in July and August so that the buds will remain dormant overwinter. Any leaves around the bud are cut off to reduce dessication. The most popular of the many budding techniques is shield or "T" budding (fig. 40). Shield budding is easier if the portion of the stock to be budded is not more than 2 or 3 years old. Older stock branches may have thick bark that is difficult to work. Shield budding is normally done during the growing season when the bark separates easily from the wood. Buds are usually taken from twigs of the current season's growth.

For all grafts the stock should be maintained in a healthy, vigorous state. The growth of the

F–521297

Figure 39—Root formation of air-layered cottonwood after 3 weeks. Hormodin 3 was applied to the girdle.

F–521339

Figure 40.—A new "T" bud graft (arrow) on a young yellow-poplar.

stock should not be reduced by pruning until it is time to force growth from the scion. Then remove leafy shoots from the stock of grafts made early in the growing season to force growth of the scion. Generally it is best to remove stock foliage gradually so the shoot from the scion bud will not develop too rapidly. Rapidly developed shoots may become too heavy and break off at the union.

Many grafting techniques are fully explained in Hartmann and Kester (1968), Snyder and Bartram (1965), or Garner (1958).

NURSERY PROTECTION

Seedbeds require protection from drying winds, flooding, excessive hect, excessive cold, drought, mammals and birds, insects, and diseases.

Windbreaks should be planted on the windward sides of nursery sections (the north and west ends in the Central States) to protect the seedbeds from erosion and drying winds (fig. 41). Flooding should occur infrequently if the nursery is adequately drained. Poor internal drainage of soils can be improved by tiling. Very high soil temperatures may cause injury to the roots or the lower portion of the stem. Heat injury to the stem may result in "white spot," light-colored shrunken lesions entirely aboye ground. (Damping-off lesions are darker colored and usually extend up the stem from below the soil surface.) Heat injury is most common on dark soils. Damage may be reduced by irrigating during the hot part of the day until the seedlings become large enough to shade themselves.

Late spring and early fall frost and freeze damage may be controlled or reduced by mulch, or by using irrigation water, which is warmer than the air. Mulch protects fall sown seed from overwinter freeze damage, and in the spring the mulch helps retard germination until the danger of freezing temperature is past.

Nurserymen should guard against introducing harmful organisms such as nematodes, insects, and diseases into the nursery. Harmful organisms could be introduced by purchased seed, seedlings, or mulch, so screening methods, such as not accepting seedlings from nurseries with histories of diseases, should be set up and followed to ensure against introduction. Also diseased or infested stock should not be sent out for field planting.

Figure 41.—Northern white-cedar windbreaks at Indiana's Vallonia Nursery.

Mammals and Birds

Many nurseries require a fence to exclude domestic livestock, deer, or rabbits. If deer are a problem, the fence should be at least 10 feet tall. Rabbits usually can be excluded with a 6-foot fence with 1- to 2-inch mesh. If rabbits continue to be a problem after fencing, they can be trapped or shot (Stoeckeler and Jones 1957).

Pocket gophers sometimes are troublesome. They may be trapped or killed with poisoned bait. Registered, prepared baits are available. Several baiting stations should be placed in each burrow system (Stoeckeler and Jones 1957). Controls are most effective during the spring and fall when gophers are most active.

Moles, chipmunks, and squirrels pilfer seed. Hardware cloth screens afford some protection against these animals, although they often get past the barrier. Moles can be poisoned with treated peanuts placed in their burrows (Stoeckeler and Jones 1957). Or they can be trapped by placing choker or harpoon traps in active runways.

Mice can be a problem, too. They pilfer seed, girdle the seedling bark, or cut off small seedlings. Mice may be trapped with ordinary snap traps baited with apple, vegetable, or oatmeal and placed in runways or near entrantes of burrows. However, baiting with registered prepared baits on warm, olear, quiet fall days just before the ground freezes is probably the cheapest, most effective way to eliminate mire (Stoeckeler and Jones 1957) . The Bureau of Sport Fisheries and Wildlife (see list of offices below) can furnish up-to-date information or techniques and will provide bait at cost.

Seed-eating birds can be excluded by hardware cloth screens. Patrols are too expensive for many hardwoods because the seeds are sown in the fall and would require a 5 or 6 month patrol. Although there are some restrictions[6] on its use, anthraquinone, an effective bird repellent, is widely used for conifer seed, has been used on acorns in the South, and may be satisfactory for other hardwoods. Repellents are not effective for squirrels and other rodents, so if these animals are present, the hardware cloth is necessary until the predation period is past.

Advice on identification and control of mammals and birds may be obtained from :

State Conservation Departments

State Colleges or Universities, Wildlife Departments

U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife.

When contacting this agency, write to the State Supervisors for your arca at the appropriate address usted below.

Arkansas
329 Post Office Bldg., Little Rock 72201

Connecticut
Rm. 644, Federal Office Bldg., Hartford 06103

Georgia
c/o School of Agriculture, Univ. of Georgia, Athens 39601

[6] Some States have restrictions and prohibitions on the use of certain pesticides. So before using check with local, State and Federal authorities to determine if the pesticide is registered for the use intended.

Florida
P.O. Box 847, Gainesville 32601

Indiana
Illinois
Iowa
Missouri
Agricultural Administration Bldg., Lafayette, Indiana 47907

Louisiana
Rm. 271-3, Agricultural Center, LSU, Baton Rouge 70803

Maine
P.O. Box 800, Augusta 04330

Maryland
Patuxent Wildlife Research Center, Laurel 20810

Massachusetts
Rhode Island
451 Russell St., Hadley, Massachusetts 01035

Minnesota
Wisconsin
568 Federal Bldg., St. Paul, Minnesota 55101

Mississippi
Alabama Drawer F S (118 Biology Bldg.) , State College, Mississippi 39762

Nebraska
233 Federal Bldg. & Courthouse, Lincoln 68508

New Hampshire
Vermont
55 Pleasant St., Concord, New Hampshire 03301

New Jersey
Delaware
P.O. Box 1684, Trenton, New Jersey 06807

New York
P.O. Box 150, Albany 12201

North Carolina
South Carolina
P.O. Box 25878, Raleigh, North Carolina 27611

North Dakota
P.O. Box 1814, Bismarck 58501

Ohio
Michigan
321 Old Post Office Bldg., 3rd & State, Columbus, Ohio 43215

Oklahoma
2432 Federal Office Bldg., Oklahoma City 73102

Pennsylvania
West Virginia
111 Ferguson Bldg., Pennsylvania State Univ., University Park, Pennsylvania 16802

South Dakota
P.O. Box 250, Pierre 57501

Tennessee
Kentucky
Rm. 511, 1720 West End Ave., Nashville, Tennessee 37203
Texas
P.O. Box 9037, Guilbeau Station, San Antonio 78204
Virginia
108 Washington St., S.E., Blackburg 24060

Insects

Insects damage hardwood seedlings in various ways : leafeaters strip the foliage, aphids or scale insects drain leaves and stems of sap causing wilt or abnormal growth, and grubs damage the root system as do nematodes, which are round worrns rather than insects. Defoliators cause the most obvious damage but other insect groups are present also. Frequent observations are necessary to detect insect damage in early stages. Early detection and prompt control will keep losses to a minimum.

Some of the different kinds of insects found in a hardwood nursery are listed and briefly described below (Baker 1972).

Chemical use registration is changing rapidly. The pesticides shown for the control of specific pests were registered for the indicated use in May, 1974. However, before using any chemical the user must malee sure that the chemical compound, the use proposed, the formulation, and the method of application are registered. The user can determine registration by a study of the chemical label.

Ants

Ants may damage seedlings by injecting formic acid finto them, burying them, tending harmful aphids, cutting the leaves or cutting the seedling off. Commonly used, registered insecticides :[7] Dieldrin, Diazinon, Chrlordane, and Mirex.

Aphids

Aphids are tiny, 1/16 to 1/8 inch long, soft-bodied, fragile, awkward looking insects that feed on plant juices. They vary in color from green to shades of red, brown, or black. Aphids may attack the seedlings aboye or below ground but most frequently congregate on new growth or on the undersides of leaves. Aphids have an enormous reproductive capacity and most give birth to living young. Lady bug beetles, the larvae of lacebugs, and parasitic wasps are a few of many natural enemies. Commonly used, registered insecticides : Malathion, Diazinon, Mexacarbate, and Azinphosmethyl.

Bagworms

Bagworms attack foliage and spend their lives incide the characteristic bags. Usually they are not noticed until much damage has been done. Commonly used, registered insecticides : Carbaryl, Malathion, Trichlorfon. If not too numerous, the bagworms should be picked off.

Blister Beetles

Blister beetles are long, cylindrical, black, gray, or striped, long-legged insects that appear suddenly in great numbers and strip the foliage from some species. Commonly used, registered insecticide is Carbaryl; control is difficult,

Caterpillars

Caterpillars are the larvae of various moths and differ in size, shape, and color. Most are ravenous leaf feeders. Identification of the species is necessary prior to application of chemical control measures. Following are examples of caterpillars common in hardwood nurseries and suggested control measures : Eastern tent caterpillar—Methoxchlor, Carbaryl, Mexacarbate ; Forest tent caterpillar—Carbaryl, Trichlorfon, Mexacarbate ; Fall webworm-Diazinon.

Willow Leaf Beetles

The adults and larvae feed on the foliage and sometimos chew the tender bark at the tips of the twigs. The head and thorax of adults are black with marginal markings or the thorax may be dark yellow or red. Young larvae are black and change to a dirty yellow as they age. Commonly used, registered insecticides : Carbaryl, Chlordane.

Cutworms

Several species confine their feeding to tender roots or stems and foliage close to the ground surface. Cutworms in general are stout, hairless, and dull grayish or brownish in color. They normally conceal themselves during the day. Commonly used, registered insecticides :

[7] Read and follow label registrations for all pesticide usage.

Mexacarbate, Chlordane, Trichlorfon, Diazinon ; control measures include clean cultivation to keep the ground free of weeds.

Galls

Galls are abnormal plant growths caused by mite or insect attack. Presence of galls does not always justify chemical control and after galls are noticed sprays are ineifective because the insects are inside. When only a few galls are present, they should be pruned off and burned.

Grasshoppers

Grasshoppers are common insects that sometimes build up to destructive populations. Commonly used, registered insecticides are Malathion, Carbaryl, Diazinon.

Lacebugs

Lacebugs are small, dark, fíat insects about one-eighth of an inch long with transparent lacy wings. Both adults and *nymphs* feed on the underside of leaves. The upper surface of infested leaves usually changes color, becoming either whitish or brownish. The under surface of infested leaves becomes speckled with eggs, excrement, and cast skins of the developing nymphs. Insecticides should be directed against the underside of the leaves and applied twice, at 2-week intervals, as soon as the young hatch in the spring. Commonly used, registered insecticides : Malathion, Carbaryl, Lindane.

Leaf hoppers

Leafhoppers are small, wedge-shaped sucking insects that are usually yellow or greenish colored. A few kinds are striped. They feed on the underside of the foliage, causing the leaves to become brown and withered or curled. Eggs are often deposited in slits in leaves, stems, or twigs. Leafhoppers frequently inoculate the host with destructive viruses. Insecticides are most effective when leafhoppers are in the nymphal stage. Commonly used, registered insecticides Malathion, Carbaryl, Azinphos-methyl, Diazinon.

Leaf Miners

The larvae of leaf miners feed by tunneling between the upper and lower leaf surfaces. Leaf miner control depends upon applying insecticides at the right time. If the insecticide is not on the foliage before the adults lay their eggs, the larvae already inside may not be killed. Commonly used, registered insecticides : Birch leaf miner—Mexacarbate, Carbaryl ; Elm and locust leaf miner—Lindane.

Leaf Rollers and Leaf Tiers

Mature caterpillars are greenish-yellow and about three-fourths inch long and provide concealment for themselves while feeding by rolling or folding leaves or typing leaves together. Commonly used, registered insecticide Carbaryl.

Mites

The European red mite and the two-spotted spider mite, which is green or yellowish, cause damage by feeding on both leaf surfaces. Infested leaves become blanched or brown and have a tendency to curl. Some leaves may drop prematurely. Some insecticides, notably carbaryl, do not control mites. Commonly used, registered insecticides : Kelthane, Mexacarbate, Dursban.

Nematodes

Nematodes, although they are microscopic eelworms and not insects, are included here for convenience. Nematodes are present in most soils. When populations reach high levels, serious damage to the seedlings may result. Symptoms of nematode damage are stunting, foliage discoloration, and susceptibility to wilt during period of moisture stress. Infestation appears in spots and causes uneven growth in the seedbeds. In many cases root rot fungí are associated with nematode infestations. Root knot nematodes produce a beaded effect on the roots of infested stock and may cause a decrease in the number of lateral roots. Infested seedlings should be destroyed and not distributed for field planting. *Control:* Fumigation is a common and effective control for nematodes. Some registered fumigants for nematode control are listed in table 8.

Nut Weevils

Larvae of certain snout beetles often eat the contents of acorns and destroy their viability. Eggs are laid from the time the meat in the acorn begins to form until it is full grown. The eggs hatch in 1 to 2 weeks. The full grown larvae cut a circular emergence hole in the shell and enter the earth to hibernate. *Control:* Collect seed as soon as possible after drop so that weevils can be killed with Serafume as described in footnote to table 4.

Scale Insects

Scale insects are small, flat, oval-shaped sucking insects that usually range from $^1/_{16}$ to $^3/_{16}$ of an inch in length. They fasten themselves to the undersides of leaves or to small stems and are noticed as small, white or gray, woolly dots, or as shiny, smooth, half-shell shapes covered with a waxy coating. Commonly used, registered insecticides: Malathion, Azinphosmethyl, Carbaryl, Diazinon.

White Grubs

White grubs are the larvae of June beetles and often requise more than 1 year to mature. Grubs may range in size from $^1/4$ inch for the young ones to 1 inch for the oldest. Damage is caused by the grubs feeding on the roots of seedlings. Commonly used, registered insecticide: Chlordane.

Wireworms

Wireworms are long, brown, so-called hand shelled worms, usually having well-developed legs. They feed in the soil on small roots and other plant material (Stoeckeler and Jones 1957) . *Control:* Keep land free of weeds. Commonly used, registered pesticide: Chlordane.

Sources of additional information

Careful evaluation of insect problems will yield majos benefits in making sound pesticide use decisions. So, if in doubt, concerning the identification, prevention or evaluation of an insect; or if not sure which chemicals, formulations, yates or methods of application are registered for control, an expert should be consultad. Help may be obtained from:

State Colleges and Universities, Entomology Department
State Agricultural Experiment Stations
State Departments of Agriculture, Division of Plant Industry
Cooperative Extension Service

USDA Forest Service
State and Private Forestry:
Northeastern. Area
6816 Market St.
Upper Darby, Pennsylvania 19082

Southeastern Area
1720 Peachtree Road, NW
Atlanta, Georgia 30309

Diseases

Disease control is usually a matter of prevention rather than cure. The infection of the nursery by pathogens is often a result of exhausted soif fertility, unskilled fertilization, use of pathogen-inviting green manure croes, excessive watering, or the building up of large populations of introduced pathogenic organisms (Wilde 1958) . Careful management of the nursery soil is one of the first requirements for protecting the stock from disease. However, diseases can be introduced by transplanting diseased stock finto a disease-free nursery.

Some sprays and dusts prevent infection but are not an antidote to established disease conditions. So sprays, dusts, and fumigants must be applied before a disease becomes established. Repeated spraying may be necessary to protect expanding new growth of seedlings and to renew protection on older growth after irrigation or age has decreased the protective qualities of previous sprays.

Damping-off

Damping-off is a general term applied to the killing of newly germinated seedlings by fungi (Davis *et al.* 1942) . With some exceptions, notably osage-orange and elm, damping-off is less serious in hardwoods than in conifers. Although damping-off is caused by fungi of several genera, *Rhizoctonia, Pythium,* and *Fusarium* are the most common. When the seed becomes infected and the seedling dies before emerging from the soil, the disease is called pre-emergence damping-off. When losses occur after seedling emergence, the disease is called post-emergence damping-off.

Post-emergence damping-off of hardwoods usually differs from that of conifers. Some infected hardwood seedlings do not become flaccid and topple over but remain upright, gradually wilt, and break off (Toole 1964)

Damping-off is favored by materials that decrease acidity, the use of poorly rotted manures, and materials that mercase the carbon-nitrogen ratio.

Control: Fumigation with chemicals listed in table 8 has ~ved effective but must be done in the registered way and according to the man u-facturer's product label. Also, the pelleting of seed with the fungicides thiram or captan, helps control damping-off.

Anthracnose

Anthracnose is common in sycamore, oak, maple, elm, and walnut. One symptom is the formation of brown dead areas along and between the leaf veins. Anthracnose of sycamore usually occurs in the spring at, or before full leaf. In black walnut it appears in late summer. Anthracnose may cause premature leaf fall and reduced growth. Reduction in growth may be offset by fertilization (Porten *et al.* 1959) .

Control: Seedlings should be sprayed to protect new tissue as it forms. Four sprays may be required ; one before bud swell, one during bud expansion, one as leaves unfold, and one at full leaf. Lime sulfur is registered for use on all hardwood species. In addition, dodine (Cyprex) is registered for use on black walnut and sycamore. And zineb is registered for use on oak and sycamore.

Leaf Spot

Leaf spot or "shot-hole" is caused by *Coccomyces* and *Phyllosicta,* and occurs on black cherry, catalpa, and to a lesser extent other species. The first symptoms are yellow to light brown, circular, *necrotic,* leaf spots which may fall out giving a shot-hole effect.

Control: Zineb is registered for the control of leaf spot on most hardwood species. Lime sulfur is registered for control of leaf blotch on all hardwood species.

Marssonina

Marssonina spp., is a leaf disease of *Populus* spp., and *Fraxinus* spp., that first appears on the upper leaf surface as small gray dots which gradually enlarge. On the lower leaf surface round pustules appear and develop into light gray masses of spores. The disease causes premature defoliation and retards growth.

Control: Marssonina may be controlled with repeated sprays containing lime sulfur.

Powdery Mildew

Powdery mildew is caused by a fungus that appears on the leaves as a whitish powder. Spread is rapid during period of hot dry weather (Garmon *et al.* 1956) . Damage is not usually severe but may sometimes warrant control measures.

Control: Lime sulfur is registered for control of powdery mildew on all hardwoods and zineb and benomyl are registered for use on some. Repeated spraying may be necessary for continued protection.

Root Rots

Among the several fungi causing root rots are *Phytophthora, Fusarium, Cylindrocladium,* and *Armillaria.* The most severe losses usually occur on heavy, poorly aerated soils. Sym ptoms are reduced growth, poor color, chlorosis, and in severe infections, death of the seedlings. Diagnosis based on symptoms is difficult because symptoms may resemble nutrient deficiencies, water imbalances, or insect attack.

Control: Crop rotation programs in the nursery are an aid in the control of root rot. Continuous production of one species in the same seedbeds without a green manure crop invites root rot as well as other nursery problems. Fumigants control most root rot organisms (table 8) . Also, captan is registered for the control of root rot.

Blackstem of Cottonwood

This disease is an infectious bark *necrosis* caused primarily by *Cytospora chrysosperma* (Gray *et al.* 1965) .

Control: High vigor seems important in creating resistance to the disease so fertilization and adequate water should be helpful. Diseased seedlings should be pulled and burned to avoid contamination. Care should be taken to avoid injury to other seedlings because infection enters through wounds.

Sources of additional information

Careful evaluation of pathological problems should be made before fungicides are used. If in doubt concerning identification, evaluation, or control of a disease, an expert should be consulted. Expert help is available from:

State Colleges and Universities, Pathology Departments
State Agricultura]. Experiment Stations
State Departments of Agriculture, Division of Plant Industry
Cooperative Extension Service

USDA Forest Service
State and Private Forestry:
Northeastern Area
6816 Market St.
Upper Darby, Pennsylvania 19082

Southeastern Area
1720 Peachtree Road, NW
Atlanta, Georgia 30309

Nurserymen must know with some degree of accuracy how many trees of each species they will have available for shipment. An error of 10 percent on only 500,000 seedlings could mean a surplus or shortage of 50,000 seedlings. A surplus of seedlings is wasteful and a shortage could embarrase the nurseryman and disappoint his customers. If accurate inventory information is available, the nurseryman can arrange to sell or trade surplus seedlings, or if he has advance information that he has a shortage of some species, he may be able to buy the species needed or trade for them.

A complete count of all seedlings in the nursery would be extremely expensive, if not impossible, so the number of seedlings is estimated by sampling. Preliminary estimates, based on only a few samples, may be made in late June or early July. Early inventories are useful for checking seed germination and for early planning for stock availability and distribution. A more intensiva sample is taken in late summer or fall to determine within 5 percent the number of plantable seedlings that will be available for shipment. Some hardwoods grow until late fall. For these species, the inventory samplings should be delayed until mid-September or later. Both total number and plantable seedlings should be determined. The percent cull will furnish a better evaluation of seed source and cultural practices.

Some seedlings will be lost during lifting due to mechanical damage, being buried, or having their tops broken off. Lifting losses may be estimated from experience if accurate inventory and shipping records have been maintained. Overwinter losses, either in the seedbed or in storage, should also be considered when the estimates of shippable seedlings are made.

Stratified Random Sampling

Stratified random sampling is considered the best for nursery inventories (Mullin 1964, Mullin *et al.* 1955, Ware *et al.* 1967). To use this method the nurseryman or a competent assistant should first prepare a detailed map showing species, seed sources, when the seed was sown (fall or spring) and approximate seedling density in the beds. These different criteria define the strata to be used in planning the inventory.

If seedbeds within each *stratum* are equal in size and density, an equal number of samples should be taken in each. Tables are available showing the number of plots needed in uniform and nonuniform beds (Stoeckeler and Jones 1957). Others are available for computing numbers of sample plots needed for certain accuracy (Mullin *et al.* 1955, Wakely 1954, Barton and Clements 1961).

If you are just getting started in the nursery business and need guidance in sampling and other inventory procedures, or if estimates from your present inventory techniques are not satisfactory, help is available from your State colleges or universities or through the State and Private Forestry branch of the USDA Forest Service. Sampling techniques and the computer program for an Iowa nursery viere developed by an undergraduate forestry student at Iowa State University (Ware *et al.* 1967).

Sampling Crew

Sampling is tedious, exacting work so the most skillful workers should be assigned to the inventory crew. Organization may vary, but a crew of five is convenient for systematic sampling. One nursery with a five-woman crew uses one woman to tally and locate sample plots for two, two-wornen counting teams. A team has a *counter* for each side of the bed.

Counting and recording numbers of seedlings in each sample must be exact so a *counting frame* is used to designate the sampling area. Hardwood seedbeds usually should be sampled with a 1- by 4-foot counting frame. They should be constructed with precise inside measurements and should be adequately braced to retain their exact shape. Anchoring pins should be used to prevent the frame from slipping after it is put in place.

The crew leader should be furnished written instructions telling whether border trees should be included _ or excluded and how to sekct sample trees to determine the proportion of plantable seedlings.

To reduce bias in the selection of sample trees for estimating the percent of plantable seedlings, the sides of the counting frame should be marked to show 10 sampling points. The seedling nearest each point is examined to determine caliper, height, vigor, and if it is plantable. Only the number plantable out of 10 is recorded. If root rot or other root damage is suspected, some sample trees should be dug to determine the percent damaged.

Tally sheets should provide adequate space to identify the nursery, block, section, unit, and bed. Also, there should be a space for date, species, minimum size seedling considered plantable, size of counting frame, names or initials of inventory crew, total number, and number of plantable seedlings. Special forms for recording this data for computer summarization were developed by Frederick.[8] and by Ware *et al.* (1967).

Field tally sheets should be checked by the nurseryman for unusual counts that would indicate an error. Also, he should check to make sure all seedbeds were included in the inventory and that each species, seed source, and stratum was sampled according to his written instructions. After the tally sheets are checked for errors and compliance with instructions, the data are ready for summary and analysis.

Inventory Data Summary and Analysis

Most inventory summaries and analyses are computed by the nurseryman or by someone on the nursery staff. However some nurseries, including State nurseries in Iowa and Indiana, have turned to automatic data processing (ADP) for fast, complete, and accurate inventory summaries. Automatic data processing relieves the nursery of laborious arithmetic calculations, is cheaper, and eliminates arithmetic errors. It also permits greater flexibility in statistical design of the inventory (Ware *et al.* 1967) . However, data for ADP must be accurately entered on tally sheets and be properly identified for use.

[8] David M. Frederick. 1969. A computerized inventory for Indiana's forest tree nurseries. (Unpublished master's thesis on file at Purdue Univ., Lafayette, Ind.)

Automatic data processing is available at most State universities where programmers are available to help develop a computer program for a particular nursery.

Inventory data can usually be mailed, processed, and returned within a week. It is often practical, if not necessary, to hire a consultant at the computer center to get the data processed more rapidly.

Information that can be made available on ADP printouts include :

1. Nursery, and nursery subdivisions to identify seedbeds.
2. Species
3. Age class
4. Seed source (State, county, elevation, etc.)
5. Seed collection crew
6. Year seed was collected
7. When seed was sown (year, and spring or fall)
8. Total square footage sown
9. Total number of trees
10. Total number of trees per square foot
11. Plantable diameter *(caliper)*
12. Total number of plantable (shippable) trees
13. Number of plantable trees per square foot
14. Percent recovery

There is hardly any limit to the information that can be furnished by automatic data processing from inventory data. If enough satisfactory data is furnished, the computer programmer can summarize it to provide any information the nurseryman may deside.

SEEDLING HANDLING

Lifting

Time of Year

Seedlings may be lifted either in the fall as soon as they are safely *hardened off,* or in the spring. Hardwoods are usually hardened off after the first few frosts, the occurrence of low temperatures, or after the seedlings lose their leaves. Some species are ready to be lifted earlier than others. Although time of leaf fall will be affected by fertility levels and moisture or irrigation schedules in the nursery, most genera can be safely grouped finto early, intermediate, and late leaf fall categories.

Time of leaf fall

Early	Intermediate	Late
Carya	*Acer*	*Alnus*
Catalpa	*Betula*	*Castanea*
Cercis	*Celtis*	*Elaeagnus*
Diospyros	*Cornus*	*Quercus*
Fraxinus	*Liquidambar*	
Juglans	*Liriodendron*	
Morus	*Maclura*	
Nyssa	*Platanus*	
Populus	*Prunus*	
Robinia	*Tilia*	
	Ulmus	

Some chemical defoliante are available but chemical defoliation is in the experimental stage. These chemicals cause leaf abscission without causing seedling damage. A 5,000 p/m concentration of Ethrel caused complete defoliation of "Cleveland" sycamore maple in 5 days (Kozel 1969).

Defoliation trials are being extended to European alder and other species that lose their leaves late. So far alder has been defoliated within 4 days after treatment.

Deciduous seedlings do not remain dormant very long in the spring after the weather becomes warm, so it is usually advisable to dig them in the fall. When lifting is delayed until spring, seedbeds often remain wet or frozen and cannot be worked to supply trees when they are needed. Fall lifted seedlings are readily available any time the planter requests them.

Seedlings should neither be lifted when the soil is frozen nor when their roots would be exposed to freezing temperatures. Frozen soil clings to the roots, and strips the secondary roots from the seedlings when dislodged. On cold mornings lifting should be postponed until later in the day when air temperatures warm to at least 33° F.

Soil moisture affects seedling lifting, too. Ideally the soil should be slightly dryer than what is considered best for plowing. The soil should crumble when rolled between the fingers. Lifting when the soil is too dry or too wet is detrimental to soil structure.

Ideally the lifter should not be run under the beds more than 2 hours bef ore the seedlings are to be pulled. Seedling roots may dry out in aerated beds, or the soil may settle, causing loss of fibrous roots through breakage at pulling time. The lifter blade should be run at a depth of 10 inches to preserve as much of the root system as practica'. Some nurserymen run the lifter under seedling roots at sufficient depth to avoid severing the taproot even though running the lifter at this depth requises the drawing power of two tractors. To avoid damage to seedling roots at the ends of seedbeds, it may be necessary to "dig-in" and "dig-out" the lifter blade.

Equipment

Seedlings may be lifted by hand in small nurseries or for small orders. But normal practice in large nurseries is to lift seedlings with a mechanical lifter (fig. 42) . A mechanical lifter should be equipped with a heavy, hard, sharp, metal blade with agitating tines attached at the rear of the blade to crumble and loosen the soil from the seedlings. There should be enough space between the blade and frame of the lifter so that neither the stems nor buds of the seedlings are damaged during the lifting operation. The rear of the blade should be raised slightly to cause a lifting action.

F-521326

Figure 42.—Seedling lifter with mechanically agitated tines to loosen soil around roots.

A seedling harvester with the capacity to harvest one million trees per day has been developed in Saskatchewan (fig. 43). It is a two-row harvester that uses a hydraulically adjusted U-blade to undercut each row. The stems of the undercut seedlings are grasped and lifted by rubber belts, which release them at the rear of the machine. As they are released, the seedlings strike a bar that flips them so they fall unto a conveyor with their tops pointing to the rear. The conveyor carries the seedlings to the side of the machine where they are dropped into a large bin. An essential part of the mechanized operation is a bin carrier that transporta 14 seedling-carrying bias to and from the harvester (fig. 44). The bin carrier is a modified truck chassis with the controls moved in frontof the motor so that the operator's visibility is unimp, ired. Five men are required for the efficient operation of the two machines; three men on the harvester, one man to operate the bin carrier, and one man to place the bias accurately so the harvester can pick them up while in motion.

Figure 43.—Seedling harvester harvesting American elm. (Photo courtesy Tree Nursery, Prairie Farm Rehabilitation Administration, Canadian Department of Regional Economic Expansion.)

Figure 44.—The Saskatchewan bin carrier which is required to take full advantage of the seedling harvester. (Photo courtesy Tree Nursery, Prairie Farm Rehabilitation Administration, Canada Department of Regional Economic Expansion.)

Three other seedling harvesters have been designed recently. A fully mechanized harvester has been developed at the Missoula Equipment Development and Testing Center and was tested in 1969. The Ontario Department of Lands and Forests has modified a two-row, low-level potato digger by adding speed control to the apron and incorporating two conveyors to further move the seedlings from the rear of the potato digger to a platform for boxing (Hergert 1968) . The North Carolina Forest Service has also developed a mechanical harvester much like the Ontario machine, except they have incorporated one wide conveyor to move seedlings from the rear of the potato digger. Plans are available from Southeastern Area State and Private Forestry for harvesters developed in Florida and Virginia. Although these three machines were designed for lifting conifer seedlings, it seems likely that they could be readily adapted to lift hardwoods.

Pulling

Spread out the crees pulling seedlings to avoid accidenta, especially eye injuries from flying soil. Start pulling at the outside of the undercut bed and work toward the center to avoid compacting the soil around the seedlings. Do not bend or twist seedling stems but pull straight and in bunches, rather than singly, to avoid damage and loss of fibrous roots. Shake seedlings to dislodge soil attached to the roots but do not slap seedlings together nor beat them against the ground. Rough treatment barks and damages the seedlings, and causes loss of the fibrous roots.

Provide each member with a container for the seedlings he pulls. To avoid seedling drying, talle the filled containers to the packing house as quickly as possible. If the pulled seedlings are to remain in the containers as long as 1 hour before going to the packing shed, protect the roots with wet burlap, or similar material. On dry, windy, or sunny days leas exposure may be permitted. A small tractor-drawn trailer constructed to straddle the beds is very handy for picking up the containers full of seedlings (fig. 45).

Grading and Counting

Grading should start in the seedbed as the seedlings are pulled. Seedlings that are obviously small, diseased, or damaged should be

F-521327

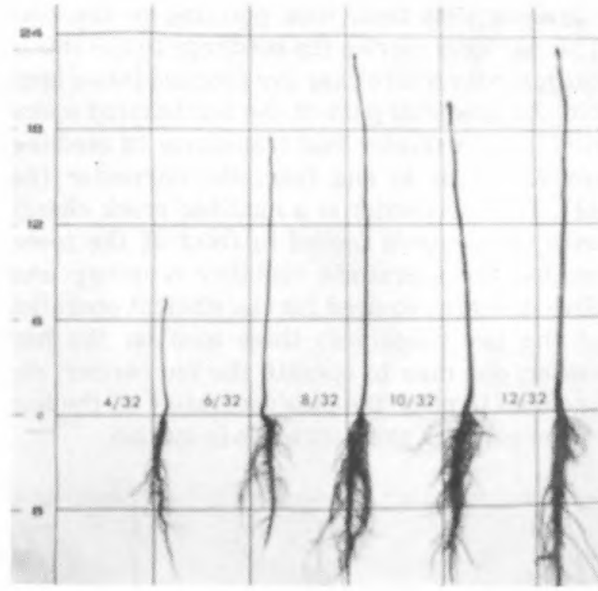
Figure 45.—A two-wheeled trailer built to straddle the seedbed being used to transport seedlings to the packing house.

discarded. But no further sorting should be made in the seedbed if the seedlings are to be graded, counted, and bunched in the packing shed.

The type of grading may vary by individual customer. A buyer who requires several thousand seedlings of one species may huy all seedlings in one or more beds. For him, the number and grade of the seedlings could be determined by inventory-type sampling. If 90 percent or more of the seedlings, or some other agreed opon percentage, meet acceptable standards, the seedlings could be sold bed run on the basis of the inventory. The buyer would grade to his specifications.

The value of planting high-quality seedlings has been demonstrated. Seedling grades have not been established for all hardwood species but for most species seedling diameter, measured 1 inch above the root collar, is a good estimator of seedling quality (fig. 46).

Minimum, preferred, and maximum seedling sizes of several hardwood species have been published (Limstrom 1963). However, more recent information for some species indicates that larger seedlings are more desirable. Although survival of small planting stock is often satisfactory, growth of large stock is far superior to small seedlings. Nugent (1971) recommended 3/8-inch be the minimum acceptable diameter of hardwood seedlings planted in the South. The trend is toward bigger seedlings, so the nurseryman's goal should be to produce the high-quality seedlings preferred by the planters.



F-521328

Figure 46.—Typical black walnut seedlings by stem diameter. Seedlings which have a stem caliper of less than 7/32-inch should be discarded. (Background grid is in 6-inch squares.)

Some planters realize the value of planting high-quality seedlings and would prefer to buy premium grade stock, even at a higher price. Others would be satisfied with smaller seedlings ata reduced price. Normal grading procedure is to furnish bed run seedlings after dead, damaged, diseased, and undersized seedlings have been discarded. It is necessary to handle every seedling anyway, so grading seedlings into size classes, such as large, medium, and small, would not add greatly to the job. For most species two size classes would be sufficient: large and small, or premium and plantable.

Grading and Counting Methods

Each nurseryman has his own method for grading, counting, and tying seedlings, though most are somewhat similar. Most nurserymen count and grade their seedlings in a packaging building where seedlings are protected from the sun and wind. Most use a conveyor belt to carry the seedlings from the grading tables to the packers. The placement of the graders along the conveyor and their specific duties varies among nurseries.

Indiana nurserymen place movable tables alongside the conveyor belt and graders are stationed on each side of the table (fig. 47). Ungraded seedlings are placed on the table and the two workers grade, count, and tie plantable seedlings finto bunches of 25 before they are placed on the conveyor belt. The length of the conveyor belt determines the number of graders that can be used.

In an Illinois nursery, a fast, simple method is used to grade and count trees. Each worker lays graded seedlings on the conveyor belt in bunches of five. A man stationed at the end of the belt groups five bunches of five and ties the 25 seedlings at an automatic tying machine.

Tennessee Valley Authority nurseries graded and counted onto diagrammed conveyor belts (Grieve and Barton 1960). Blocks containing 10 numbered spaces were painted onto the belt. Each of 10 workers was assigned one of the numbered spaces and had the responsibility of placing five graded seedlings on his number. Fifty seedlings were counted onto each block. Culis were dropped to the floor. When stock was uniform, only five graders were used and each grader placed 10 seedlings on his number instead of five.

Some nurseries count seedlings by weight (Eliason 1962). Uniformity of nursery stock is important in such a counting system. The Georgia Forestry Commission chips conifers by weighted count but culis undersized seedlings from the seedbeds during the fall prior to shipping season. Glose density control and intensive cultural practices can reduce culi percentage to a level which makes weighed counting an advantageous alternative to normal counting methods.

Seedling Quality

A nurseryman should know the characteristics of high-quality seedlings. Then he should learn to produce high-quality seedlings of each species in his nursery. History plots and rather

F-521329

Figure 47—Grading and counting seedlings at Indiana's Yallonia Nursery. Graders work on each side of tables and place graded, counted seedlings on a conveyor belt that carnes them to the packers.

detailed records may be necessary to find out what seedbeds, methods , and practices produce high-quality seedlings of each species. Some of the factors that influence seedling quality are:

1. Seed source and seed size.
2. Soil management, including soil organic matter, fertility, pH, and soil moisture.
3. Seedbed density.
4. Length of growing season. Fall sown seed usually germinates sooner than spring sown seed. If 1-0 seedlings are too small, the seedlings may be held and shipped as 2-0 seedlings.
5. Pruning : top or root pruning, or both.
6. Seedbed care, especially weed control.

Storage

Hardwood seedlings can be stored safely for long or short periods. It is imperativa, however, that seedlings be hardened off before they are lifted for storage.

Season of storage varies between the North and South, but the reasons for seedling storage are about the same in both localities :

1. Stored seedlings are available any time the planter requests them. In the North planters south of the nursery often require seedlings before the nursery soil thaws.
2. Seedling storage pumas spreading the workload to keep "key men" busy.
3. If seedbed space is needed, especially in the north, beds lifted in the fall may be utilized.

Seedlings should be planted before bud-break. In the South, seedlings are usually stored only a short period, from late fall until they are planted in early winter. In the North, seedlings are- planted in the spring, so seedlings lifted in the fall are held overwinter and those lifted in the spring are held only a short time.

Fall-lifted trees may be held overwinter in heeling-in beds or in cold storage. Usually hardwoods are held overwinter in heeling-in beds. Williams (1963) found that fall-lifted hardwoods, heeled-in overwinter, survived and greca as well as spring-lifted seedlings.

Heeling-in

It is important that the seedlings be heeled-in correctly. The recommended procedure follows :

L Lift the trees after they are hardened-off.

2. Cull out and discard all diseased and damaged seedlings.
3. Use only sandy soil in the heeling-in yard, even if sand must be hauled in. Clods that cause air pockets are not as apt to form in sandy soil as in heavier soils.
4. Dig the trench for the seedlings deep enough. The root collar should be buried about 1 inch without bending the roots. Trenches may be dug with laying-off plows (fig. 48). Heavy duty garden tractors are adequate.
5. Place seedlings in the trench. Small-stemmed seedlings may be heeled-in in bunches of 25, but large seedlings should be heeled-in loose. Air spaces around the roots must be filled with soil or the roots will dry out. Bunches of large seedlings would create large air pockets on the inside that would be very difficult to eliminate.
6. Cover seedling roots with soil as seedlings are placed in the trench.
7. Dig next trench far enough away that roots of heeled-in seedlings are not exposed but do not make rows so far apart that space is wasted.
8. Drench the seedlings after several rows have been heeled-in to wash soil around the roots to fill all air pockets.
9. If disease has been a problem in the heeling-in bed, the seedlings should be dipped in a registered fungicide solution or drenched with a registered fungicide solution after the seedlings are heeled-in.
10. The heeled-in seedlings in northern nurseries should be mulched with 2 or more inches of sawdust or some other mulching material to prevent alternate freezing and thawing. Soil under the mulch is protected from deep frost so seedlings from a mulched heeling-in bed are available anytime. Mulches also help maintain uniform soil moisture.
11. Lath houses built over the heeling-in yard provide shade and some protection from the elements. Although not essential, lath houses are useful and may be more beneficial for some species than for others.
12. Species identification by untrained workmen can be simplified by using labels or color coding the stock in the heelin-in bed with spray paint. Caution : some paints are phytotoxic.

Cold Storage

Because heeled-in seedlings may break dormancy during prolonged warm periods **in** spring, cold storage in refrigerated rooms is preferred to heeling in. The temperature should be kept at 33 to 38° F. In many States there is

F-521331

Figure 48.—The heeling-in trench can be laid off and the seedling roots covered with a walking plow.

a limited period of time between the time seedlings are hardened off in the fall and freeze-up. Many nurserymen take advantage of their cold storage facility by filling it with field lifted nursery stock before freeze-up. When it becomes impossible to continue lifting, or the planned lifting is accomplished, stock is then graded and tied in bundles for storage. Until tests on this practice are completed, seedlings should not be packed but stored loose during overnight cold storage.

Short-term Storage

Seedlings may be in transit or storage several days. To ensure that the seedlings arrive as fresh as possible, those packed for shipping should be placed in cold storage if they are to remain at the nursery longer than 24 hours. If refrigerated cold storage is not available, suitable short-term cold storage can be provided in the spring in central and northern States by drawing cold, outside air finto a basement or partially insulated building with fans. Fans could be rigged for operation by thermostats.

Packing

Packaging seedlings is a critical part of the nurseryman's responsibility.

Producing high-quality seedlings is of no value if they do not reach the planting site in good condition. Trees should be packaged to maintain the roots in moist condition and to prevent damage from repeated handling. Packaging materials should retain moisture and insulate the seedlings from the outside environment.

Freshly dug stock should be transported as soon as possible from the field to a packing building. If prompt processing is anticipated, the stock may be stored for short periods in the parking building where it is protected from wind and sun. But if packaging is to be delayed longer than 24 hours, the stock should be held in cold storage where temperature and moisture conditions are controlled.

Generally, seedlings are packaged in either the Forest Service Olsen bale or a jellyroll bale, but other methods such as the vencer mat bale (fig. 49), the polyethylene lined graft paper bag (fig. 50), and the lined cardboard box are finding favor in some nurseries. The kraft bag is really the only new type of bundle. Seedlings, along with a minimum amount of moisture retaining medium, are totally enclosed in a moisture proof bag. The top of the bag is either sewed or stapled shut.

Large seedlings are bundled with all tops in orle direction (fig. 51). The roots are packed with a moisture holding medium, wrapped, and tied. Usually asphalt impregnated paper, polyethylene or waterproof burlap paper is used.

The greatest change in packaging during the past 10 years has been in the choice of moisture retaining medium. The scarcity and high price of spaghnum moss, along with the hazard of *Sporotrichosis,* a fungus infection that is usually limited to the skin of the hands and arms, has caused a decline in the use of moss (D'Alessio 1963). Excelsior, cotton waste, kaolin clay, paper pulp, and absorbent paper are being used as the moisture retaining medium in Cree packaging. Only kaolin clay is a departure from previously used materials.

The finely ground clay is mixed with water into a cream consistency slurry and the seedling roots are dipped to coat all roots with clay. Following a brief draining period the seedlings are either bundled in an Olsen-type bale or jellyroll, or they are placed in poly-lined paper bags. In the Olsen or jellyroll bundle, an absorbent paper inner liner is used inside the burIap or waterproof paper wrapper. Mechanization of the slurry mixing, seedling dipping, draining and packaging process has been achieved to some degree (Brenneman 1965) .

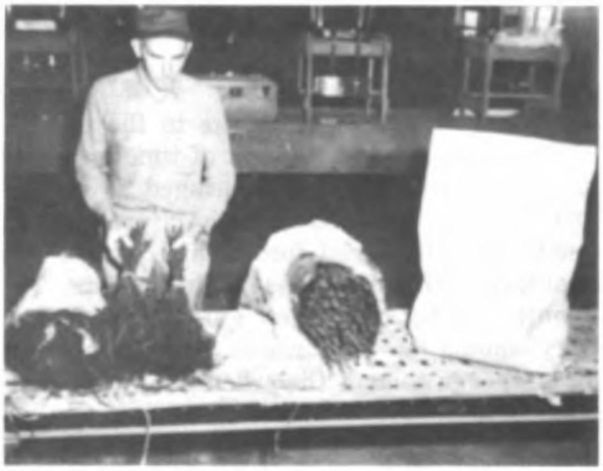
Numerous variations on baling frames have been developed for packaging seedlings (Bigelow 1963, Slayton 1969). Basically, these variations are designed to facilitate particular operations or use of new materials such as strapping steel, wire, or plastic. The pneumatic strapping devices and twine tiers do an outstanding job of automated tying (Gehron 1969).

The Forest Service Olsen bale (fig. 52) is formed in a baler as follows:

1. Insert tie wires or strapping.

F-521332, 521336

Figure 49.—Baling European alder seedlings at the Illinois Mason State Nursery: A, Belt-type baler operated by electric hoist: B, forming a veneer-mat bale.



F–519682

Figure 50.—Black walnut seedlings being packed in a polyethylene lined kraft bag.

F–521339

Figure 51.—Black walnut seedlings packed and tagged for shipment.

2. Place two 1- by 2- by 24-inch boards on the vires.
3. Line baling box with burlap, asphalt impregnated paper, burlene, or other suitable covering.
4. Spread a suitable moisture holding medium on bottom of box.
5. Place a layer of seedlings on the moist moss with all roots to the center and half the tops at either end.
6. Alternate layers of moss and seedlings, topping off the open bundle with moss. Add moss to sides of open bundle if needed.
7. Bring the two ends of the burlap together and wrap both around a third 1- by 2- by 24-inch board.
8. Turn the board to roll up and tighten the burlap. When the proper tension is reached, tie the wires with the Girard wire-typing machine.

F–521338

Figure 52.—Packing trees in the Forest Service Olsen baler.

The jellyroll bundle (figs. 53 and 54) is formed on a packing table as follows :

1. Spread the outer cover of burlap, burlene, or heavy 90-pound weight reinforced asphalt impregnated paper on a 4- by 6-foot table. Line, if needed, with 30-pound Kraft inner liner.
2. Spread a 2- to 3-inch layer of moisture-holding material over the center 18 inches of the length of burlap.
3. Place seedling roots on the moss and all the tops at one end.
4. Spread another layer of moist moss over the seedling roots.
5. Moisten with sprinkler if needed.
6. Roll firmly, pull bottom edge of burlap over roots, finish rolling, and tie with light rope, tying machine, or a steel strapping machine.

Finished bundles should be labeled to show species, seed source and grade, if applicable.

F-521334

Figure 53.—Placing moisture-holding material on seedlings to make jellyroll pack.

F-521335

Figure 54.—Rolling jellyroll seedling pack.

Shipping

Seedlings should be in transit as short a time as possible. While in transit, seedlings are subject to molding and drying. The mode of transportation will be governed, to some extent, by the number of trees in an order. Large orders are normally picked up at the nursery by truck while smaller orders are shipped by common carrier. Some of the shipping methods used are truck, paree] post, express, and United Paree' Service.

To ensure getting seedlings to the planting cite with a minimum amount of time in transita, the plantes should be encouraged to pick up his trees at the nursery. This is practical for public and industrial forests and for contract planters with large consolidated orders. Tree planters living only a few miles from the nursery should be encouraged to pick up their orders, even though the orders might be small.

Some nurserymen, by pre-arranged scheduling, deliver all seedling orders in a county to the county agricultural agent, the district forester, or other forestry work center, which is normally located at the county seat. For example, the George O. White State Tree Nursery first prepares a schedule of deliveries, starting in the southern counties and moving to the more northern counties, until all counties of the State are covered. Before seedlings are delivered to a county, post cards are mailed to each tree buyer in the county informing him of the delivery date and place of delivery. This method places some responsibility on the buyer. He must pick up his trees from the county agent or other pre-arranged delivery point within a day of two after they are delivered or they will dry out.

United Parcel Service is a new and reliable method of tree delivery. Seedlings shipped within a state will be delivered within 24 hours, if the buyer is at home. This stipulation may necessitate a post card to inform buyers of delivery date. Several State nurseries now use United Parcel Service to ship small orders.

Indiana nurserymen caution tree buyers to give clear delivery instructions because United Parcel Service cannot deliver to post office box numbers.

Parcel post and express round out the different modes of seedling transport. Seedlings shipped by either method could be stored in a warehouse a considerable period of time while the shipment is awaiting pickup or is delivered by the agency.

The nurseryman must work with the mearas of transportation available to get seedlings to the planting site in good physiological condition. To avoid warehouse storage, seedlings should not be assigned to a common carrier on Friday or any day preceding a holiday.

Nurserymen making interstate shipments of plants should be familiar with Federal and State regulations that apply. The necessary information can be secured from :

Plant Quarantine Branch
Regulatory Program Section,
Animal and Plant Health Inspection Service,
U.S. Department of Agriculture,
Washington, D.C. 20250

or the Department of Agriculture of your State.

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APPENDIX

Seed Dealers

The names and addresses of dealers selling seed are compiled by the Forest Service periodically, and can be obtained from the USDA Forest Service, Washington, D.C. The current list was published in 1972. Seed should be purchased on the basis of germinability and vigor as established by a seed testing laboratory. For example, if the price of black locust seed was quoted as $10 per pound and only 75 percent of the seed germinated and produced normal seedlings, the seed dealer would be paid $7.50 per pound for his seed. For more information concerning the collection, extraction, germination, storage, and sowing of seed, nurserymen should contact :

State Agricultural Experiment Stations
State Seed Testing Laboratorios
Eastern Tree Seed Laboratory
P.O. Box 819, Macon, Georgia 31202
USDA Forest Service
(See listing of Forest Experiment Stations and State and Private Forestry Offices on last page under Soil Management)

Cleaning Sprayers

Sprayers that are used to spray insecticides, fungicides, and herbicides must be cleaned thoroughly when changing pesticides, especially when the change is from a herbicide to an insecticide or fungicide. Just as some herbicides are more toxic than others, some are more difficult to remove from sprayers than others. Some herbicides cannot be removed satisfactorily.

Certain hormone-type herbicides can be cleaned out fairly well with special treatment. Fill the tank nearly full with clean, preferably hot water, then add the cleansers as given below. Run the pump to thoroughly agitate the cleaning solution, then circulate the solution throughout the entire sprayer. Shut off and allow solution to stand for 24 to 48 hours)12 to 24 hours with hot water). Drain and rinse with clear water.

For amine and salt forms of herbicides (consult label) add one of the following to each 100 gallons of water used : (1) 1 gallon of household ammonia or (2) 2 pounds of lye (sodium hydroxide) or (3) 5 pounds of sal soda (sodium carbonate or washing soda).

For ester and oil soluble forms of herbicides (consult label) , add one of the following to each 95 gallons of water used : (1) 2 pounds of lye, or (2) 5 pounds of sal soda, then add soap or emulsifier, then add 5 gallons of kerosene or diesel oil, or (3) 5 pounds of trisodium phosphate, then add soap or emulsifier, then add 5 gallons of kerosene or diesel oil.

Another method to clean herbicides from sprayers is to rinse the sprayers for **2** minutes with 0.25 percent suspension of activated charcoal (1/4 pounds of activated charcoal in 10 gallons of water containing household detergent) followed by a rinse of clean water (USDA ARS 1969).

Quick-Test for Phytotoxic Residues in Fumigated Soils[3]

Equipment

1. Four 1-pint mason jars with caes and rubber gaskets.
2. One package lettuce seed (head or leaf variety).
3. Four 1-inch squares of absorbent cotton.

Procedure

1. Fill three 1-pint mason jars three-fourths full with fumigated soil. CAP THE JARS IMMEDIATEL Y. *THESE SOIL SAMPLES SHOULD RE TAKEN FROM THE DEPTH AT WHICH THE FUMIGANT WAS APPLIED.* NOTE : If the ground is uneven, take samples from the lowest spots in the fumigated area.

2. Fill one jar three-fourths full with an untreated soil sample. Cap the jar. This will serve as a control or check.

3. Soak the lettuce seed for 1/2 hour in water at room temperature.

4. Dip the absorbent cotton square in water and drain off the excess water. Do not squeeze the cotton since too much water will be lost.

5. Place 10 to 15 presoaked lettuce seeds on top of each wet cotton square.

6. One at a time, remove the cap from each soil jar and quickly place the wet cotton squares containing the lettuce seed on top of the soil so that the seeds are up. *RECAP EACH JAR IMMEDIATELY.*

7. Leave the jars at room temperature in an area where daylight is available. *DO NOT PLACE IN THE DARK.*

8. After 2 days, examine the seed. If the seeds in the jars of the *treated* soil are not germinating but the seeds in the jar of untreated soil (the control or check sample) are germinating, the fumigated soil should be worked up and aerated for an additional period of time.

[3] Taken from Morton Chemical Company's Lettuce Seed Test.

Glossary

Words explained in the glossary are italicized the first time they appear in the text.

Caliper : Stem diameter.

Chlorosis : A diseased condition of plants, shown by the blanching of green parts.

Clone : A group of plants propagated only by vegetative and asexual means, all members of which have been derived by repeated propagation from a single individual.

Colloid, soil : Organic or inorganic matter having very small particle size and a correspondingly large surface area per unit of mass. Soil colloids do not go into true solution but may be dispersed into a relatively stable suspension. By treatment with salts and other chemicals colloids may be flocculated, or aggregated, into small crumbs or granules that settle out of water.

Counter : One who counts the number of seedlings within the sampling area.

Counting frame : A sturdy frame with exact dimensions. The frame contains the sampling area in which all seedlings are counted.

Cull factor : The percent of seedlings that will be either diseased, damaged, or undersize; not shippable.

Denitrification : The process in which nitrates or nitrites in the soil or organic deposits are reduced to ammonia or free nitrogen by bacterial action. The process results in the escape of nitrogen into the air and is therefore wasteful.

Dioecious : Having mate and female fiowers on different plants.

Ectomycorrhizae : A mycorrhizae in which the fungal hyphae form a closely woven envelope covering the root apex and penetrating to a limited extent between the cells of the cortex ; generally formed by basidiomycete fungi.

Endomycorrhizae : A mycorrhizae in which the fungal hyphae are entirely within the root cortex and largely intracellular ; generally formed by phycomycete fungi.

Germination: The beginning of growth of a mature, generally dormant, seed.

Germinative capacity : The percent, by number, of seeds in a given sample that actually germinate, regardless of time.

Germinative energy : The percent of seed that have germinated at the time the trend of germination reaches its peak.

Harden off : Generally the natural process of adaptation by plants to cold, drought, etc. Usually characterized by the plants losing their leaves.

Micronutrient : Nutrients that plants need in only small, trace, or minute amounts.

Monoecious : Having male and female elements in different fiowers on the same plant.

Mycorrhizae : The morphological association, usually symbiotic, of fungi and roots of seed plants. The feeding roots are enshrouded or partially penetrated by fine filaments of fungi ; such roots commonly are more branched and lose their root hairs.

Necrosis: Death of tissue or a cell while still part of a living organism.

Necrotic : Characterized by death of tissue which is generally darker than surrounding tissue.

Nitrifying bacteria : Bacteria in the soil that changes ammonia or ammonia compounds to nitrates and nitrites.

Nymph An immature insect with an incomplete metamorphosis having all adult structures but differing from the adult mainly in its incompletely developed wings and genetalia.

Perfect-hermaphrodite : Having effective male and female elements in the same flower on a plant.

pH : A symbol indicating acidity or alkalinity. pH values run from O to 14. ph 7 indicates neutrality, numbers less than 7 increasing acidity, and numbers greater than 7 increasing alkalinity. pH 6 indicates silght acidity.

Polygamous : Having both perfect flowers and unisexual or imperfect flowers.

Polygamo-dioecious Having both perfect and unisexual flowers on the same plant, the male and female fiowers on different plants.

Polygamo-monoecious : Having perfect flowers and the two kinds of unisexual flowers (male and female) all on the same plant.

Provenance tests : A progeny test of population of the same species but of different provenances for the purpose of studying their performance under a range of site and climatic conditions, determining the distribution of selected progeny characters in related provenance, identifying the most desirable provenances for silvicultural use, and establishing a collection of biotypes of direct and potential breeding value.

Rooting auxin : One of a number of natural organic compounds formed in actively growing parís of plants, which regulate cell expansion and other developmental processes, and are used to promote rooting of cuttings.

Stratum : A subdivision of a population for sampling purposes which is more homogeneous in respect to the variable than the population as a whole.

1-0 and 2-0 seedlings : The first number indicates the number of year in a seedbed and the second number indicates the number of years in a transplant bed. Thus 1-0 would indicate a seedling that had spent 1 year in the seedbed and 0 years in a transplant bed.

INDEX TO SCIENTIFIC AND COMMON NAMES

INDEX TO SCIENTIFIC AND COMMON NAMES (continued)

* U.S. GOVERNMENT PRINTING OFFICE: 1976 O-552-630

Pesticide Precautionary Statement

Pesticides used improperly can be injurious to human beings, animals, and plants. Follow the directions and heed all precautions on labels. Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides where there is danger of drift when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment, if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Environmental Protection Agency, consult your local forest pathologist, county agriculture agent, or State extension specialist to be sure the intended use is still registered.