

Forest Nursery Practice in the Lake States

by J. H. Stoeckeler
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Forest Nursery Practice

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Lake States

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INTRODUCTION

In 1950, Michigan, Wisconsin, and Minnesota had an estimated 12.5 million acres of forest land in need of planting (131).¹ A 1952 estimate, based on a different set of criteria for plantable area, was 8.5 million acres (180a). The latter, more conservative estimate accounts for about one-sixth of all the commercial forest land in the Lakes States region. Only 10 percent of the original pine, spruce, and fir² forests have sur-

vived logging and fire. The remainder of the forest land is denuded or understocked, or has converted to lower value species.

Because the region is not self-sustaining in wood production and demands for wood products are increasing, these understocked and denuded areas should be restored to high productivity by tree planting. In addition, decades of fire protection and encouragement of natural reseeding by scientifically managed cutting of the remaining forest will be required.

A rebuilding program is already under way and gaining more support every year. One large

¹ Italic numbers in parentheses refer to Literature Cited, p. 112.

² A list of common and scientific names of trees and shrubs mentioned in this publication appears in the Appendix, p. 118.

TABLE 1.—*Forest tree nurseries in the Lake States operated by local public agencies, the Federal Government, and forest industries to grow stock for reforestation and shelterbelts, 1952*

State and nursery	Location	Ownership class ¹	Operator	Trees produced
				<i>Thousands</i>
Michigan:				
Bogue	East Lansing	S	Mich. State University	2,361
Chittenden	Wellston	F	Forest Service	4,831
Dunbar	Sault Ste. Marie	S	Mich. State University	1,660
Hardwood State	Boyne Falls	S	Mich. Dept. Conserv.	1,580
Higgins Lake State	Roscommon	S	do	14,869
North Muskegon Soil Conserv. Dist.	Dalton	C	Soil Conserv. Dist.	500
South Muskegon Soil Conserv. Dist.	Fruitport	C	do	550
West Ottawa Soil Conserv. Dist.	West Olive	C	do	1,496
Russ	Decatur	S	Mich. State University	849
J. W. Toumey	Watersmeet	F	Forest Service	2,644
Wyman	Manistique	S	Mich. Dept. Conserv.	256
Total (11 nurseries)				31,596
Minnesota:				
Badoura	Akeley	S	Minn. Conserv. Dept.	3,598
Eveleth	Eveleth	F	Forest Service	1,925
General Andrews	Willow River	S	Minn. Conserv. Dept.	3,598
Knife River	Two Harbors	I	No. Star Timber Co.	20
Lydick	Cass Lake	F	Forest Service	(3)
Winona	Winona	F ⁴	Soil Conserv. Serv.	3,904
Total (6 nurseries)				13,025
Wisconsin:				
Butternut	Butternut	F	Forest Service	(3)
Clark County Transplant	Neilsville	S	Wis. Conserv. Dept.	247
Gordon State	Gordon	S	do	3,389
Griffith State	Wisconsin Rapids	S	do	8,889
Hayward State	Hayward	S	do	3,604
Hugo Sauer	Rhineland	F	do	2,338
Marathon County Transplant	Wausau	S	do	110
Monico	Monico	I	Consolidated Water Power & Paper Co.	292
Nepco Lake	Port Edwards	I	Nekoosa-Edwards Paper Co.	1,500
Trout Lake	Boulder Junction	S	Wis. Conserv. Dept.	2,634
Total (10 nurseries)				23,003
Grand total (27 nurseries)				67,624

¹ F = Federal, S = State, C = Commercial, I = Industry.

² Recently reactivated.

³ Inactive.

⁴ In 1954 this nursery was transferred to the Game Division of the Minnesota Conservation Department.

phase of the program is the reforestation of cut-over and burned-over lands. Participants include Federal, State, county, township, and city governments, and pulp and paper mills, lumbermen, and farmers. The trees are supplied largely by 27 nurseries located within the region and operated by local public agencies, the Federal Government, and forest industries (table 1). The combined production of these nurseries in 1952 was 67.6 million trees.

As an example of the rebuilding program, some 69 thousand acres of forests and shelterbelts were planted between July 1, 1951, and June 30, 1952. This planting was on land in all classes of owner-

ship, with 29 percent of it in Wisconsin, 18 percent in Minnesota, and 53 percent in Michigan. Together, the 3 States planted 13 percent of the national total for that year. To 1952, they had planted about 22 percent of the national total.

The large-scale program of tree planting in this region, which began in the 1930's, has furnished a rich background of experience in production of nursery stock. This publication presents the results of that experience and supplements it with observations from a large number of nursery experiments and field-planting tests. Emphasis is on mass production of 1- to 4-year-old nursery stock grown from seed and suitable for reforestation.

COLLECTION AND HANDLING OF SEED

IMPORTANCE OF SEED SOURCE

"Seed source" refers to the geographic locality and type of trees from which seed is collected. It is desirable to use seed from well-formed, vigorous trees of local origin wherever possible, because trees grown from seed of distant areas often suffer more damage from freezing, drought, insects, disease, or physiological disturbances. Moreover, such trees are sometimes crooked, limby, stunted, or rapid in taper, and these defects may not show up for 20 years or more after planting. If seed from distant sources are used, tests should first establish the superiority of the race.

European countries have a much broader experience than the United States on the harmful effects of the use of seed without regard to its origin. Some of them have passed strict laws providing for certification of the source of seed. Germany, particularly, developed a rigid seed certification program which became a law in 1934 (3).

One of the early advocates of a better seed program in the Lake States was C. G. Bates (6) who suggested certification of seed that was collected from disease-free trees of desirable form. He also proposed setting aside "tree seed farms" consisting of the best natural or planted stands in various locations and using them as seed collection areas (7). As a supplement, he suggested standwise progeny tests to verify the value of various geographical strains (8).

In reviewing the experiences of European countries, Baldwin and Shirley (3) outlined a forest seed program for the United States. It was based on the use of local seed of known origin and, in case of dependence on distant sources, on intelligent selection based on a knowledge of mean temperature of the growing season (usually June to September) along with a knowledge of length of growing season.

Bates (9), in a study of frost hardiness of geographic sources of red pine, found in controlled laboratory tests that the northern sources were much superior to those of southern origin.

In general, species native to the Lake States have shown much better results than exotics as regards survival, form, and resistance to winter injury (162). In the Lake States, as well as in the Northeast, Scotch pine has proved to be a particularly poor species in spite of good initial growth. Not only has it generally been surpassed in growth by red pine, but it has tended to be heavy limbed and often crooked boled, by comparison. It is also more subject to attack by insects, such as the root collar weevil, and to attack by porcupines.

The general failure of Scotch pine in the Lake States is attributed in large part to poor seed source.

A great deal of work in Sweden has led to the recommendation that the mean summer temperature of the planting site should not vary more than about 1° C. (1.8° F.) from that of the home of the parent seed trees (84).

Wakeley (183) found that loblolly pine trees from seed collected from within 50 miles of the planting site produced 1.9 to 2.7 times as much merchantable pulpwood as did stock grown from seed originating 350 to 450 miles away.

On May 16, 1939, the U. S. Department of Agriculture adopted a uniform seed policy approved by the Forest Service and the Soil Conservation Service (appendix, p. 124). It requires these agencies to use, wherever possible, seed of known origin from areas of similar climatic influences. This usually means collected within 100 miles and within 1,000 feet elevation of the planting site. It further recommends keeping a record on such seed: lot number, year of seed crop, species, origin as to State and county locality, range of elevation, and proof of origin.

For the more important reforestation species, such as red, white, and jack pines, and white and black spruces, the above policy can be followed in the Lake States region without too much difficulty. "Tree seed farms" should be designated in local stands of well-formed native species and efforts made to collect seed from such areas. The price of seed is a minor item in the ultimate cost of a forest plantation or windbreak planting, and it is penny-wise and pound-foolish not to take advantage of the best seed sources.

An alternative to importing seed from other countries would be to collect seed of nonnative species, such as Norway spruce, European larch, and Scotch pine, from older plantings (preferably over 40 years of age) in the Lake States. There are a few such plantations and windbreaks in the region in which the trees have good form, satisfactory growth rate (50 to 80 feet high), and have shown some natural reseeding in their new habitat. These plantings ought to be earmarked as "tree seed farms."

In summation, a sound seed-collection policy for the Lake States region should include the following points:

1. Each State should be zoned into at least 3 or 4 homogeneous seed-collection zones.
2. The progeny obtained from seed collected from a zone should be planted in that zone wherever possible.

3. The seed should be from trees and stands of reasonably good growth rate and form, with straight, clear stems free from internal defect and with branches of small diameter in relation to bole.

4. Seed imported from European or Asiatic countries should not be used to any extent in the reforestation program. If used at all, it should come from localities climatically similar to the Lake States area where the trees are to be planted, and the program should be limited to those few species that have shown good growth and adaptability in provenience (seed-source) tests. A few older plantations of exotics now growing in the Lake States could qualify.

5. A tree seed certification program should be developed with particular emphasis on a guarantee of the origin of the seed.

WHERE AND WHEN TO COLLECT SEED

Tree seed collection should be confined to areas where the trees are of good form and vigor, because trees of poor form may transmit this undesirable character to the progeny. There are good collection areas on national and State forests, and on industrial forests and other private lands. Windbreaks and shelterbelts offer another possible source for seed. Landowners seldom object to the gathering of cones from standing trees or squirrel caches by seed collectors even though the cones collected will be sold to others. However, the seed picker should first get permission from the landowner.

Many species of trees produce a bumper crop of seed only once in 4 or 5 years, and a fairly good crop only every second or third year (180). Therefore it is to the advantage of the collector to concentrate seed picking in those years when cones or fruits are plentiful and well filled. The seed thus obtained will generally be of high viability and much cheaper per pound than lots collected in lean years. It can be stored for 4 or 5 years without losing much of its viability if proper conditions of moisture and temperature are maintained.

The abundance of seed crops during an 8-year period (1946-53) in Wisconsin varied widely (table 2). Red pine and tamarack had good or bumper crops in only 1 out of 8 years, and white spruce in only 2 out of 8 years. Lack of seed of the pine and spruce is likely to be a bottleneck in nursery production if a fairly good carryover of seed is not provided. It was noted that a good or bumper crop was rather frequently followed by a failure or by a poor crop but that in no case were there two complete crop failures in a row.

For tree-seed production generally, the 8 years for Wisconsin can be rated as follows: 1946, poor; some species fair. 1947, good; some species fair; a few bumper. 1948, fair; quite a few species

good. 1949, a failure. 1950, bumper; quite a few species good. 1951, fair; some species poor. 1952, fair; some species good. 1953, fair; some species good.

Species in the same genera, for example the birches, often act alike as regards abundance of seed produced. This is especially true for species whose seed ripen at about the same time of year.

TABLE 2.—Frequency of seed crops in Wisconsin, 1946-53

Species	Years with seed crops rated as ¹ —					Years with good or better crop
	Bumper	Good	Medium	Poor	Failure	
	Number	Number	Number	Number	Number	Percent
Conifers:						
Fir, balsam.....	2	3	0	1	2	62
Hemlock.....	2	2	2	2	0	50
Pine, jack.....	0	3	4	0	1	37
Pine, red.....	0	1	2	4	1	12
Pine, white.....	1	2	2	3	0	37
Spruce, black.....	1	2	2	2	1	37
Spruce, white.....	1	1	3	1	2	25
Tamarack.....	1	0	3	2	2	12
White-cedar.....	2	2	2	1	1	50
Broadleaves:						
Ash, black.....	1	2	2	1	2	37
Ash, white.....	1	3	1	1	2	50
Basswood.....	2	3	1	1	1	62
Birch, paper.....	1	3	1	1	2	50
Birch, yellow.....	2	2	2	1	1	50
Cherry, black ²	2	1	2	1	1	43
Elm, American ³	0	3	2	0	1	50
Hickory, shagbark ³	2	1	2	1	0	50
Maple, sugar.....	0	4	1	2	1	50
Oak, red.....	1	2	3	1	1	37
Oak, white ²	0	3	3	1	0	43
Walnut, black ⁴	0	3	2	0	0	60

¹ Abundance is described as follows in terms of percentage of full crop: bumper, 91-100; good, 61-90; medium, 36-60; poor, 16-35; failure, 0-15.

² Basis: 7-year record.

³ Basis: 6-year record.

⁴ Basis: 5-year record.

Seed crops in the Lake States are likely to be less abundant on trees growing near the edge of the natural range of the species. For instance, good or bumper seed crops of northern red oak were observed only 1 year out of 6 in northern Wisconsin near the northern limit of its geographic range, whereas in southern Wisconsin good or bumper crops were observed in 2 out of 6 years.

Most pines require 2 years to mature cones; hence, in late summer or fall the cone crop for the year following can be predicted to some extent from the number of immature first-year cones. Weeviling or adverse weather, such as severe drought, in the following year can, of course, upset such estimates.

DETERMINATION OF SEED RIPENESS AND QUALITY

Seeds of most tree species ripen and are ready for picking in the late summer or fall, but there are exceptions. For instance, American elm and aspen seeds ripen in May; those of red maple and rock elm in June. Some conifers, notably white spruce, open their cones and disperse seed the last week of August. Such cones must be harvested during a very short period, often no longer than 10 days in contrast to the 20 to 30 or more days for most other conifers.

Ripeness of cones of some species can be judged by a change in the color as from green to deep purple or brown. For instance, red pine cones are ripe when they turn purplish with brown on the scale tips, and white pine cones turn yellowish green with brown on the scale tips. Jack pine can be collected when half or more of the cone surface is brown. Change of color in balsam fir cones (purpling) and in juniper berries (blue) is indicative of ripeness.

The specific gravity of freshly picked cones is also an indication of ripeness, particularly for some pines (130). A simple method for determining the specific gravity of red and white pine cones is to use separate containers with water, linseed oil, equal parts of linseed oil and kerosene, and kerosene. If five or more freshly picked cones sink in water, the crop is still too green for collection. If the white pine cones float in linseed oil (specific gravity about 0.93), they are ripe enough for collection. Red pine is not fully ripe until the cones float in the solution of lowest specific gravity, i. e., kerosene, having a specific gravity of about 0.80. However, red pine cones floating in the 50-50 mixture of linseed oil and kerosene are within 10 days of being fully ripe.

Seeds of broadleaf species are judged to be ripe when they have lost their watery or milky character, they are firm and fully developed, and their color has changed from green to tan or grayish. However, fully ripened seeds of some broadleaf species can only be obtained with certainty by waiting until seed dispersal begins. This applies particularly to oaks and poplars.

Seed quality can be determined by cutting tests made in the field. Areas producing a high percentage of hollow or weeviled seed should be avoided.

COLLECTION OF SEED AND CONTROL OF ITS ORIGIN

It may be more feasible for commercial nurseries to purchase seed than to engage in collecting. Seed can be obtained from collectors or seed dealers or by the open-market purchase of cones. If a reliable collector or seed dealer will guarantee collection area and year of collection, seed of good

quality from stands reasonably good to excellent in form may be obtained.

Tighter control of seed origin can be had by hiring seed pickers to collect ripe cones or seed from a specific timber sale area as the timber is felled. A further refinement is to have a collecting-crew foreman designate individual trees from which the cones or seed will be picked. Another control method is to have an agreement with the operator on the sale area for felling the very best seed-bearing trees at the proper time of seed ripeness prior to the late fall or winter cutting. This procedure is applicable to red pine, white pine, balsam fir, and other species whose cones open or whose seed is dispersed naturally in late September or October, but it is of especial value for white spruce whose cone-harvesting span is often only a 1-week period in late August.

Cones can also be collected from squirrel caches or from the ground as squirrels cut them. Pine cones collected from squirrel caches or cuttings will probably be of fairly good genetic character if the stand as a whole is composed of trees of good form.

Cones or fruits of some species, notably elm, ash, and low white-cedar or junipers, can be shaken, flailed, or stripped onto canvas or cloth. Elm seed is occasionally swept up from streets, sidewalks, or other hard surfaces.

Collecting from standing trees is the most difficult. Seed pickers are usually equipped with climbing irons or ladders, depending on height and limbiness of the trees. The cones or seeds are stripped off by hand and dropped into a sack or picking bag. For species like ash, a light fine-toothed rake can be used to dislodge the seed; the seed can then be caught in a net held by the picker or allowed to fall onto tarps or burlap. Juniper berries and white-cedar cones can be stripped from lower branches onto canvas by gloved hands or with a fine-toothed rake.

Considerably more cones or seed per day can be harvested from felled, individual trees if a large square of burlap, old canvas, or cheesecloth is placed where the seed-bearing top will strike. This procedure is of value chiefly where large amounts of seed will become detached when the tree strikes the ground. Cutting out the heavily laden tops of spruce or balsam fir trees at the time of seed ripeness and dropping or lowering them to the ground is another method of collection. The trees are felled in the logging operation later.

The volume or weight of cones or seed that can be collected in an 8-hour day by a picker varies greatly according to species, character of the stand and individual trees, abundance of seed, method of collection, organization, and equipment. For instance, a picker can collect only a bushel of cones per day from standing red pine trees, but from felled trees, he may obtain 2 to 3 bushels. Some collectors have obtained as many as 6 to 8 bushels in a day from squirrel caches.

Small cones, such as jack pine, tamarack or white-cedar and others, are rather slow to collect. From felled trees, when the crop is good, 1 man in 1 day can gather 2 bushels of spruce or balsam fir cones, 1 bushel of red oak acorns, or about $\frac{1}{2}$ to $\frac{3}{4}$ bushel of white oak acorns. One man in one day can easily collect $\frac{1}{2}$ bushel of fruits of such species as sugar maple, basswood, ash, and birch. Collins (34) reported in an Ozark study that from 0.2 to 1.9 bushels of acorns were picked per man-day, with best production obtained from recently felled trees.

Oak seed can also be picked efficiently from the ground after natural seed fall. The acorns that fall earliest are often wormy, hollow, and of poor quality. They should be avoided if possible. To remove hollow or wormy acorns, the collection should be dumped into a tub of water and the floaters skimmed off and discarded. The remaining acorns and $\frac{1}{2}$ to 1 cup of carbon disulfide should be placed in a metal container, such as a seed or milk can, and sealed up for about 48 hours to kill the seed-eating larvae often found in acorns.

Miller (96) in time studies on cone collection in Chippewa National Forest, Minn., found that production per man-day was as follows when handpicking from ladders: Jack pine, red pine, and white spruce, $1\frac{1}{2}$ to 2 bushels; white pine, 3 to 4 bushels. This agrees rather well with a study made in Ontario by Richardson (118) who reported that 2.15 bushels of red pine were collected per man-day of 9 hours when cones were picked from the tree with hooks and bags. Miller reported that when cones were obtained from squirrel caches, the men were able to get from 5 to 6 bushels of white pine and up to a maximum of 8 bushels of red pine. Individual squirrel caches may contain up to $1\frac{1}{2}$ bushels of cones of red pine. Recommended practice is to leave part of the cache for the squirrels.

Cones found in squirrel caches generally are of good size and contain well-filled seed. Squirrels do, however, cut cones slightly before full maturity. Barton,³ in comparing red pine cones freshly cut by squirrels with those handpicked at the same time, noted that germination increased somewhat between early September collections and those made 2 to 3 weeks later:

Date collected	Method of collection	Percent of seed germination
Sept. 3	Squirrel-cut	88
3	Handpicked	87
17	Squirrel-cut	97
17	Handpicked	96
24	Squirrel-cut	100
24	Handpicked	100

Other observations indicated that squirrels began cutting red pine cones 10 to 14 days before the seed had attained high germinability, but that they did not begin to cut white pine cones until the seed were highly germinable (130).

³ Hugo Sauer Nursery, Rhinelander, Wis. Unpublished annual report, 1938.

Picking from trees felled in logging operations during a period when the seed is fully matured will reduce seed collection costs. This practice has the further advantage of allowing one to pick from some very select, tall trees that would be extremely difficult or risky to climb. Bryan (20) reported that Civilian Conservation Corps men were able to pick an average of 3 bushels of short-leaf pine cones per man-day from felled trees but only $\frac{1}{2}$ bushel per man-day from standing trees.

Studies of red pine cone size in relation to seed yield made at Rhinelander, Wis., in 1938 revealed that medium- and large-sized cones had between 2.1 and 2.2 times as many viable seeds per bushel as small cones, although the total weight of seed per unit volume of each class of cones was about the same. Small cones were defined as those with a volume of 8 to 13 cubic centimeters per freshly collected cone, medium cones ranged from 13 to 17, and large cones from 17 to 22. Average volumes were 9.5, 15.0, and 18.1 cubic centimeters, respectively, and average total number of seed per cone was 19.6, 34.1, and 43.1, respectively.

The number of red pine seedlings produced per cone also increased with cone volume, as follows:

Volume of fresh cones (cubic centimeters)	Seedlings produced per cone (number)	Volume of fresh cones (cubic centimeters)	Seedlings produced per cone (number)
5	0	13	4.4
6	0	14	5.0
7	0	15	5.7
8	0.7	16	6.3
9	1.5	17	7.2
10	2.2	18	7.9
11	3.0	19	8.6
12	3.6	20	9.3

Cones with a volume less than about 8 cubic centimeters contained practically no viable seed, whereas cones 15 to 20 cubic centimeters in volume gave especially good yields. The amount of viable seed was not as high as expected because of early collection, but the general conclusion was that small, runty cones should neither be collected nor purchased.

Eliason and Heit (45) found similar results in Scotch pine and concluded that cones less than 1.5 inches long produced smaller seed and also smaller seedlings than three larger grades of cones ranging from 1.5 to 2.25 inches in length.

Normally, cones are purchased by the bushel, but there may be great variation in the number of cones per unit of volume. As a general rule, in the Lake States cones can be measured satisfactorily by volume if they are completely unopened at the time of delivery.

Cottonwood or aspen seeds are collected by picking the clusters of cottony material just as the first ones are beginning to open and drift away in the wind. The clusters need drying for several days on screens. They should then be rubbed gently to separate the seed, and the seed immediately sown (19).

More details on methods of collecting various species of tree seed are given in table 3. The table is based on experience in a number of nurseries in the Lake States and on seed tests in sand flats at those nurseries as well as at other testing laboratories (180).

HANDLING OF CONES AND FRUITS IMMEDIATELY AFTER COLLECTION

Practically all cones, berries, strobiles, or other fruits must be spread out in layers on hardware-cloth trays in a cone shed or on a floor in a barn or shed to obtain enough superficial drying to prevent molding or heating. The layers should not be more than 2 to 4 inches thick for cones, or 1 to 2 inches for the seed of the broadleaf species. They should be protected from rain. This predrying will require some 3 to 10 days, depending on drying conditions.

Predrying is especially necessary for maple, birch, ash, and elm because they mold and heat readily if left in collection sacks. Fruits should be turned over daily to expedite drying, and it is advisable to turn the soft, relatively moist fruits of broadleaf species twice a day during the first few days. At the Cass Lake Extractory of the United States Forest Service, red pine cones are predried from the time of collection until midwinter to obtain the highest seed yield in extraction.

In most State or Federal nurseries of the Lake States, cone storage sheds are designed with ventilators at the top to give a maximum of air circulation (fig. 1).⁴ Along the sides, upward-swinging, horizontally hinged doors can be lifted to expose openings screened over with $\frac{1}{2}$ -inch hardware cloth. The cones are placed in trays which vary in size

⁴ Detailed plans for cone shed are available from the Regional Forester, U. S. Forest Service, Milwaukee 3, Wis.

from 4 by 4 feet to 4 by 12 feet. The trays, usually 4 inches deep, have hardware-cloth bottoms. A tray 4 by 8 feet will hold about 4 bushels of cones. Often 15 or more trays are stacked in a tier, at the bottom of which is placed fine screen to catch seeds which drop out of the cones.

Pine cones can conveniently be left in the trays for 2 months of predrying and then dumped in stockpiles in a corner of the warehouse or cone shed until ready for extraction in the kiln. Each lot of a specific origin should be kept separate in storage and extraction to comply with the United States Department of Agriculture Seed Policy or with such rules as are in line with an agency's policies. The Forest Service in the Lake States area keeps seed lots separate by national forests and year collected.

EXTRACTION OF CONIFER SEED

In the Lake States most conifer seed is extracted from cones in artificially heated, specially constructed kilns (fig. 2). Artificial heat usually gives more complete extraction of the seed than air-drying or solar heat. Balsam fir, however, does not require kiln treatment. When cones of this species are air-dried in a cone shed, the scales break away from the central axis of the cone and the mixture of seed and scales is then separated by dewinging and cleaning in a fanning mill.

The temperature, humidity, and duration of kiln treatment vary for different species (table 4). The temperatures used in the forced-air kiln at the Hugo Sauer Nursery (table 4) are slightly lower than those given by Rietz (119). He recommends 140° F. for 12 hours at 17 percent relative humidity for air-dried cones of eastern white pine; 170° for 7 hours at 20 percent humidity for jack pine; and 160° for 9 hours at 17 percent relative humidity for air-dry or fresh cones of red pine.

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FIGURE 1.—This cone storage shed is 30 by 70 feet and will hold 2,300 bushels of red pine cones on trays. (Chittenden Nursery, Wellston, Mich.)



TABLE 3.—Summary table for seed collection, extraction, treatment, and nursery seedling

Species	Data on fruits and cones		Time of collection	Collection method ¹	Extraction method ²	Weight per rough bushel of fruit as picked	Clean seed per rough bushel of fruits ³	Seeds per pound ⁴	Cutting test	Germination in laboratory flats	Approximate ratio 1-0 nursery standard laboratory germination ⁵	Depth of seedling	Type of seed dormancy	Season of sowing and seed pretreatment if spring sown ⁶
	Type and shape	Length												
Conifers:														
Douglas-fir	Cone	3.0	Late Aug.-Sept.	2 or 4	1	35	0.70	40,300	92	85	0.40	3/4	Embryo	Fall-sow or stratify 60 days.
Fir, balsam	Upright purplish cone	1.7-2.7	Sept.	2	7 2	25	2.10	57,000	51	22	.60	3/4	do	Fall-sow or stratify 90 days.
Hemlock, eastern	Cone	.4	do	2	1	45	1.95	187,000	80	38	.40	3/4	do	Fall-sow or stratify 60 days.
Larch, European	do	.7-1.2	do	2	1	20	.63	73,900	55	40	.40	3/4	Embryo, slight	Do.
Pine, Austrian	do	2.0-4.0	Sept.-Oct.	2	1	45	.60	26,000	88	70	.60	1/2	None	Spring or fall.
Pine, jack	do	1.5-2.0	Sept.-Nov.	2	1	40	.52	123,000	94	68	.50	3/4	do	Do.
Pine, ponderosa	do	3.0	Sept.	2 or 5	2 or 1	44	1.25	14,840	75	54	.70	1/2	do	Do.
Pine, red	do	1.5-2.5	do	2 or 5	1	35	.46	55,000	96	85	.65	3/4	do	Do.
Pine, Scotch	do	1.2-2.0	Late Sept.-Nov.	2	1	32	.50	66,000	96	44	.70	3/4	do	Do.
Pine, white	do	5.0-7.0	Sept.	2 or 5	1	32	.95	27,000	92	64	.65	1/2	Embryo	Fall-sow or stratify 60 days.
Redcedar, eastern	Blue berrylike cone	.1-.2	Oct.-Nov.	3 or 2	5	35	5.20	41,000	60	35	.60	3/4-1/2	Embryo and seedcoat.	Fall-sow or stratify 90 days.
Spruce, black	Cone	.6-.9	Oct.	2	1	39	.25	390,000	80	50	.40	1/4	Embryo, slight	Fall or spring.
Spruce, Norway	do	4.0-6.5	Sept.	2	1	35	.65	60,000	85	70	.35	1/4	do	Do.
Spruce, western white	do	1.0-2.0	Late Aug.-early Sept.	2	1	25	.40	180,000	85	50	.40	1/4	None	Spring or fall.
Spruce, white	do	1.0-2.5	do	2	1	25	.45	216,000	80	50	.35	1/4	Embryo	Fall-sow or stratify 60 days.
Tamarack	do	.5-.7	Sept.	2	1	25	.75	278,800	60	47	.50	1/4	Embryo, slight	Fall or spring.
White-cedar, northern	Conclet.	.25	Late Sept.-Oct.	2 or 3	2 or 1	24	1.05	300,000	52	50	.10	1/8	do	Fall-sow or stratify 30 days.
Broadleaves:														
Ash, black	Paddle-shaped samara	1.0-1.5	Oct.-Nov.	2 or 3	3 or 4	12	9.00	8,070	95	20	.75	3/4	Embryo and seedcoat.	Stratify in April, seed in fall.
Ash, green	do	1.2-1.5	Sept.-Oct.	2 or 3	3 or 4	12	8.00	16,000	85	42	.70	1/2	Embryo	Fall-sow or in spring soak in cold water 10 days, changing daily.
Ash, white	do	1.2-1.5	do	2 or 3	3 or 4	12	8.00	10,200	92	50	.70	1/2	do	Fall-sow or stratify 60 to 90 days.
Aspen, quaking	Silky-winged seed borne in long, pendulous catkins.	2.5-3.5	Apr.-May	2	8	15		3,001,000		90	.01	0	None	Sow as soon as collected.
Basswood	Several grayish-brown, round nutlets attached to curved wing.	.25	Sept.-Nov.	2	3	10	5.00	3,550	73	25	.30	3/4	Embryo and seedcoat.	Fall-sow; mulch for 1 1/2 years.
Beech, American	A 2-celled burr	.5-.7	Sept.-Oct.	1	3	25	9.00	1,385	90	86	.75	3/4	Embryo	Fall-sow or stratify over-winter.
Birch, paper	Strobiles contain tiny, flat, disklike samaras.	1.2-1.7	do	2	3	13 1/2	2.10	918,000		35	.15	1/4	Embryo, slight	Fall-sow or stratify 30 days.
Birch, yellow	do	.9-1.2	do	2	3	9	2.70	371,000		29	.12	1/4	do	Do.
Cherry, black	Black, 1-seeded drupe	.2-.25	Aug.-Sept.	3 or 2	5	55	11.00	5,000	94	63	.50	1/2	Embryo	Fall-sow or stratify 120 days.

Cottonwood, eastern	2.5-4.0	Apr.-May	2	8	15	350,000	95	88	.10	0	None	Sow as soon as collected.
Silky-winged seed borne in pendulous catkins.												
Elm, American	.3-.4	May	3 or 6	3	\$4½	\$3.50	96	74	.15	¼	do	Do.
Elm, rock	.5-.6	June	2	3	\$8	\$6.00	97	70	.35	¼	do	Do.
Locust, black	3.0-4.0	Sept.-Oct.	3	4	9	22,850	84	67	.40	¾	Seedcoat	Spring. Searify; 20-40 minutes sulfuric acid; or hot-water immersion.
Maple, red	.6-.8	May-June	2 or 6	3	\$13	\$9.00	87	46	.40	½	Embryo	Fall-sow or stratify 40 days.
Maple, silver	1.2-2.2	do	2 or 6	3	\$14	\$10.00	97	76	.40	½	None	Sow as soon as collected.
Maple, sugar	.8-1.2	Sept.-Oct.	2 or 6	3	\$16	\$12.00	52	40	.40	½	Embryo	Fall-sow.
Oak, northern red	.7-.9	do	1	7	49	45,000	85	68	.95	1	do	Fall-sow or stratify over-winter.
Oak, white	.7-.8	do	1	7	65	58,000	85	65	.95	1	None	Fall-sow.
Walnut, black	2.5-3.0	Oct.	1	6	40	10,000	90	70	.90	1	Embryo and seedcoat.	Fall-sow or stratify over-winter.

¹ Collection method:

1. Pick from ground after natural fall. If necessary, shake trees or jar limbs to remove the fruit.
2. Hand-pick from trees, or from tops after felling.
3. Flail, strip, or shake onto canvas, burlap, or cheesecloth.
4. Pick from ground after squirrel cutting.
5. Remove from squirrel caches.
6. Sweep up or rake up after natural fall on streets.

² Extraction method:

1. Open cones with artificial heat. Tumble in cone shaker. Fan or screen to separate from cone scales.
2. Open by air-drying on screens. Tumble in cone shaker.
3. Screen through hardware cloth. Pick debris from screen if necessary. Fan seed to remove impurities.

4. Run dry through macerator. Fan to remove impurities.

5. Run wet through macerator with water. Float off or screen out pulp.
6. Run through corn sheller to remove husks.
7. Float in water to remove hollow seed.
8. Pick catkins; dry on screens until open and remove capsules and stems.

³ Refers to seed with pulp, pod, or wings removed except where indicated.

⁴ Rough cleaned to usual standard as seed comes from extractory.

⁵ Assuming overhead irrigation.

⁶ See text for supplemental details.

⁷ Balsam fir does not require cone shaking treatment.

⁸ With wings left on seed.

⁹ Estimated.

Some cones offer great resistance to complete opening because of "case-hardening" that results from improper storage of cones or other causes. Red pine and Scotch pine cones especially tend to case-harden. To overcome this, the cones are either sprayed with water or submerged in water for 12 to 24 hours at room temperature, or they are soaked for 5 to 20 minutes in water heated to 130° F. After such treatment they are dried superficially for a day or two and then put into the dry kiln. Some extractories introduce live steam into the kiln for 30 minutes to aid in opening case-hardened cones.

TABLE 4.—*Drying schedule for forced hot-air kiln, Hugo Sauer Nursery, Wis.*

Species	Fahren- heit temper- ature	Rela- tive humid- ity	Time in kiln	Amount of cones per tray ¹
	<i>Degrees</i>	<i>Percent</i>	<i>Hours</i>	<i>Bushels</i>
White pine.....	120	37	12	1/2
Red pine.....	130	15	9	1/4
Jack pine.....	150	27	6	1/4
White spruce.....	130	37	10	1/4
Black spruce.....	150	37	20	1/6
Norway spruce.....	130	37	18	1/8
Tamarack.....	150	37	24	1/6
Hemlock.....	150	37	12	1/6

¹ Size of trays, 44 1/4 by 23 1/2 by 3 inches.

Internal-fan type extractories have a considerably faster schedule of extraction (table 5) than do other kilns. They handle charges ranging from 11 to 44 bushels per kiln, depending on tray loading and spacing. At 1/4 bushel per tray, the number of bushels is 16.5 at 2-inch spacing; 13.5 at 2.5 inches; and 11.0 at 3 inches. Tray loadings may be 1/4, 1/2, 1/2, or 3/8's of a bushel. The usual tray spacing for most Lake States species is 2 or 3 inches with tray loadings of 1/2 to 1/2 bushel, or an average of about 22 bushels per single kiln charge.

It is desirable to do as complete a job of extraction as possible, because of the financial loss when seed are left in the cones. For example, in 1935 an especially recalcitrant batch of red pine cones was encountered at the Hugo Sauer Nursery. These cones, on which rather poor extraction was obtained in the first run, were then soaked in vats of water for 12 to 24 hours, spread in the sun for 24 to 48 hours, and again run through the kiln. An additional average yield of 0.31 pound of seed per bushel of cones was obtained.

There are as yet relatively few cone-extraction installations that use a continuous extraction process. The Mt. Shasta Nursery in California uses a tumbler-type, automatic seed extractor with infrared heat. In Ontario, Carmichael (22) has successfully used infrared lamps for extracting pine seed. The method is entirely feasible where power rates are low.

TABLE 5.—*Drying schedule for internal-fan type of seed extractories*

Species	Fahren- heit temper- ature ¹	Rela- tive humid- ity	Time in kiln	Amount of cones per tray ²
	<i>Degrees</i>	<i>Percent</i>	<i>Hours</i>	<i>Bushel</i>
White pine.....	140	41	4-5	1/2
Red pine.....	150	18	7	1/2
Jack pine.....	150	18	4-6	1/2
White spruce.....	130	38	4	1/2
Black spruce.....	150	27	4-6	1/2
Tamarack.....	130	24	4-5	1/2
White-cedar.....	130	38	4	1/2

¹ Wet bulb temperatures are held at about 92° F. for tamarack; 100° for red pine and jack pine; 102° for white spruce and white-cedar; 109° for black spruce; and 112° for white pine.

² Size of trays is 36 by 48 by 1 1/2 inches.

At the Badoura State Nursery at Akeley, Minn., seeds of pine and white spruce are extracted by placing cones in a cylindrical drum 4 feet in diameter and 15 feet long. Its exterior is covered with 1/2-inch mesh hardware cloth. The drum is turned at about 5 rotations per minute for 4 to 6 hours. Heat, from a furnace in the basement, in the range of 130° to 180° F. depending on species, passes through the metal-encased cylinder. The extracted seed falls into a seed hopper and is not subjected to more and perhaps unnecessary drying. Yields and costs in this operation are fairly well in line with those of the usual type of kiln.

A rather good job of extraction of seed has been accomplished without a kiln. Rindt (123) dried 1,495 bushels of white pine cones by spreading them on the floor of a shed heated to 70° F. The cones started to open on the second day and in 1 week's time were well opened. A seed dealer at Stanford, Mont., opens Douglas-fir and other cones by placing them on heavy Kraft paper in the sun. Methods of extraction using solar heat or room temperatures are cheaper for some species than kiln treatment. They are, however, often limited because of space or weather.

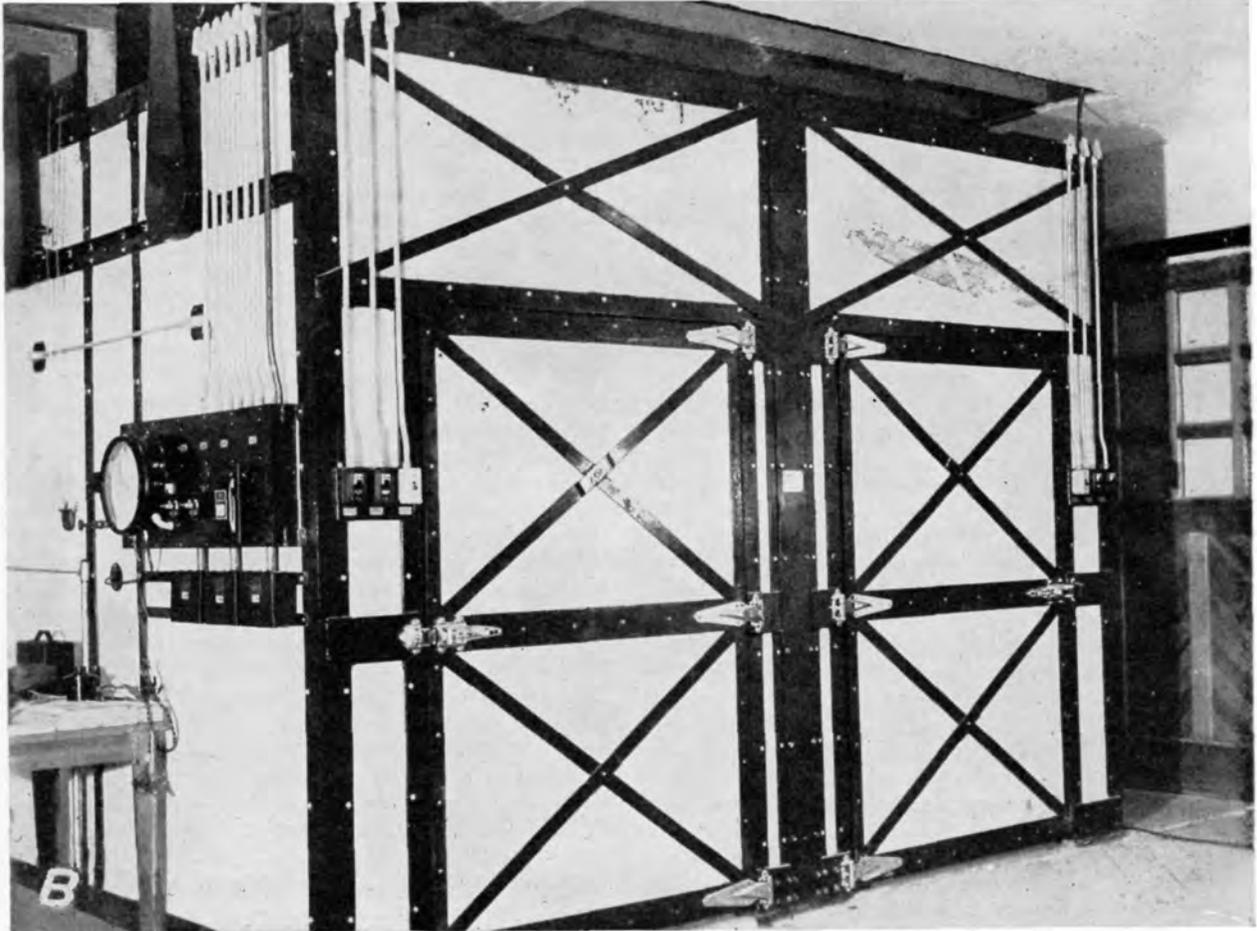
CONE SHAKER

After cones have been through the kiln, they are placed in wire-covered shakers that are from 6 to 10 sided in shape, about 5 to 8 feet in diameter, and 6 feet long (fig. 3). The wire covering is usually 1/2-inch mesh hardware cloth. Inside the shaker, 1- by 6-inch slats increase the jarring action on the cones and expedite extraction. A metal jacket, vented to the exterior to remove dirt, completely covers the shaker. The shaker operates at about 13 revolutions per minute and is usually powered by an electric motor.

Up to 5 bushels of open cones are put into the shaker through a trapdoor, and seed falls into a

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FIGURE 2.—A, Loading kiln trays with cones. B, Two-unit cone kiln designed by U. S. Forest Products Laboratory. (Chittenden Nursery, Wellston, Mich.)





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FIGURE 3.—Cone shaker.

hopper directly below the revolving drum and into bags or containers. These bags or containers are sometimes located in the seed-cleaning room on the floor level directly below. In some instances the seed is conducted by delivery tube directly to the dewinger. Extraction generally is more complete if only a 2- to 4-bushel charge is used.

A continuous-process cone shaker, used at the Chittenden Nursery at Wellston, Mich., is a truncated cone-shaped screen 8 feet long, 3 feet in diameter at one end and 2½ feet at the other. Cones are fed into one end and as the screen rotates they work their way to the other end in about 1 minute. The screen, powered by a 1-hp. electric motor, rotates about 30 times per minute. The time cones remain in the screen can be regulated by changing the pitch of the axis of the screen.

Once a batch of cones is extracted, the trapdoor on the drum is removed, and empty cones are discharged into a hopper leading to a storage bin alongside the furnace. These cones usually are burned as part of the fuel for the extractory furnace. In some instances extracted cones of red and white pines are sold to commercial firms that use them for Christmas decorations, wreaths, and table ornaments.

DEWINGING OF SEED

In Lake States nurseries, seed of conifers are always dewinged but those of broadleaf species usually are not. The seed are dewinged by machines of various types or by being flailed in sacks. A common machine design consists of a cylinder of tight wire screen with an interior

rotating shaft to which four brushes are attached. As the seeds pass between the revolving brushes and the wire wall, the wings are rubbed off and fall through the screen into a box below. The cleaned seed works its way to the end of the machine where it is collected in a trough. A suction fan underneath the screen aids in removal of trash.

The brushes must be of rather soft material and the speed of the machine rather low. The dewinger at the Hugo Sauer Nursery has a speed of 44 r. p. m. Some conifer seed, notably spruce and jack pine, are subject to injury by crushing or bruising in the dewinging process as determined by Barton.⁵ Damage to red pine seed from a dewinger speed of 120 r. p. m. was reported in New York (46). When the speed was reduced to 60, no damage occurred.

In a comparative test of dewinging jack pine seed by machine and by flailing in sacks, it was found that seed yields were slightly higher and germination somewhat better in the lot dewinged by flailing. A study made at the Lake States Station with jack pine seed showed a difference of 25 to 30 percent in real germination between the following methods, ranging from best to worst: (1) rubbing over a screen by hand or by power-driven brushes, (2) hand rubbing, (3) beating in a bag, (4) leaving wings undisturbed, and (5) trampling in a sack and then putting through a small fanning mill (180).

Olson (108) removed wings of spruce seed with a minimum of damage in a device consisting of a drum of webbing or burlap revolving in a hammock of the same material. A heavy elastic band kept the hammock under proper tension. This

⁵ Hugo Sauer Nursery, Rhinelander, Wis. Unpublished annual report, 1938.

method removed the objectionable feature of rubbing the seed against metal with its attendant danger of breakage or bruising.

The Badoura State Nursery near Akeley, Minn., removes wings of pine and spruce seeds by moistening them slightly and then tumbling them slowly in a small concrete mixer. The tumbling action removes the wings.

At the Cass Lake Nursery, Minn., seeds are placed in a grain sack which is walked on slowly, with a circular shuffling motion.

By fanning in sacks, George (54) has successfully dewinged American elm fruits and made them adaptable for mechanical seeding. The seeds of the ashes, birches, etc., are rather difficult to sow mechanically unless dewinged. Therefore, they are generally sowed by hand. Maple seeds, however, can be sowed mechanically after being dewinged because they are more nearly spherical than the long, tapered seeds of the ashes.

At the Mt. Shasta Nursery, Calif., pine and fir seed are dewinged without injury by adjustable brushes that revolve against a soft, corrugated rubber mat.

FANNING AND CLEANING THE SEED

Once the seed of conifers such as pines, spruces, or firs has been dewinged, the mixture of seed, wings, and pieces of broken cone scales is passed through a Clipper cleaner equipped with interchangeable mesh screens of various sizes. As the mixture of seed and debris moves over two slightly tilted screens, controlled wind velocities aid in separating chaff from seed. A number of runs, usually four, must be made before the seed is quite clean. With very light-seeded species, particularly white-cedar, no fan is used.

Screen sizes used in the fanning mill at the Chittenden Nursery for some of the more important Lake States conifers are as follows: (1) For white pine, a Chaffer Type A screen is used in the bottom on all runs, with a No. 13 or 14 top screen on the first run and a No. 12 top screen on succeeding runs; (2) for red pine, the Chaffer Type A screen is used in the bottom on all runs, with a No. 13 top screen on the first run and a No. 10 on succeeding runs; (3) jack pine, being smaller than red pine, requires a $\frac{1}{16}$ -inch screen in the bottom on all runs, with No. 10 and No. 8 top screens for the first run and succeeding runs, respectively; (4) for white spruce, $\frac{1}{18}$ - and $\frac{1}{22}$ -inch screens are used in the bottom for the first and successive runs respectively, while No. 8 and No. 6 screens, respectively, are used in the top.

If the seed have been moistened before the dewinging process, the mixture of seed and wings must be predried at about 80° F. for 16 hours. After being fanned, the seed must again be checked for moisture content, which generally will be about 10 to 12 percent. Pine and spruce seeds may require some additional drying to reduce the

moisture content to about 5 to 10 percent. Canadian practice is to lower the moisture content of pine and spruce seeds to some 3 to 6 percent before placing in cold storage in sealed containers (21).

SIZE OF SEED IN RELATION TO GERMINATION AND SIZE OF SEEDLINGS PRODUCED

It has been a general observation that the larger seeds within any lot germinate better than the others. Deen (41) found that only 0 to 4 percent of the lightest 11 percent by weight of longleaf pine seed germinated, while 52 to 100 percent of the remainder of the seeds were viable. For the great bulk of this seed, germination was more than 96 percent.

Tests on red pine at the Hugo Sauer Nursery in Wisconsin indicated that the larger seeds germinated better but did not produce larger than average seedlings. If there is any advantage in seedling size in trees produced from larger seed, it generally disappears within 18 years after field planting and usually much sooner (36, 180).

The low germination of the smallest seeds is an incentive for sufficient additional screening and cleaning to remove the poorest fraction. However, there would seem to be no need in the Lake States to grade seed into several sizes before sowing it in the nursery.

EXTRACTING SEEDS OF DRY-FRUITED BROADLEAF SPECIES

The fruits of broadleaf species are first dried and then handled by various methods to extract the seed. Fruits of some species, such as maples, ashes, basswood, birches, and beech, are rubbed through hardware screens after sticks and leaves have been picked out. This treatment separates the clusters of seed or breaks up the strobiles of birches. Fanning or running the seed through a clipper mill will remove the remaining debris.

With the oaks and similar species, nothing need be done except to remove debris such as sticks, stones, and leaves. Acorns require no predrying, and they are damaged by excessive drying. Preferably, acorns should be sowed shortly after collection.

Fruits of black locust and other similar legumes can be run dry through a macerator (47) or through an ordinary farm threshing machine. Sanford (135) used the latter in extracting the seed from 3,000 bushels of black locust pods which yielded 6,471 pounds of seed, 6,120 of which was classed as grade 1. Using a 4-man crew, 2 men opened bags, 1 fed pods into the machine, and 1 measured and sacked the seed. The threshing operation required 54 man-hours. The seed was fanned before sacking, using No. 4 screen on top and No. 12 below.

EXTRACTING SEEDS OF PULPY-FRUITED SPECIES

Seeds of pulpy-fruited species (juniper, mountain ash, plum, etc.) are extracted if the fruits are macerated in water and then the pulp floated off. Such fruits may be softened for a few days in water—changed several times daily to prevent fermentation—before they are run through the macerator. After extraction, juniper seeds can be cleaned further in a solution of lye that helps remove the pitchy outer layer of resinous material.

Black walnut seeds can be extracted readily if the seeds are run through a corn sheller to remove the husks. This method was mentioned as early as 1900 by Sudworth (164).

The Soil Conservation Service Nursery at Winona, Minn., used a hammer mill to extract seeds of pulpy-fruited species.⁶ The mill was run at a speed of about 400 r. p. m., by means of a farm tractor with flat-belt drive. The fruits were poured into the mill with ample quantities of water supplied by 1 or 2 garden hoses and left there for 3 to 5 minutes. The cleaned seeds were retained in the bottom of the mill on a screen, along with some of the debris. After treatment the seeds and pulp were dumped on screens to dry. Then the material was run through a fanning mill to remove the seeds from the debris. Juniper

⁶ Information furnished by Thor Bergh, former Nursery Superintendent.

fruits can be depulped by this method except that the seeds must be left in the mill for about 20 minutes.

YIELDS AND COSTS OF SEED EXTRACTION

Seed yields per bushel of cones vary by species and quality of cones. Some typical cone and extraction costs are given in table 6. There is considerable variation in the amount of seed obtained per bushel not only between species but also within species. For instance, in red pine the yield ranged from 7.3 to 14.3 ounces per bushel with a very close relationship between yield and cost per bushel—the higher the yield the lower the cost.

Johnson (73) reported that it required 0.97 man-hours per bushel to handle pine cones and extract seed from them.

Cone costs per bushel in the 5-year period 1948–52 in the Lake States were as follows: Red pine, \$3 to \$10; white pine, \$1.50 to \$4.20; jack pine, \$3 to \$8; white spruce, \$7 to \$12; black spruce, \$10 to \$12; and balsam fir, \$4.

Costs for some nonconiferous seeds were as follows: Eastern redcedar, \$3.45 per bushel of berries; white oak, \$2.50; red oak, \$3.70; black walnut, \$0.70 per bushel not hulled; and silver maple, \$0.50 per bushel.

TABLE 6.—Costs and yields in extraction of cones over a 4-year period at several Lake States extractories

Extractory and species	Bushels extracted	Average price per bushel	Seed obtained per bushel of cones	Cost per pound of clean seed	Year of crop	Class of cone crop
Chittenden:	<i>Number</i>	<i>Dollars</i>	<i>Ounces</i>	<i>Dollars</i>		
Red pine.....	721.2	5.00	14.3	8.76	1951	Good.
Do.....	646.3	5.00	12.7	9.00	1951	Do.
Do.....	155.1	6.00	7.3	17.46	1953	Poor.
Do.....	573.0	6.00	10.0	11.89	1954	Fair.
White pine.....	734.0	1.75	15.5	4.16	1951	Good.
Do.....	39.7	1.75	11.1	6.78	1952	Poor.
Do.....	200.0	2.00	13.4	3.90	1953	Bumper in some areas.
Do.....	445.5	2.00	13.4	4.18	1953	
Jack pine.....	113.0	3.00	9.0	8.52	1951	Good.
Do.....	235.2	3.00	6.1	12.15	1952	Poor. ¹
Hugo Sauer:						
Red pine.....	1,556.0	5.00	11.3	8.57	1951	Good.
Do.....	583.3	6.00	11.7	11.60	1953	Fair.
White pine.....	454.0	1.50	10.2	4.90	1951	Do.
Do.....	1,534.3	1.50	12.8	3.58	1953	Good.
White spruce.....	23.9	7.00	9.0	13.50	1953	Poor.
Do.....	885.3	7.00	10.5	12.58	1954	Good.
Norway spruce.....	261.0	3.50	11.8	8.55	1948	Do.
Do.....	10.75	3.00	16.7	6.25	1951	Fair.
Balsam fir.....	11.0	4.00	32.0	3.08	1952	Poor.
White-cedar.....	6.0		² 18.6	³ 4.34	1952	Good.

¹ About 75 percent of cones were 2 or more years old.

² This seed was not dewinged; all other lots were.

³ Cones picked by prison crew, hence cost is not typical or comparable with others.

SEED STORAGE

After extraction, the moisture content should be determined for any seed, particularly of conifers, scheduled for several years' storage. A moisture content of 5 to 10 percent is preferred for the seeds of pines and spruces used in Lake States nurseries. Kiln-dried seeds often have about this moisture content and may need no further drying. If the seeds are still too moist, they should be returned to the kiln for further drying.

In Lake States forest tree nurseries seeds usually are stored in one or more of the following three ways: (1) Dry cold storage in sealed containers; (2) dry storage at room temperature; (3) moist cold storage.

Dry Cold Storage

In the larger Lake States nurseries, seed usually are stored in specially constructed seed storage houses. The seed house at the Hugo Sauer Nursery, for example, is a frame structure with cinder block walls. It has a fir floor laid over concrete which, in turn, is on a cinder fill. The ceiling is of 1-inch insulation board with a 2-inch blanket of mineral wool. The temperature in this unrefrigerated seed house on a warm day was found to be 23° F. cooler than the outside temperature in the shade.

Dry cold storage at 33° to 40° F. in sealed containers is best for prolonged storage of seeds of all pines, spruces, firs, birches, ashes, white-cedar, junipers, larches, basswood, and hemlock. Usually the seed are stored in cylindrical cans about 36 inches high and 18 inches in diameter, with an approximate capacity of 150 to 160 pounds of conifer seed. These cans are sealed with a rubber gasket and a bronze screw cap. Small batches of seed can be stored handily in 5-gallon, rectangular oil cans that hold about 20 pounds each.

Seeds of red and jack pines have been stored for 5 years in northern Wisconsin under situations where summer temperature in the storage chamber was as high as 50° to 60° F., with a reduction in germination of as little as 5 to 10 percent. Balsam fir seed, however, rapidly loses its viability in a few years unless held at 40° or below.

Red pine and white spruce seeds with moisture contents of 6 to 10 percent have been held for 10 years in dry cold, sealed storage with only a 5- to 10-percent drop in germination.

George (54) was able to store American elm seeds for a full year in open as well as closed containers, after first drying them for 2 weeks over sulfuric acid. Storage at 0° C. was better than at 10° or 20°.

Dry Storage at Room Temperature

The seeds of some species, such as black locust, other legumes, and basswood, can be stored under rodentproof conditions at room temperature for a year or two without serious losses in viability. Seeds of pines and spruces native to the Lake States area can also be so stored, although their very high per-pound value warrants cold storage to hold germination at a maximum.

Moist Cold Storage

Seeds of certain species of Lake States trees, such as the oaks, black walnut, hickories, beech, and silver maple, must not be dried and should be kept at a moisture content above 35 percent. If they are allowed to dry out, they promptly lose their viability. By far the simplest and safest way to handle them is to simulate nature by sowing promptly after collection.

If for some reason the seeds cannot be sowed until spring, they can be held in cold moist storage, stratified in moist sand at temperatures of 33° to 50° F., placed in outdoor pits, or held in a root cellar for overwinter storage (77, 150, 170). If outdoor pits are used, a well-drained area of sandy soil should be selected and the seed stratified in 2 or 3 parts of moist sand to 1 part of seeds in boxes covered with rodentproof hardware cloth. The upper part of the boxes should be about 8 to 12 inches below the level of the top of the covering soil. If 3-inch layers of soil and straw are alternated for the topmost covering, the buried boxes can be removed more easily in early spring even if the soil is frozen. Seeds stratified over winter must be removed promptly in early spring to avoid premature sprouting in storage and subsequent deformation of the seedlings in the nursery.

SEED DORMANCY AND PRETREATMENT

Some tree seeds, such as those of jack or red pines, germinate promptly after spring sowing without any pretreatment. Other seeds, such as those of white pine and white spruce, have embryo dormancy and will have rather low germination and a prolonged germination period if sowed dry in the spring. Dormancy can be overcome by a period of cold moist stratification during which certain chemical changes take place in the seed, making it ready for prompt germination. It should be clearly understood that stratification is a method of treating seed to make it germinate more promptly once seeded in the nursery. It is not to be regarded as a means of storing seed for 1 or more years. Expensive

lots of seed have, on occasion, been ruined because stratification was mistaken for storage.

Embryo dormancy ordinarily can be overcome by fall seeding which often provides the necessary cold moist pretreatment. However, stratifying the seed in moist sand or peat for a period of 30 to 120 days (depending on species) at temperatures of 40° to 50° F. immediately preceding spring sowing (166, 180) will bring about prompt and often fuller germination.

Seeds of some tree species with tough or impermeable seedcoats have seedcoat dormancy. Black locust, for example, has a seedcoat so impervious that water absorption is very slow and germination may straggle along for several months after seeding. Seedcoat dormancy can be overcome by mechanical or chemical treatments that break, soften, or etch the impervious seedcoat and make it readily permeable to moisture. Seeds of some species, for example, must increase from about 7 percent to about 45 to 65 percent in moisture content before they can germinate (180). Seeds with impervious coats usually are scarified by (1) tumbling them in a drum lined with sandpaper or blowing them against a curved surface lined with sandpaper, (2) immersing them in concentrated sulfuric acid for a specific period depending on the species, or (3) pouring boiling water over them.

Black locust seeds vary considerably in seedcoat dormancy. Some lots may be treated satisfactorily with boiling water, while others require acid treatment for 30 minutes, more or less, or mechanical scarification (4, 42, 192). Mony (100) suggests testing each lot of black locust before pretreatment, using variable periods of soaking in acid and a swelling test as an indicator of the best method. He warns that seed should not be stirred too vigorously during or after acid treatment, that it should be washed thoroughly after treatment, and that the temperature of the acid containers during treatment should be held down to avoid damage to the seed.

Chapman (26) used a modified Ames scarifier consisting of a 12-inch forge blower with a 1-hp. electric motor to blow black locust seed against a 6- to 8-inch-wide curved surface lined with No. 3 garnet paper. A fan speed of 1,700-2,200 r. p. m. was required. With this device he obtained continuous scarification at the rate of 1 bushel per minute.

Disk scarifiers are useful for small or experimental lots of seed (158).

Drum scarifiers were successfully used by Dayharsh (40) in treating eastern juniper seed, but other methods of seed treatment have now superseded this drum-scarification procedure.

Seeds of certain tree species, such as basswood and eastern redcedar, have both seedcoat and embryo dormancy. Such seeds may require a combination of scarification and stratification (or fall sowing) to get germination the following spring.

Basswood seeds are among the most difficult to germinate promptly. Under the ordinary practice of fall seeding only about 5 to 10 percent of the seeds germinate the following spring, with an additional 30 to 50 percent coming up the next spring. Methods recommended to date for Lake States nurseries have not proved successful.

A recently developed procedure, not yet tested in Lake States nurseries, is as follows (72): (1) Soak fruits in water for 3 days and then dry them superficially; (2) immerse fruits in sulfuric acid (technical grade), stirring vigorously for about 4 minutes, and cool down to 130° F., then leave them for about 40 minutes; (3) force fruits through a 4-mesh screen and catch material on an 8-mesh screen, flushing well with water to remove acid; (4) dry seeds and pericarp fragments on absorbent material; (5) separate seeds from debris by passing latter through 8-mesh screen; (6) air-dry seeds thoroughly and immerse in concentrated sulfuric acid for 10 to 15 minutes, then rinse thoroughly with water; (7) stratify seeds in moist sand or peat at 36° to 40° F. for 110 to 130 days.

Uniformly successful germination of eastern redcedar has been obtained in Soil Conservation Service nurseries⁷ by collecting the seed in late August and sowing it no later than the first week in September. The soil is mulched to keep the seedbed in moist condition. The seeds generally, germinate promptly the following spring.

SEED TESTING

Accurate tests of the number of seeds per pound, purity, and germination percent are necessary in order that seed can be sowed in the nursery at rates that will assure approximately the desired stand per square foot. Thin stands waste space and increase stock costs. Overdense seedbeds produce undersized, spindly stock with a high cull percent and poor survival or growth.

For test purposes, samples are generally taken out of each large container of seed, or at least out of each large lot of seed, for a specific year and place of collection. The seed are drawn out of the containers with a long, brass sampling tube specially designed for this purpose. The tube takes a uniform, equal sample from top to bottom of the container. Several tubefuls, or enough to constitute several ounces of seed, are needed for an adequate sample of each 50- to 100-pound can or separate smaller lot. This sample then must be subdivided until a small representative sample of 2,000 to 3,000 seeds is obtained. The sample can be subdivided with a mechanical device or by being successively quartered and mixed.

Purity of seed is expressed in percent and is determined by the formula:

$$\text{Purity} = \frac{\text{Weight of clean seeds} \times 100}{\text{Weight of seeds plus impurities}}$$

⁷ Information furnished by Thor Bergh, former nursery superintendent.

Each seed must be inspected to separate the apparently sound seeds from the chaff, broken wings, needles, and other debris. Purity should generally be above 95 percent for most tree seed. In some species, such as balsam fir, seed purity may be low because of difficulty in removing fragments of cone scales that are similar to the seed in size and specific gravity.

Because the nurseryman normally sows the seed as it comes from the seed container, he should know the number of seeds per pound. He can obtain this information by weighing in grams on a sensitive balance a small sample of uncleaned seed and then accurately counting the number of whole, apparently sound seeds in the sample. A formula for determining clean seeds per pound follows:

$$\frac{\text{Clean seeds per pound of unclean seeds} \times \text{Weight of unclean seeds in sample, in grams}}{\text{Number of clean seeds counted} \times 454}$$

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

Sometimes the seeds are cut open to determine what proportion is filled. Cutting tests are useful as emergency guides in fall sowing of freshly collected seed that have embryo dormancy, or for other seed that have not been tested for germination. Cutting tests are particularly useful if previous experience shows the results of past cutting tests together with the number of seed per pound and the germination or tree percent. In cutting tests, several hundred representative seeds usually are split with a sharp knife. Large-seeded species, such as walnut or hickory, can be cracked in a vise. Good seeds are well filled and have white or cream-colored kernels.

Stains can also be used to determine viability, and they are more reliable than visual estimates. For example, indigo carmine will not affect the color of viable seeds (98), but it will stain dead or injured embryos (180).

Germination can be determined best if the lots of seed are sown in sand flats, each flat usually containing 200 or 250 seeds of any one individual lot. The flats are filled with washed and sterilized fine sand. A small board that fits just inside of the flat is used to level the sand to sowing depths from $\frac{1}{8}$ to 1 inch below the top of the flat. The exact number of seeds is counted out and broadcast uniformly over the sand. The seed is then pressed lightly into the surface, sand is sifted over it, and the surplus struck off with a slat to obtain uniform depth. The flat is labeled with a metal tag showing collection or accession number.

Germination tests in the Lake States are generally made on 4 or 5 replicated samples of 200 to 250 seeds each, with each replication occurring in a separate flat. A flat usually contains four separate properly labeled lots of seed. The reason for having each replication in a separate flat is to reduce the odds of having damping-off disease wipe out all replications. This is more likely to happen if all replications are in the same flat. Some investigators recommend 8 replications of 100 seeds for each lot (183). This has the advan-

tage of providing a better average germination percent, especially if results of 1 or 2 replications have to be discarded.

For species with prompt seed germination, the sand flats are placed in a greenhouse or in a germination room that can be lighted during the normal daylight hours and heated to provide a diurnal fluctuation from about 68° F. at night to 86° in daytime. The flats should be watered daily.

Dormant seeds must be properly pretreated before germination will start. The seeds can be chilled before sowing or, after sowing, the entire flat can be placed in a cold room at the desired temperature and left there for the period needed to break dormancy. The flats must be watered often enough to keep them moist while in the cold chamber. Where large cold-storage chambers are not available, the seed sample can be stratified or mixed with a small quantity of moist peat or sand, wrapped in cheesecloth, and placed in glass jars in an ordinary refrigerator set to the proper temperature.

Once germination starts, the seedlings can be removed every 1 to 3 days and recorded. Un-germinated seeds remain in the flats until germination appears complete, usually 30 to 60 days.

Once germination is completed, the results of the 4 or 5 replicated samples are pooled and averaged. If 1 or 2 of these appear badly out of line with the average of the remainder, their results are discarded provided there is evidence of pre-emergent damping-off or similar trouble. As a general rule, results of all replications should be used in computing an average.

One can also test germination by placing the seeds between moist blotters in petri dishes. It is desirable to have three glass rods or pieces of glass tubing about three-sixteenths inch in diameter in the bottom of the petri dish to support the layer of blotter paper. The water level should be maintained at the approximate level of the blotting paper. Petri dishes, blotters, and glass rods should be sterilized with heat or boiling water to reduce the incidence of mold which is invariably a problem with unsterilized petri-dish tests (172). A Jacobsen germinator or similar device can be used in lieu of petri-dish tests (180).

Peat mats have not been used in the Lake States but they have been widely employed in the South. They probably would work equally well in the Lake States.

APPLICATION OF GERMINATION TESTS TO NURSERY SEEDING

Eighty to ninety-five percent of freshly collected tree seeds of good quality often will germinate in the laboratory where conditions are nearly ideal for full germination. Under nursery conditions, however, germination usually is lower and the proportion of seeds producing usable 1-0 seedlings is still less. This reflects such obstacles as unfavorable moisture conditions, pre-emergent or

post-emergent damping-off, too deep a soil covering, heat injury, and other losses from rodents or birds, or from cultivation and weeding damage, which reduce germination or survival in spite of extreme vigilance on the part of the nurserymen. Usually the small-seeded species have lower germination and survival than the large-seeded species (table 3, p. 8). With large-seeded species, such as red oak or white oak, the ratio of 1-0 nursery stand to laboratory germination may be as high as 0.95. This means that about 95 1-year-

old seedlings can be expected for every 100 viable seeds sown, based on laboratory germination tests. With pines and spruces the ratio is usually from 0.40 to 0.70; with birches it may be only 0.12 to 0.15.

Individual nurseries often have experience tables giving ratio of 1-0 nursery stand to laboratory germination, as well as the number of trees produced per pound of seed sown. In their absence the data in table 3 will serve as a general guide to determine sowing rate.

HOW TO SELECT A NURSERY SITE

Careful consideration must be given to the selection of the nursery. A level, or nearly level, well-drained site suitable for production of seedlings or transplants should be chosen in or near the area where the trees are to be planted. Rolling, hilly areas are unsuitable for forest nurseries. A detailed discussion of the important factors affecting the selection of a nursery follows.

CLIMATE

The nursery should be located close to, or slightly south of, the areas where the trees will be field-planted. If the nursery is located too far to the north, frozen soil may make it impossible to dig trees at the very time when conditions for field planting farther south are at their best. The frequency of late spring frosts should not be overlooked. They are likely to be more severe in basins or other low areas known as "frost pockets."

TOPOGRAPHY

Level or nearly level areas are desirable so that comparatively little money will need to be spent for grading and leveling. Then too, mechanical equipment, such as nursery lifters and transplanting machines, works better on level ground and erosion is less of a problem.

For conifer seedbed areas, maximum grades should be no more than 1 or 2 percent. All minor depressions where water will stand, even for a few days, require leveling; otherwise seedlings will drown out or be damaged by ice in the winter. Such leveling is an expensive operation. For transplant areas, grades of 5 percent are permissible if the slopes are long and gradual and the topography is not rolling. However, when mechanical transplanters are used, slopes even of 5 percent can be annoying because of the tendency of the machines to creep sideways and space rows unevenly.

SOIL TEXTURE

For conifer nurseries, soils should have a silt-plus-clay content not less than 10 nor more than 25 percent. Loamy sands or light sandy loam with 15 to 20 percent silt-plus-clay are preferred. For hardwood nurseries the silt-plus-clay content

may be as high as 35 percent. The soil must have adequate surface drainage and the subsoil, preferably a fine sand or loamy sand, should also have good drainage. The land should be quite free from stones or coarse gravel. Large numbers of boulders, rocks, or stones create serious problems in cultivation, transplanting, lifting, and other operations. Their removal can be very expensive.

Light, sandy soils are well adapted for conifer production (188), and they offer the following advantages in contrast to heavy soils:

1. Because they are easier to work, costs are lower for ground preparation, seeding, cultivation, weeding, and lifting.

2. The seeds can be drilled directly into the soil surface; sand must be brought in for covering conifer seedbeds in heavy soils.

3. Sandy soils thaw out sooner in the spring and operations can begin earlier; they dry up sooner after rains.

4. Frost heaving is less in sandy soils.

5. In lifting operations, there is less chance for root stripping or breakage in light soils. Better root systems are produced.

6. Sandy soils do not puddle or become flooded as readily as heavy soils. Flooding even for a period of a few days may drown out the small trees, cover them with mud, or cause damaging ice sheets in late winter.

7. The problem of regulating acidity is not as serious on sandy soils.

Light soils have some disadvantages—they are more droughty than heavy soils, require more irrigation water, are generally lower in fertility and ability to retain soil nutrients, and are somewhat subject to wind erosion. However, their advantages for coniferous seedling and transplant production far outweigh their disadvantages.

SOIL FERTILITY

A nursery site should have soil adequate in fertility. Based on numerous soil analyses in forest nurseries where good stock was being produced, the following are minimum standards for the top 8 inches of soil: total nitrogen 0.08 percent; available nitrogen (nitrate and ammonia nitrogen), about 20 pounds per acre; available phosphoric acid (as P_2O_5), 50 pounds per acre; available potash (as K_2O), 125 pounds per acre;

replaceable calcium, 3 milliequivalents per 100 grams; and replaceable magnesium, 1.0 milliequivalents per 100 grams.

For growing the conifers commonly planted in the Lake States, the soil acidity should be between pH 5.2 and 5.8. For hardwood-stock production, a pH between 5.5 and 6.5 is desirable.

Tests of the soil should be based on at least 6 to 10 individual samples taken at random over the proposed nursery site. For details on correction of deficiencies in nutrients in either new or well-established nursery sites, see page 41.

VEGETATIVE COVER

In the absence of detailed tests, a reliable method for selecting a nursery site is to pick an area of well-drained, upland, sandy soil that supports or formerly supported red pine, good-site jack pine, or a mixture of white and red pines. Such soils usually will be satisfactory in fertility and texture for producing suitable stock, despite the fact that they may currently support aspen or paper birch which have followed past forest fires.

A forested area is considered more desirable for a nursery site than is a cultivated agricultural field of the same soil texture, for these reasons: (1) the levels of fertility and organic matter usually are better; (2) desirable mycorrhizal and favorable soil organisms are more abundant; (3) weeds and weed seeds are not so numerous; (4) diseases and insect pests usually are not so serious. The presence of a stand 40 to 70 feet tall also makes it possible to leave standing strips or shelterbelts of trees for protecting the nursery seedlings (figs. 4 and 6).

These advantages of wooded lands as nursery sites do not preclude the use of former agricultural

fields. Such fields have made satisfactory nursery sites, and the cost of clearing them was saved. However, they often require large amounts of peat, compost, duff, or other types of organic matter. Another serious disadvantage of old fields and pastures is that they often are infested with quackgrass and white grubs (28).

WATER SUPPLY

Sufficient water must be available to provide a sustained flow of at least 10 gallons per minute per acre of nursery ground. It should not contain more than 200 parts per million of dissolved solids (47). This is equivalent to an electrical conductivity of about 330 microhms/cm. at 25° C. (1). Preferably, the sodium absorption ratio of the water should be under 10, and the boron content less than one-half part per million (1).

Lakes, rivers, or streams reasonably free from industrial wastes may be satisfactory, or a drilled well may suffice. Water that is alkaline or heavily polluted with industrial wastes is especially troublesome in conifer nurseries because it increases damping-off and creates soil-fertility problems. Likewise, if too heavily laden with organic matter or mud, it will clog the irrigation lines or oscillators that turn them.

Before a source of water for a nursery is developed, it is advisable to consult the State geologist about water-bearing formations—their depth, constancy of supply, and quality—and the State laws concerning the taking of water from open bodies of water or streams.

In the northern Lake States the large number of lakes and streams and huge areas of water-bearing sands usually simplify the problem of obtaining an adequate supply of water suitable for

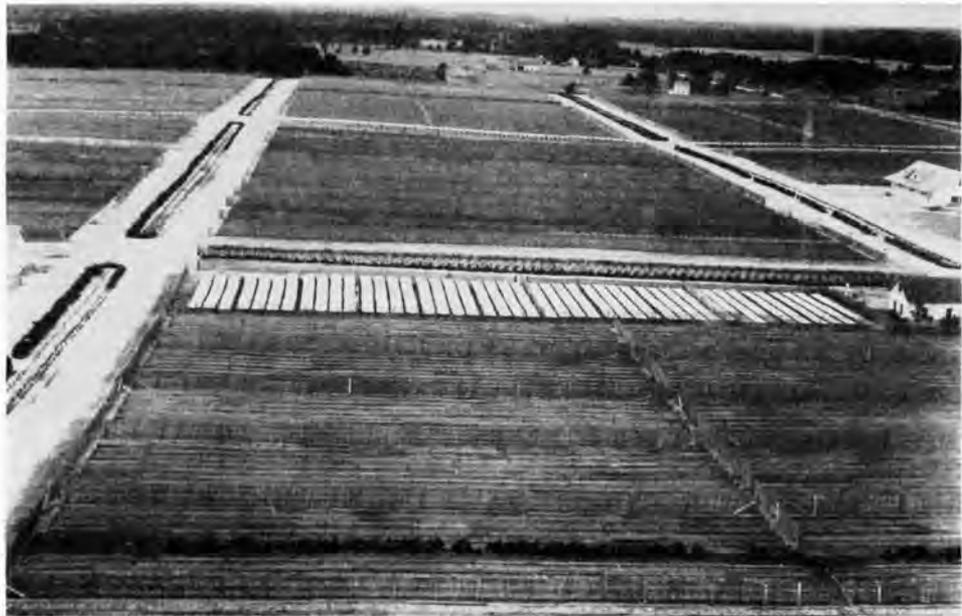


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FIGURE 4.—Note shelterbelts that provide wind protection. (Griffith State Nursery, Wisconsin Rapids, Wis.)

F-385064

FIGURE 5.—Main road into nursery is at right. It provides for two lanes of travel separated by a parkway planted to a shelterbelt. (Lydiek Nursery, Cass Lake, Minn.)



nursery irrigation. In the southern part of these States and in the prairie areas of Minnesota there is more of a problem because waters often are alkaline or laden with mud or industrial wastes.

LABOR SUPPLY

There must be an adequate supply of labor near the nursery site. From April to late September an average of 3 laborers will be required for every 10 acres of land in nurseries producing seedlings and transplants for reforestation. In spring peak periods, such as late April and May, 8 to 10 laborers per 10 acres of nursery must be available. Women and girls have proved adept at some of the nursery tasks such as transplanting, weeding, sorting, and grading. They have made up 50 percent or more of the labor force in some of the Federal nurseries.

TRANSPORTATION AND COMMUNICATION

The nursery should be so located that it has easy access to railroads and highways (fig. 5). Since some State and private nurseries often ship the bulk of their stock by rail express, closeness to a railhead is advantageous. Federal nurseries which usually ship most, if not all, of their production by truck directly from the nursery to the field planting site must be located on or near all-weather roads. Motortruck shipments by common carrier, or on bids by private truckers, provide a speedy, efficient method of shipping nursery stock. Telegraph and telephone facilities must be available to the nursery for expediting shipments and transacting other required business. It is also necessary that modern nurseries be located on or near a powerline.

NEARBY SOURCES OF PEAT AND SPHAGNUM MOSS

It is highly desirable to have adequate, easily accessible sources of peat and duff for fertilizer and compost, and sphagnum moss or shingle tow for packing material. Nearby sources of sand also are useful for stratifying seed or covering seedbeds. Sand used for covering seedbeds should be acid in reaction; if it effervesces when treated with a few drops of a 10-percent solution of hydrochloric or sulfuric acid, it should not be used.

SIZE OF AREA AS RELATED TO PRODUCTION NEEDS

The tract selected must be large enough to accommodate anticipated production needs. About $\frac{2}{3}$ to $\frac{3}{4}$ of the total area can be devoted to growing trees each year, and the other $\frac{1}{3}$ to $\frac{1}{4}$ of the area should be available for growing a soil-improvement or cover crop, such as legumes or rye. The minimum size for a fairly large-scale public nursery is about 20 acres, which gives a production capacity of 3 million seedlings and transplants. For a corporation or private nursery, the minimum size is about 10 acres.

To compute the space required for a nursery, the production of usable plants per square foot of nursery bed must be known. Conifer seedbeds usually will produce about 50 plantable seedlings per square foot. Mechanically transplanted conifers usually are spaced $2\frac{1}{4}$ inches apart in rows 7 or 8 inches apart and commonly yield about 8 plants per square foot. Only about 75 percent of the nursery bed area is actually available for production, the remainder being in paths, ends of beds, and turning areas.

The net space requirements vary for different classes of coniferous nursery stock (table 7). Seedling hardwoods, grown usually as 1-0, 2-0, or 3-0 for field planting,⁸ produce about 10 plantable trees per square foot and hence require 5 times the net area estimated for seedling conifers of the same classes of stock.

Because they vary in inherent characteristics and in their requirements for light and space, the species as well as the class of stock will influence the size of the nursery required to produce a given amount of stock. This subject is discussed in more detail on page 61.

The size of the nursery to be developed will also be governed by the possibilities of expanding production and the provision for adequate rotation of the nursery blocks so that proper soil maintenance practices can be carried out.

⁸ Forest nursery stock is known by a numerical system, the first number representing number of years in the seedbed and the second, number of years transplanted. Thus, 1-year-old seedlings are called 1-0 stock, and 2-year-old seedlings transplanted at the end of the second year and grown 1 year in the transplant beds are known as 2-1 stock.

TABLE 7.—*Net space requirements per million conifer seedlings, excluding nonproducing areas such as paths, turn areas, and roads*¹

Class of stock	Net area required—					Total
	1st year	2d year	3d year	4th year	5th year	
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1-0	0.46					0.46
2-0	.46	0.46				.92
3-0	.46	.46	0.46			1.38
1-1	.46	2.87				3.33
2-1	.46	.46	2.87			3.79
1-2	.46	2.87	2.87			6.20
2-2	.46	.46	2.87	2.87		6.66
3-2	.46	.46	.46	2.87	2.87	7.12
2-3	.46	.46	2.87	2.87	2.87	9.53

¹ Assuming 50 plantable seedlings produced per square foot, and 8 plantable transplants per square foot. For computation of gross area required, multiply the net area in this table by 1.33 since this allows adequate margin for nonproductive areas.

DEVELOPMENT OF THE NURSERY SITE

An accurate survey of the nursery site and the preparation of a topographic map should provide the basis for a detailed development plan. Some of the primary points to be observed in making the plan are as follows: Location of buildings with reference to the nursery area; the layout of water distribution system; size of subdivisions of nursery area to allow efficient use of machinery; and the location of roads and interior windbreaks which should take up a minimum of space and yet allow the most efficient use of the nursery. In regions where snow removal is a problem, particular attention should be given to locating the nurseryman's residence near main highways and other buildings.

SUBDIVIDING THE NURSERY

For efficient and economical management, the nursery should be divided into blocks or compartments of convenient size. Further division of the compartments will depend upon the practices and methods to be used.

Since much of the nursery work lends itself to mechanization, there should be sufficient space at the ends of the compartments to turn motorized equipment. This area usually serves a dual purpose, i. e., for turning space and for roads for easy access to various points in the nursery. The width and length of beds to be installed will play an important part in determining how the nursery should be subdivided into compartments.

The seedbed width accepted by most nurserymen is 42 to 48 inches. The length varies, depending on the size of the compartment, but a maximum length of 525 feet is recommended where overhead irrigation is planned. Although subdividing the compartment into units is not important where flooding or a temporary surface-irrigation system is to be used, it is extremely important that attention be paid to planning and laying out these units if a permanent irrigation system is to be installed.

WINDBREAK PROTECTION

To reduce the eroding and drying effect of strong winds, interior windbreaks often are needed. Nurseries of only a few acres seldom require them, but they are essential for nurseries of 20 acres or more. Windbreaks can be provided by leaving strips of natural tree growth (fig. 6), or by planting strips of trees at strategic locations throughout the nursery. They should be located on the windward side of the nursery and parallel to the beds to give maximum protection and yet not interfere with nursery operations.

Because planted hedges or windbreaks do not afford maximum protection during the first few years after planting, natural stands should be used wherever possible. It may be necessary to select a species for windbreak-planting purposes that is not commonly produced in the nursery, since some States have laws against the use of the same

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FIGURE 6.—A natural windbreak of balsam fir, black spruce, white spruce, eastern hemlock, white pine, and red pine. When the site was cleared, these trees were left in strips about 20 feet wide to provide a natural windbreak. (Manistique Nursery, Mich.)



species. Because of their small demand for field planting, northern white-cedar, black spruce, and junipers usually are acceptable for interior windbreaks in the Lake States.

If the selected nursery site has existing tree growth, it is desirable to leave 20- to 30-foot wide strips of standing trees, with a spacing of about 600 feet between the strips. A general rule is that windbreaks have a zone of protection equal to approximately 10 times their average height. In the Lake States, one may expect ultimate heights of 60 feet or more for pines. Hence, the zone of reasonably good protection will be about 600 feet.

Natural strips of timber left as windbreaks usually suffer considerable mortality from sudden exposure, breakage, and uprooting in the development of a nursery site. In such cases reinforcement planting, preferably with red pine, white spruce, or black spruce, is necessary.

If the prospective nursery site has no natural growth, parallel shelterbelts or a gridwork of 3- to 5-row shelterbelts of red pine, jack pine, and white spruce should be planted, using at least one row of each and keeping the spruce on the outside. As a supplement to this system, some nurseries use additional shelterbelts of one row of white-cedar, white spruce, or blue spruce spaced between the larger shelterbelt rows. Some nurseries also use interior hedges of trimmed white spruce or juniper at intervals of about 100 feet. Because such hedges suppress growth in adjoining seedbeds, many nurserymen prefer to use slat-wire snow fence supported on posts under every second pipeline. The sapping effect of interior hedges can be reduced considerably by severing their lateral roots with a knife-blade trencher, a plow, or rolling coulter run parallel to the hedge and several feet away from it at 3-year intervals.

In nurseries where mechanical transplanting, cultivation, and lifting are used, long beds or rows are desirable; they should not be interrupted by cross hedges or cross fences.

LAND DEVELOPMENT

The nursery should be carefully staked out on the ground in accordance with the development plan before clearing or leveling is started. The areas to be used for tree production should be defined, as well as the location of roads, natural or planted windbreaks, building sites, and parking areas.

Nursery development requires a variety of types and sizes of equipment, depending upon conditions on the site. Areas that have been in farm crops or pasture do not present so serious a problem as do those that must be cleared of brush, stumps, and tree growth. To maintain uniform fertility, the surface soil must not be disturbed more than is necessary (71); therefore, heavy equipment such as bulldozers should not be used for bunching the trees and brush. Rather, it should be cut and the stumps pulled or removed by blasting. The slash

should be hauled from the area and not burned in place. Burning creates a temporary alkaline condition through release of potash and lime, which may cause serious damping-off, and it destroys some of the valuable humus.

The amount of leveling that is necessary will depend upon the topography and the nursery practices to be used, particularly the method of irrigation. In any event, leveling should be held to a minimum. Moving the topsoil complicates the maintenance of a uniformly fertile nursery soil. Therefore, when it is necessary to do a major job of leveling, the topsoil should be pushed aside and then spread back on the area after the subsoil has been excavated. This operation can be accomplished with a bulldozer, land plane, or road maintainer.

When the site has been cleared, a heavy plow especially designed for breaking new land should be used. This type of plow is sturdily constructed and stands up under use on land infested with roots, small stumps, and clumps of brush. After being plowed, the land should be disked with a heavy tandem disk to cut up the sod and hasten deterioration of the vegetative material. Disking should be repeated and followed by harrowing with a spring-tooth harrow until the land is thoroughly tilled. Pieces of stumps, roots, limbs, and stones should be picked up and hauled off the area. A spike-tooth harrow or drag can be used very effectively in leveling the ground as the last operation prior to placing the land in production. Low areas, almost unnoticeable otherwise, often can be detected readily after heavy rains.

It is very important that the nursery soil be in good tilth and as free of weeds as possible for the production of conifer seedlings. Therefore, pasturelands or areas that have been in heavy sod for a long time preferably should be planted to a cultivated crop or kept fallow before being converted to nursery use.

On areas that have considerable quackgrass, repeated cultivation with a special cultivator is necessary. One nurseryman solved this problem by running a potato digger over such an area and scooping up the quackgrass roots and stones with a fork before doing the regular ground preparation (28).

ROAD SYSTEM

An adequate road system, carefully laid out and well maintained, is essential to efficient operation of a nursery. Major improvements such as warehouses, compost pits, and cone storage facilities must be accessible. Where sufficient area is available and the layout of the nursery precludes planting windbreaks across the ends of the beds, a double driveway with a hedge between the two is a very satisfactory arrangement in the operation of large nurseries (fig. 5, p. 21). Interior roads should be wide enough to provide turning space for tractor-drawn equipment. A 20-foot road width is a minimum for operating and turning

most types of equipment. Thirty feet is recommended particularly for large nurseries where mechanization of nursery operations is proposed.

An application of crushed rock or fine gravel ordinarily is required for main roads. The surfacing should be confined as nearly as possible to a 10- to 12-foot strip down the center of the road. Care should be taken to keep the surfacing material from spreading onto the production areas and becoming mixed with the nursery soil. This is particularly important if the surfacing material contains calcareous rock or fine materials that would lower the acidity of the soil.

FENCES

A well-constructed fence around the nursery is essential to protect the beds from livestock and deer; it should include cattle guards to provide easy access. For nurseries in the Lake States, a heavy galvanized, woven-wire fence is recommended. This type requires slightly more maintenance than the ordinary barbed-wire fence, but maintenance will be reduced if the posts are no farther than 12 feet apart. Close spacing of posts is particularly advantageous in areas where heavy snows tend to pull the fence out of alinement.

PUMPING AND IRRIGATION PLANTS

Because of the relatively light rainfall during the growing season in the Lake States, some type of irrigation is essential while the seeds are germinating and during periods of drought. Accordingly, an adequate supply of water should be available at all times. Ordinarily, this is not a serious problem in the Lake States because of the large number of streams and lakes and the high water table generally present.

An open water source has an advantage over a well in that less investment is required to develop it. Another advantage is that the nurseryman can insure an adequate supply of water, to some extent, by constructing a diversion dam on a watercourse, by impounding a supply, or by dropping the intake channel from a lake to the pumping unit to take care of any fluctuation in the lake level.

Well points may be adequate for small nurseries but are not recommended where a large quantity of water is required. Because of the frequent fluctuations in the depth of the water table as a result of long drought periods and the heavy drain upon the underground water supply, it is difficult to maintain a satisfactory water level in the ordinary shallow well or battery of well points. Increasing the depth of the well as the water table drops or constructing, at the outset, a deep well equipped with a deep-well turbine pump will overcome this difficulty. A deep well usually is more expensive than an open water supply and is recommended only as a last resort.

Pumping From Open Water Supply Into an Overhead Irrigation System

Pumping units drawing from a lake, reservoir, or stream should be placed a short distance back from the water's edge and at least 3 feet above the highest water level that is likely to occur. This will permit the installation of a system for screening or filtering out small particles of sand or debris that could clog the irrigation system. The water should be pumped from a sump connected with the main water supply by a canal or conduit. The size of the sump needed will depend upon the capacity of the pumping units. It should be large enough to insure a constant supply of water even though the flow through the connecting channel may be reduced by the screens placed in the channel. To insure a good head of water passing through the filtration system, the bottom of the sump should be from 4 to 5 feet below the surface of the reservoir.

The number of screens required in a filtration system is influenced by the character and amount of material to be removed from the water. Ordinarily, 3 screens of different sized mesh, placed 16 to 24 inches apart in the channel, should suffice. The first screen usually is of $\frac{1}{4}$ - or $\frac{1}{2}$ -inch hardware cloth and the second and third screens of much smaller mesh, as $\frac{1}{16}$ - and $\frac{1}{30}$ -inch mesh which have proved satisfactory for filtering out very fine material.

Pumping From Wells

Water can be pumped from one or more well points, or an open well, where the water table is within 10 to 20 feet of the surface and the water stratum is composed of sand and gravel. A series of connected well points can be used effectively but an open, gravel-packed well is recommended because it is more efficient and trouble-free.

To construct a gravel-packed well (fig. 7), a 24- to 30-inch, or larger, blank casing is sunk first to the full depth of the well. The fine material is removed from inside the casing with a bucket or dipper as the casing is sunk. Then a perforated casing or well screen is placed in the center of the larger casing. Coarse gravel is packed next to the screen and fine gravel is placed at the outer edge of the well. The level of the gravel should be kept above the bottom of the outer casing as it is raised to the top of the water-bearing strata.

A concrete slab 3 to 4 inches thick is poured on top of the gravel to prevent infiltration of silt and fine material into the well. A section of the outer well casing is left in place to facilitate any maintenance work that may be necessary at a later date. The suction pipe, equipped with a foot valve and strainer and connected to the pump, is placed inside the smaller well casing. This pipe must be airtight and should be long enough to reach within 8 to 10 inches of the bottom of the well.

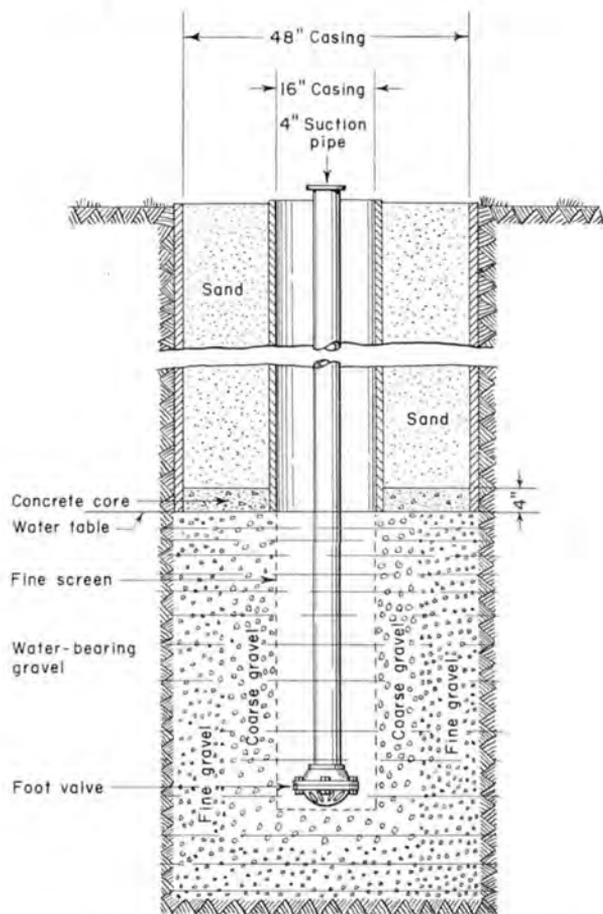


FIGURE 7.—Details of a gravel-packed well.

Because of their simplicity, high efficiency, and low operating and maintenance costs, horizontal centrifugal pumps commonly are used in shallow wells (fig. 8). The maximum suction lift of a centrifugal pump is 18 to 22 feet, a fact to be considered in planning the water system. Single-stage pumps can be used where the required output is low and the total head is less than 150 feet. The total head consists of the sum of (1) suction lift, (2) discharge head, (3) friction head, and (4) velocity head. The latter can be ignored in

the ordinary installations. Where the total head is more than 150 feet, and delivery of 200 gallons or more per minute is required, a horizontal multistage pump is generally recommended. Because the efficiency of this type of pump drops off rapidly when the head varies from that for which the pump is designed, the correct head should be specified very carefully when purchasing the pumping unit.

Where the vertical distance from the pump to the lowest water level is more than the suction lift, a deep-well pumping unit is necessary. Two general types of deep-well pumps are in common use. One, commonly used for wells where the required output is small, is the plunger and cylinder type. The other is the turbine type (including centrifugal, auger, and jet pumps), and it is used where the required output is large and pumping must be continuous. As a rule, the turbine-type, deep-well pump has a higher initial cost, but, in most cases, this can be justified by low operating costs and long life of the pumping unit. Vertical, multistage, turbine-type pumps have been in use in U. S. Forest Service nurseries for a number of years and have given satisfactory service.

Because they are simple to operate, electric motors ordinarily are recommended as a source of power for pumping units. However, power costs should be investigated thoroughly and operating costs determined carefully before deciding on the installation of electric motor-driven pumping units. Squirrel cage, induction, open-type electric motors, designed for operation on 3-phase, 60-cycle, 440-volt current, are recommended where electric power is used.

A gasoline engine power unit usually is cheaper to install and operate than either diesel or electric units, and it is recommended for the average nursery. The industrial-type gasoline engine should be chosen instead of an automobile engine because it is more compact, more sturdily constructed, and a more efficient power unit. In order to insure against serious losses in the seedbeds by drought or heat as a result of a breakdown of the pumping unit, a standby unit should be installed.



FIGURE 8.—Pump on right is a 225-gallon-per-minute, double-suction centrifugal, driven by a 15-hp., single-phase, electric motor. Pump on the left is of the same type and capacity but made by a different manufacturer.

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Distributing Mains

A well-designed system of water mains for distributing water to the various sections of the nursery is required for overhead irrigation. Because irrigation equipment is not in use during the winter, the pipes need not be put down below the frostline provided they are installed on a slight gradient to permit draining the system in the fall. A convenient depth is 18 to 24 inches, which places the mains below the plow level and affords adequate support for the risers. To provide for the contraction and expansion due to temperature changes, an expansion joint should be included for every 1,000 feet of main.

The size of pipe used in the system varies with the size of the nursery, the overall length of the mains, and the amount of water to be delivered. For a typical 20-acre setup, 6-inch pipe is used first; after about 600 feet, a 4-inch size is used, and 3-inch lateral pipes are placed at right angles to the 6- and 4-inch pipes. A nursery layout of the water-main system for a nursery of about 50 acres is shown in figure 9.

Ordinarily, it is not necessary to sprinkle the entire nursery at one time and, in any event, it is not practical to install pumping facilities of sufficient capacity to operate all of the overhead lines simultaneously. The number of lines that should be considered will depend upon the ability of the proposed system to supply those farthest from the source of supply. It is helpful in laying out a water system to know the frictional losses in pipes of various sizes and different discharge rates per minute (table 8).

The following data are necessary in determining the pipe sizes needed when water is pumped from

a well or reservoir through a system of mains and distributed through overhead irrigation lines:

1. Working pressure required at the most distant unit served. Pressure in pounds per square inch can be converted to feet of head by multiplying by 2.31.

2. The flow in gallons per minute required at the most distant unit served.

3. Elevation difference in feet between the water level at source of supply well or reservoir and the point of discharge.

4. Loss in head resulting from friction as the water flows through the pipe (see table 8).

5. Total head in feet required to deliver the water to the point of discharge. This is the summation of the head at the outlet plus elevation head and friction head loss expressed in feet.

Example: Assume 800 feet of pipe, including the intake pipe, is required to deliver 200 gallons per minute to the farthestmost section to be served; the pressure required in the pipe at the discharge point is 30 pounds; and the difference in elevation between water level and point of discharge is 15 feet. The total head in feet then becomes—

Head (pressure) at point of discharge (30 x 2.31)	69 feet
Friction head loss, 200 g. p. m. through 800 feet 3-inch pipe (17.8 x 8)	142 feet
Elevation head	15 feet
Total head	226 feet

Experience has shown that the total head should not exceed 275 feet and that pump capacities of 200 and 225 gallons per minute, per individual pump, are most practical for nursery installations. Several pumps, of course, may be needed in larger nurseries.

The horsepower required to operate a pumping unit is directly proportional to the total head and

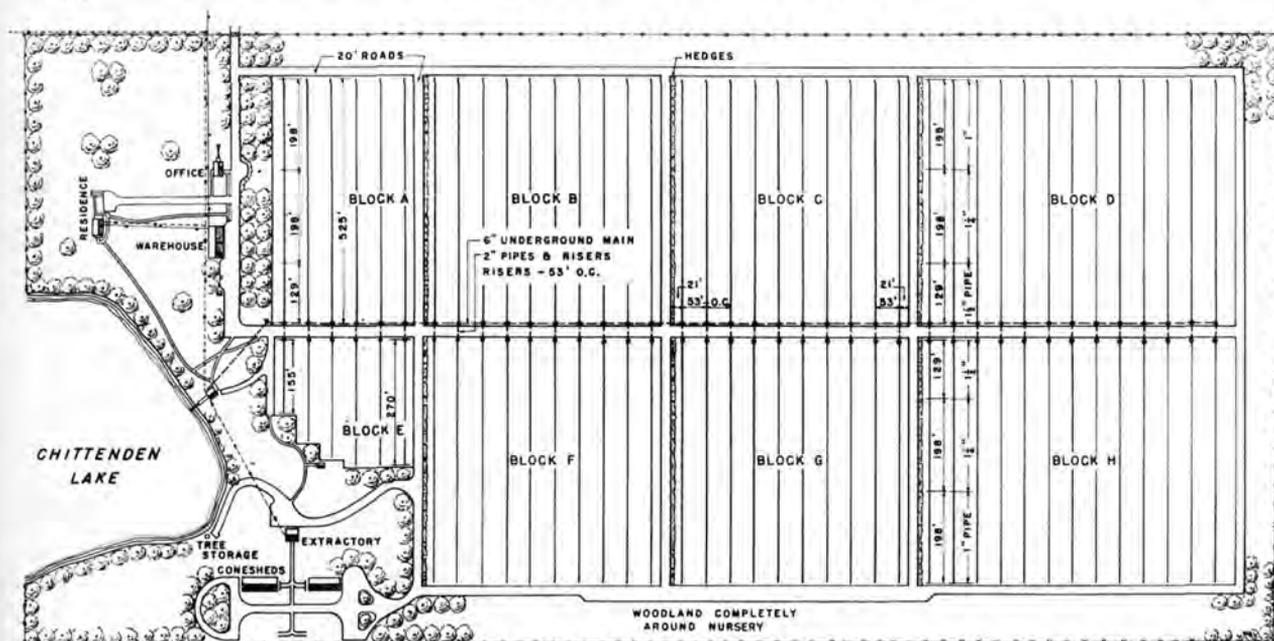


FIGURE 9.—Diagrammatic layout of water system at Chittenden Nursery, Wellston, Mich.

TABLE 8.—Loss in head in 15-year-old ordinary iron pipe, caused by friction per 100 feet of pipe

Discharge (gallons per minute)	Loss of head when pipe size was—											
	½- inch	¾- inch	1- inch	1¼- inch	1½- inch	2- inch	2½- inch	3- inch	4- inch	5- inch	6- inch	8- inch
1	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
2	2.1											
3	7.4	1.9										
4	15.8	4.1	1.26									
5	27.0	7.0	2.14	0.57	0.26							
10	41.0	10.5	3.25	.84	.40							
15	147.0	38.0	11.70	3.05	1.43	0.50	0.17	0.07				
20		80.0	25.00	6.50	3.00	1.08	.36	.15				
25		136.0	42.00	11.10	5.20	1.82	.61	.25				
30			64.00	16.60	7.80	2.73	.92	.38				
35			89.00	23.50	11.00	3.84	1.29	.54				
40			119.00	31.20	14.70	5.10	1.72	.71				
45			152.00	40.00	18.80	6.60	2.20	.91	0.22			
50				50.00	23.20	8.20	2.80	1.15	.28			
55				60.00	28.40	9.90	3.32	1.38	.34			
60				113.00	53.00	18.40	6.21	2.57	.63	0.21		
75					60.00	20.90	7.10	3.05	.73	.24		
100					102.00	35.80	12.00	4.96	1.22	.41	0.14	
120					143.00	50.00	16.80	7.00	1.71	.58	.25	
125						54.00	18.20	7.60	1.86	.64	.28	
150						76.00	25.50	10.50	2.55	.88	.32	
175						102.00	33.80	14.00	3.44	1.18	.48	
200						129.00	43.10	17.80	4.40	1.48	.62	
225							54.30	22.30	5.45	1.86	.74	
250							66.00	27.20	6.72	2.24	.92	0.22
270								31.30	7.70	2.60	1.13	.25
275								32.50	7.90	2.72	1.15	.27
300								38.00	9.30	3.14	1.29	.32
350									12.32	4.19	1.75	.42
400									16.00	5.40	2.21	.54
450									19.80	6.70	2.65	.68
470									22.40	7.22	2.90	.75
475									22.96	7.42	2.95	.76
500									24.00	8.12	3.30	.82
550										9.60	3.93	.97
600										11.30	4.70	1.14
650										13.20	5.40	1.34
700										15.10	6.20	1.54
750										17.20	7.00	1.74
800											8.00	1.97
850											8.95	2.28
900											10.11	2.46
950											10.80	2.87
1,000											12.04	3.02
1,050											13.30	3.21
1,100											14.31	3.51
1,150											15.60	3.84
1,200											16.69	4.15
1,250											18.50	4.45
1,500												6.27

influences the economical operation of the unit. Horsepower can be determined by the following formula:

$$HP = \frac{G. P. M. \times H}{3,950 \times E} \text{ where } HP = \text{horsepower}$$

required; G. P. M.=gallons per minute to be discharged; H=the total head in feet; and E=efficiency of the pump.

For example: In determining the horsepower required to operate a pump having a capacity of 225 gallons per minute, at a total head of 226 feet, and a rated pump efficiency of 60 percent, the formula becomes:

$$HP = \frac{225 \times 226}{3,950 \times 0.60} = 21.45 \text{ or } 22.$$

Irrigation Systems

It is important to develop an adequate and efficient method of irrigation in most sections of the Lake States because the sandy loam soil best adapted for nursery production loses water rapidly. To some extent, the general contour of the area selected will dictate the method that can be used. Ditch irrigation, a method commonly used in agriculture, is not satisfactory for Lake States nurseries.

Overhead irrigation is most commonly used in conifer nurseries. Because overhead systems are efficient, simple to operate, and relatively cheap to maintain, their higher installation cost usually can be justified. Both portable and permanent types are in common use. Where it is necessary to irrigate frequently to prevent drought, counteract freezing, and control wind erosion, a permanent system is recommended. Such a system, including water mains, overhead pipes, motors, pumps, and automatic oscillators, cost about \$500 to \$600 per acre in 1951; labor and supervision for trenching water mains and installation cost about another \$150 per acre.

The portable system is equipped with quick-action couplings and connections so that it can be taken apart easily and moved from one section of the nursery to another. It is easier and cheaper to install and requires only $\frac{1}{3}$ to $\frac{1}{2}$ as many overhead lines as the permanent system. However, the frequent tearing-down and re-erecting of the system adds to maintenance costs and makes it as expensive as the permanent type within a few years.

The length of overhead lines and the number of lines required for each compartment will be dictated by the length and width of the compartments. The maximum length of line that can be used effectively is approximately 525 feet. Lines longer than this require the use of large pipe, which increases the weight of the line and makes repair more difficult. Where extremely long lines are used as a unit, there usually is some lag in turning the relatively flexible pipe at the far end of the line. This results in poor coverage of the area. Although this difficulty is sometimes experienced in lines 525 feet long, the trouble can be overcome by keeping the pipe in perfect alignment and using a satisfactory type of pipe support.

The commonly used overhead irrigation system consists of a series of parallel pipes usually spaced 52 to 53 feet apart and resting on pipe supports at 12-foot intervals on which turns an entire section of coupled pipe 200 to 500 feet long.⁹ The pipe supports have rollers to reduce friction. About every 3 feet the overhead pipe has brass or other rust-resistant nozzles that supply 7 to 8 gallons per minute per 100 feet of line, or an inch of water in 7 to 9 hours. An oscillator commonly turns the

⁹ A spacing of 53.0 feet between pipelines is often used in Forest Service nurseries, with a 1.0-foot path on either side of the pipeline and a 1.22-foot path between each of the ten 4-foot-wide beds.

pipe so that about 28 feet of soil on either side of the pipeline is watered. The water, coming from the mains and up through the riser, passes through the oscillator. The pressure of the water makes the whole length of overhead pipe oscillate through 90 to 110 degrees of arc, half of it on each side of the pipeline.

A typical overhead irrigation pipeline includes risers, oscillators, flush valves, and pipe supports (fig. 10). Flush valves at the end of the line and a bibb on every second riser are necessary. Bibbs are useful for such tasks as packing stock and watering ends of beds.

Roads and pipelines should be located with a transit, and all underground parts and fittings of the water system should be plotted accurately on a map with exact distances, locations, and dimensions. Such a map will be very useful in draining or repairing the water system.

Overhead irrigation pipe and fittings can be obtained from several irrigation equipment supply companies, or it may be made up at the nursery. If made at the nursery, the outlets in the pipe for insertion of the small nozzles must be well aligned. However, where a substantial amount of overhead pipe is to be used, it ordinarily is cheaper and more satisfactory to purchase the drilled pipe.

Wherever possible, standard pipe lengths should be used because assembly is more rapid and uniform, and repairs or replacements are easier. To assure uniform distribution of water throughout the length of the overhead line, runs of various lengths of different sizes of pipe are required. The pipe sizes specified by most suppliers differ slightly from the specifications set up by the Forest Service. Forest Service specifications are for slightly larger pipe to give good pressure at the far end of the line (table 9). To provide for a uniform assembly at the riser so as to facilitate

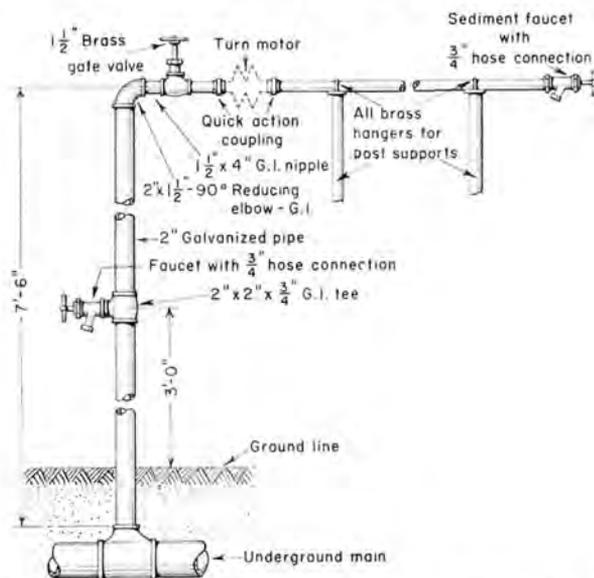


FIGURE 10.—Overhead system of irrigation, showing assembly.

interchanging of the turn motors which are used for oscillating the lines, at least one length of 1½-inch pipe has been specified for each line.

TABLE 9.—Standard pipe required for overhead irrigation lines

Total length of line (feet)	1½-inch pipe		1¼-inch pipe		1-inch pipe	
	Length of run	Pieces 18-foot pipe required	Length of run	Pieces 18-foot pipe required	Length of run	Pieces 18-foot pipe required
	Feet	Number	Feet	Number	Feet	Number
54	18	1	0	0	36	2
72	18	1	0	0	54	3
90	18	1	0	0	72	4
108	18	1	0	0	90	5
126	18	1	0	0	108	6
144	18	1	0	0	126	7
162	18	1	0	0	144	8
180	18	1	0	0	162	9
198	18	1	0	0	180	10
216	18	1	0	0	198	11
234	18	1	18	1	198	11
252	18	1	36	2	198	11
270	18	1	54	3	198	11
288	18	1	72	4	198	11
306	36	2	72	4	198	11
324	36	2	90	5	198	11
342	36	2	108	6	198	11
360	36	2	126	7	198	11
378	36	2	144	8	198	11
396	54	3	144	8	198	11
414	54	3	162	9	198	11
432	54	3	180	10	198	11
450	54	3	198	11	198	11
468	72	4	198	11	198	11
486	90	5	198	11	198	11
504	108	6	198	11	198	11
522	126	7	198	11	198	11

Protection Against Freezing

Damage from freezing resulting in burst water pipes and oscillators should be avoided. Not only should the oscillators on the overhead irrigation lines be drained during the early spring and late fall when temperatures frequently go below freezing, but the complete system also should be drained when fieldwork is completed in the fall. This usually is done by opening the gate valve on the discharge side of the pump and removing the suction pipe to allow the water to run back through the pump. Points in the line that cannot be drained in this manner should be drained by opening valves or by removing a plug at the low points.

The pumps must also be drained by removing the bottom plugs provided for this purpose. The overhead lines are drained by turning them so that the nozzles are pointing down. To insure

that the nursery is closed satisfactorily for the winter, the nurseryman should have a list of the various jobs to be done and check them carefully.

NURSERY BUILDINGS AND OTHER INSTALLATIONS

The number and types of buildings required for the efficient operation of the nursery will be influenced by its size and permanency. Each nursery will need certain structures for adequate storage and protection of equipment (fig. 11).

Pumphouse.—Obviously, it is important that the pumping equipment be protected adequately. The building should be large enough to accommodate at least two units and to provide sufficient space in which to do light repair work on the equipment. The pumphouse never should be used for purposes that will expose the equipment to damage.

Warehouse.—The amount of warehouse space required will depend to some extent upon the amount of equipment to be stored. Some equipment, such as seedbed boards, bed screens, etc., can be stored out-of-doors, but storage room should be provided for the mechanized equipment. Experience has shown that it is more economical to build a large warehouse that ac-



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FIGURE 11.—Note office in foreground, garage in center, and field warehouse upper left. (Griffith State Nursery, Wisconsin Rapids, Wis.)

commodates a number of pieces of automotive equipment and small tools than it is to build several small buildings for special types of equipment.

For storing farm implements, a closed-shed type of building has proved to be very satisfactory and very economical. If a blacksmith shop is proposed, fire protection dictates that it not be in the warehouse. Some nurseries find it advantageous to have a repair shop in one end of the warehouse, or in a separate building.

Office building.—The nurseryman should have an office in which to keep his records and conduct business with the public and nursery personnel. In some instances it is expedient to locate the office in one of the warehouses, but a separate building has proved to be more satisfactory at the Forest Service nurseries throughout the Lake States. To handle such jobs as seed testing and soil analyses, simple laboratory facilities are desirable in the administrative building. The office should be convenient to the nursery work and easily accessible to the general public.

Seed house.—A small supply of seed kept on hand to meet production needs can be stored for short periods in a room set off for this purpose in one of the nursery buildings. If a large supply is involved, the value of which is considerable, it is desirable to have a separate building for seed storage. The species commonly used in the Lake States keep much better at low temperatures (33° to 41° F.), so the seed-storage building should be well insulated and equipped with a thermostatically controlled refrigeration unit. The size and type of the unit will depend upon the size and type of building and the outside temperatures which normally exist. A competent refrigeration engineer should be consulted about specifications for the refrigeration unit.

Some nurserymen have found it convenient and economical to build the seed-storage room in the side of a hill. The temperatures to be maintained and the location of the seed-storage room influence the type of construction and the kind of insulation that should be used. Reinforced concrete usually is specified for underground walls, roofs, and floors. In addition, several thicknesses of cork board ordinarily are necessary on the inner walls for adequate insulation, and a thick coat of asphalt on the outer walls for moisture-proofing. Ground cork and one or two thicknesses of cork board to reduce heat exchange through the walls and ceiling are recommended for seed-storage buildings built aboveground. Specifications for such a building are available from the Regional Forester, U. S. Forest Service, Milwaukee 3, Wis.

Seed-extractory and cone-storage buildings. If the demand for local seed is large or several nurseries are to be supplied, it is advantageous to have an extractory. The Forest Service has two types of extractories in the Lake States—the con-

vection and the internal-fan types (119). They each require about the same kind of housing, but the cost of equipment for the convection type is much less than for the steam-heated, internal-fan type.

The space needed for cone storage varies with the species and the method of storing. It is important that the cone-storage sheds be located near the extractory and connected to it by ramps to facilitate the handling of the cones. However, the buildings should be spaced far enough apart to facilitate fire protection.

Compost pits.—It is desirable for each nursery to have one or more pits in which to prepare compost. Materials stratified in a heap lose much of their value as compost. A simple pit is a rectangular hole dug in the ground with the sides "cribbed up" with poles or planks. However, experience has proved that for long life the pit should be built of reinforced concrete.

The floor of a concrete pit should have a slight gradient to allow drainage toward one end where the percolate, which contains a high concentration of mineral fertilizers, can be recovered. Usually, a cistern is provided as a catch basin for the runoff. At least one wall should be removable to facilitate loading and unloading. Pits constructed below the general level of the surrounding ground are not so desirable as pits constructed on the ground, because they are subject to flooding. Enough space should be left near the pit to permit piling the material to be stratified and to operate a shredding machine where necessary.

The size of the pit depends upon the annual need for compost fertilizers. A pit 50 by 20 by 4½ feet, with a capacity of about 166 cubic yards, will suffice for treating approximately 5 acres of seed-bed at the rate of 1 cubic foot per 50 square feet of bed, or 32.2 cubic yards per acre.

Puddled clay compost pits work reasonably well. To make one, a shallow hole, some 15 by 20 feet, is covered with several inches of fine clay that is moistened and tamped or rolled with a sheep's-foot roller. This creates a fairly impervious layer that will retain the nutrient-laden liquids of the compost heap.

Nursery dwelling.—Where the nurseryman must be on 24-hour call, a modern dwelling at the nursery is desirable. However, nurserymen often prefer to live in a neighboring town.

Cold storage building.—Nurseries that have a large production program and a long shipping season in the fall and spring require adequate storage facilities. The initial cost, together with subsequent maintenance, usually makes such plants impractical for small nurseries.

Forest Service experience in the Lake States has indicated that a storage capacity for 1 to 1½ million trees is required for nurseries having an annual production of 5 to 8 million trees. This is based on shipping stock during both the fall and spring. A building 27½ by 48 by 9 feet will suffice for this

storage providing most of the stock is seedling age. About 400 bundles of stock can be stored on pallets. The number of conifers per bundle for various classes of stock averages about as follows: 3.7 thousand for 2-0, 1.6 thousand for 3-0, 1.8 thousand for 2-1, and 0.6 thousand for 2-2.

The Forest Service has found that cold storage buildings built partly underground have functioned as well as those entirely above ground. The essentials of a satisfactory plant are an adequate refrigeration system, proper insulation, and good construction. The walls should be moisture-proofed to prevent rot in the wooden members as a result of condensation on the walls and ceiling. Adequate ventilation also is necessary while the plant is standing idle.

Most hardwood species are not so sensitive to rapid changes in weather conditions as are conifers. They can be stored satisfactorily on racks in a building that has been properly insulated and constructed for the control of temperature, humidity, and aeration (47).

Dressing room for laborers.—A clean room or building in which employees can wash up and change their clothes helps to maintain high morale and good production. The type of a building to

provide will depend upon local conditions and regulations governing such facilities.

Landscaping.—It is desirable to maintain the natural appearance of the nursery. Landscape planting should be simple and limited to screening from view areas that would otherwise detract from the appearance of the nursery. Areas of lawn should be held to a minimum. Native species that grow on areas not suitable for nursery production should be protected and encouraged. However, undesirable species or plants that are hosts for disease or insect pests should be removed. Parking accommodations should be provided for visitors where their cars will not be damaged by traffic within the nursery nor interfere with nursery operations.

Fire protection.—To minimize the danger of fire loss, the nurseryman should arrange with the local fire department to answer emergency calls. Facilities for fighting fires also should be included in the development plan.

Cash investment in a nursery.—The investment in a forest nursery, including buildings, overhead irrigation, and equipment, is substantial. The cost of several typical Lake States nurseries of 20 to 50 acres, developed before 1937, ranged from \$70,560 to \$171,500 (23).

NURSERY PERSONNEL

Much of the work in a forest tree nursery is similar to farming or gardening, but the crop is distinctly different. Therefore, it is important that the nursery superintendent have some technical training in forestry or horticulture. He must (1) have some knowledge of agronomy and the origin and composition of soils; (2) be able to recognize insect and disease attacks and take prompt remedial action; (3) be capable of training personnel, organizing and supervising crews, and planning the various nursery projects; and (4) be able to design and construct simple, efficient pieces of equipment to meet special needs. A capable assistant nurseryman is also desirable.

A few year-round key personnel are needed, and most nurseries require some seasonal supervisory personnel who are capable of doing a variety of jobs and of accepting responsibility. A backlog of work for the year-round key personnel can be provided by postponing until fall or winter such

tasks as overhauling equipment, constructing new equipment, building up of stocks of materials, and extracting seed.

The importance of a local labor supply has already been stressed. Labor recruited from distant sources usually requires living quarters and mess at the nursery, which imposes extra work upon the nurseryman. Also, experience has shown that local labor is more satisfactory than transient labor, both because local residents usually are interested in doing a better job and because there is less of a labor turnover.

Where local labor is in short supply, it is highly desirable for the nurseryman to develop methods of work that will permit him to employ both men and women. Operations that require nimble fingers usually can be performed better by women than men. Women also are very effective on other light work where physical endurance or strength is not required.

MACHINERY, TOOLS, AND SPECIALIZED EQUIPMENT

Mechanization of most phases of nursery operations has resulted in a marked reduction in manpower requirements. Studies in other regions have shown a reduction up to 97 percent for seeding (92) and of 76 percent for all operations (48). Comparable savings doubtless have been made in Lake States nurseries through labor-saving devices.

Many of the standard pieces of farm equipment, such as plows, disks, and harrows, can be used effectively in the nursery. However, special types, including seeders, transplanters, cultivators, root pruners, and lifters, must be constructed locally or modified from commercial models. For standard equipment some modification is usually necessary because of differences in soil types.

It is important that all equipment, including small tools, be kept in good condition. This can be accomplished only by current inspection of each piece and replacement of wornout or broken parts. All equipment and machinery should be stored under cover during the winter or other periods when not in use.

Equipment placed in storage for long periods should be thoroughly cleaned and oiled beforehand. In addition, a thin coat of heavy oil should be applied to equipment surfaces that come in contact with the soil; for example, the plow point, moldboard and landside on a plow, and the disks on a disk harrow.

TRACTION EQUIPMENT

Tractors and other motorized equipment have almost completely replaced horses in Lake States nurseries. In choosing a tractor, the nurseryman should consider the jobs and the character of the soil on which the tractor primarily will be used. The job of pulling the tree lifter through the beds at a depth of 8 to 10 inches probably will be the heaviest job that the tractor will have. Consequently, where only one tractor is available it should be of a size adequate for that job. If the nursery is large enough to justify having 2 tractors, it is best to have 1 large tractor and 1 small tractor.

The wheel-type tractor is preferred to the crawler-type for general nursery work. This is because it is more maneuverable and less expensive to operate. One with 33- to 35-drawbar horsepower is satisfactory for the heavy work, such as plowing, disking, or pulling the tree lifter; for the light work, such as drawing a utility trailer, mechanical seeder, or fertilizer spreader, 15- to 18-drawbar horsepower is adequate.

GROUND PREPARATION EQUIPMENT

A sturdily constructed plow and disk harrow usually are required for breaking new ground or plowing old fields with brush or a heavy sod. Following initial ground preparation, a 16-inch, 2-bottom plow, or a 26-inch disk plow with disks 10 to 12 inches apart, is a very effective tool for turning under soil-improvement crops and doing general tillage work. Disk plows and chisels are favored by some as a safeguard against formation of a plow sole.

Where dead furrows are a hindrance in maintaining a level seedbed, a two-way plow is useful. It is fitted with both a right- and left-hand bottom and, when plowing back and forth across the field, it throws all of the furrows one way.

A spike-tooth harrow aids materially in breaking clods and can be used effectively for leveling the ground. Various depths of penetration can be obtained by adjusting the angle of the spikes. The width of cut varies with the size of the single section and the number of sections hooked together and pulled abreast as a unit.

The spring-tooth harrow is useful for shallow cultivation in the final preparation of seedbeds. It can also be used to dig out quackgrass and other noxious weeds, and to rake debris to the surface. Depth of penetration is governed by changing the pressure on the teeth. This tool is made in sections and the width of cut is governed by the number of sections assembled as a unit.

After being cleared or cultivated, the land usually can be leveled with a "float" drawn across the field at right angles to the direction traveled earlier by the harrow. The nurseryman can build a "float" by lapping four or five 10- or 12-inch planks, 8 to 10 feet long, and securely fastening them together with bolts or spikes; they should be braced across the top to give the unit rigidity. Short lengths of chain fastened 24 to 30 inches from the ends of the front plank will serve as a hitch. Extra weight or pressure can be obtained by using stones or sandbags as ballast.

The rotary tiller is a new tool that in effect plows, disks, and harrows in one operation. It has proved very satisfactory for preparing ground and working compost and green cover crops into the soil. Also, this tiller is ideal for preparing a very loose, friable seedbed in light sandy soils. However, it has the disadvantage of destroying crumb structure and so rendering the soil more subject to wind erosion. Tests in

Forest Service nurseries indicate that the rotary tiller is effective in destroying some insects, such as white grubs, which infest the soil and feed on the roots of seedlings.

This tool has a high-speed rotor equipped with tines that pulverize and thoroughly mix the soil. The very small models are compact, self-propelled units, and the larger ones, which vary from 3 to 6 feet in width, operate from a power takeoff or are powered by an engine mounted on the forward part of the machine (fig. 12). The power is



F-464650, 355838

FIGURE 12.—A, A self-propelled rotary tiller. B, A 4-foot rotary tiller operated by power takeoff from a tractor.

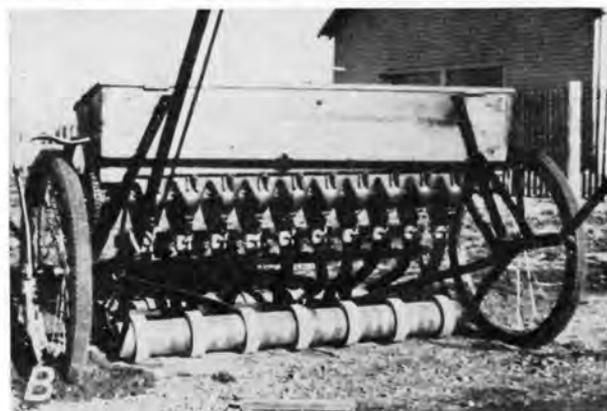
transmitted by a double universal joint and spiral bevel gear to the rotor assembly. A hood mounted over the rotor confines the pulverized soil to the area being tilled. Depth of tillage is accurately controlled by adjustments provided by the rotor lifting bar.

SEEDING EQUIPMENT

It is important that uniform stands of seedlings or cover crops be obtained. Although broadcast seeding by hand can be done quite successfully by trained and experienced help, it cannot be done with the uniformity and efficiency that is obtainable with mechanical seeders.

The ordinary farm grain drill is used in the Lake States nurseries to advantage for seeding cover and green manure crops. These machines are adaptable to sowing grain, grass, and legume seeds, and can be adjusted to sow at desired rates per acre. Since slightly better results can be obtained if the seed is firmly packed, drills equipped with packing attachments are recommended for use in sandy soils. Experience has shown that an 8-foot drill is better adapted to nursery requirements than either a wider or narrower drill. Grain drills can be obtained with attachments for fertilizing the crop at time of drilling the seed.

Because of the limited demand for equipment that will handle tree seed, it usually is necessary for nurserymen to design and construct their own seeders. Seed drills used in the Forest Service nurseries in the Lake States for conifer seed (fig. 13) are composed of standard parts available on various types of commercial equipment. The grain cups and grain tubes that convey the seed from the hopper to the seeding assembly are from a commercial farm seed drill.



F-464643, 464646

FIGURE 13.—A, Standard 4-foot-wide, 10-row conifer seed drill. Seeding rate can be adjusted by changing the size of the sprocket gears on the right side of the machine. The machine is pulled by two men or by a bed-straddling tractor. B, A 7-row seed drill with flanged roller that controls depth of seeding.

The seeding assembly parts, including an adjustable furrow-opening shoe, a furrow coverer, and a packing wheel mounted on a frame, are from commercial hand seeders.

Although the basic tree seeder will sow 10 drills lengthwise of the seedbed in one operation, fewer drills can be sown by closing off as many grain cups as desired and spacing the seeding assembly accordingly. The spacing between drills where 10 drills are made per 48-inch bed is 4.6 inches. Broadcast seeding can be done with this seeder by removing the seeding assembly and substituting a splashboard on which the seed strikes as it falls to the ground.

The basic seeder is designed to sow seeds of various conifers at different densities as required. For the larger seed, rate of sowing is regulated by a change of gear ratios and size of the grain cup opening by an adjustment of the hopper bottom; for the very fine seed, grain cup reducers are inserted.

Some nurseries use lawn seeders for broadcast seeding of beds, subsequently covering the seed with sand by means of a mechanical sander or, in case of small lots, by hand. These seeders range in width from 18 to 48 inches. The narrow model, in two trips on each bed, seeds slightly less than half of the bed and leaves an unseeded strip down the middle.

A mechanical drill seeder can be used for a few of the broadleaf species, such as mountain ash, yellow birch, and black locust. Maple and ash seeds whose wings are difficult to remove, and acorns and nuts, can best be seeded by hand in small, open furrows. Several simple tools are available for making these furrows (fig. 14).



FIGURE 14.—A 5-row furrow opener for hand-seeding hardwood species.

FERTILIZING EQUIPMENT

It is important that fertilizers be distributed as evenly as possible in order to produce uniform crops of seedlings. Several types of manure spreaders are available for distributing manures and composts. These machines vary in capacity but all are equipped with devices to regulate the

rate of application. Machines that shred or break up clods are preferred because they spread fertilizer more evenly than other types of machines.

There are attachments, to be used on grain drills, for applying mineral fertilizers. These devices are satisfactory when the fertilizers are sufficiently uniform in texture to flow evenly. If relatively heavy applications of mineral fertilizer are required, a spreader designed for lime or other fine materials can be used effectively. This equipment, mounted on wheels, consists of a hopper with adjustable, slotted openings in the bottom. An agitator mounted within the hopper and slightly above the openings maintains an even flow of fertilizer, and a baffle board, mounted at an angle beneath the openings, disperses the fertilizer uniformly. Fertilizer spreaders of this type can be obtained in widths of 2 to 10 feet with capacities of 1 to 18 bushels.

TRANSPLANTING EQUIPMENT

Hand transplanting of nursery stock has almost disappeared in the larger Lake States nurseries because of the availability of agricultural equipment that can be easily modified. For small operations, where the investment in a transplanting machine cannot be justified, hand methods and equipment can be used very effectively (fig. 15).

The mechanical transplanter used in Lake States nurseries is a modification of the commercial transplanter for celery, tomato, and cabbage plants (fig. 16). This self-propelled machine is equipped with a self-steering device. The power unit is a small, air-cooled, gasoline engine that can be regulated for various speeds. Power is transmitted to the clutch shaft by a V-belt drive and thence, by a series of sprockets and drive chains, to the rear driving wheels. The planting devices include revolving disks with plant pockets or holders, a 12-inch rolling coulter, a furrow-opening shoe, 2 packing wheels, a plant-box holder, and an operator's seat.

The operation of the planter is relatively simple. As the unit travels over the ground at 11 to 14 feet per minute, the coulter and shoe open a trench 2 inches wide and 6 inches deep. The seedlings are placed in the pockets of the revolving plant-holding disks, with their tops toward the center of the disks. When they reach an upright position in the trench, they are released and packed firmly in the ground by the packing wheels.

The 2 planting units with which the machine is equipped are demountable and can be adjusted to 7 positions on the drawbar to vary spacing between rows. The machines used in Forest Service nurseries in the Lake States will plant in two adjacent beds at one time; this provides an even draft and facilitates guiding the machine to produce evenly spaced rows. Machines that transplant a full bed of 5 or 6 rows, evenly spaced, simultaneously, are in operation at 2 nurseries in Ohio and 1 in Wisconsin.



F-473980, 409148

FIGURE 15.—A, A hand trencher for transplanting operations. Blade, 2 pieces of $\frac{1}{4}$ -inch steel 14.5 by 6.5 inches in size, 2-inch spread at top; handle, 32.5 inches long; handle grip, 1-inch iron pipe 13.5 inches long; braces, $\frac{1}{2}$ -inch solid iron bars. B, A tractor-drawn trencher.

WEEDING AND CULTIVATING EQUIPMENT

Although much of the weeding in conifer nursery beds now is done with oil sprays, there still is a need for mechanical tools for removing weeds resistant to sprays. Because of the close spacing used in the seedbeds and the susceptibility of the small seedlings to mechanical injury, few of the standard mechanical garden tools can be used. Some, however, such as the rotary type of hoe and cultivator, and wheel-type cultivators with adjustable attachments, can be used for cultivating conifer transplant beds and hardwood seedbeds.

Lake States nurserymen have developed a rotary-type mechanical weeder and mulcher. This tool has proved very effective in weeding seedbeds during the very early period of germination when hand-weeding methods and applications of herbicides would damage the young seedlings. It consists of a battery of small rotors equipped with metal spines that stir and mulch the ground as they rotate. The rotors are powered by sprockets and chains from a main drive shaft that receives its power from a small gasoline engine mounted forward on the frame of the machine. The frame on which the rotors and engine are mounted is supported on four small pneumatic-tired wheels. Although the machine is not self-propelled, the action of the rotors gives it a forward motion. The additional power required to draw the machine over the beds is furnished by two men.

Another very effective tractor-drawn mechanical weeder was devised by the Tennessee Valley Authority and adopted by the Wisconsin Conserva-



F-450868

FIGURE 16.—Transplanting machine used in the Lake States.

tion Department (179). This tool (fig. 17) consists of a standard Planet Jr. pulverizer attachment No. 7730X equipped with shields; each cultivator unit is mounted independently on a rubber-tired carrier unit. The entire battery of cultivators can be moved to either side by wheel or lever while the unit is in forward motion. Thus, it is possible to follow slight unevenness in rows and to compensate for the tendency of the cultivator to creep sideways on gentle slopes. The cultivator rotors get their chopping-knife action by forward motion of the entire cultivator unit. This device has been successfully used in 10-row, 4-foot-wide beds where space between rows is about 4.5 inches.

Garden hoes, rakes that have been cut down, and stirrup hand hoes are effective for weeding and cultivating close to the rows of seedlings where mechanical methods of weeding and cultivation are impractical.

LIFTERS AND ROOT PRUNERS

Two types of tree lifters, the single-row U-blade type and the multiple-row sled type, are effective for removing seedlings from the beds without injury to the plant root systems. Originally lifters were horse-drawn, but various schemes for mounting them have been worked out successfully (fig. 18). Because the U-blade type is light in weight, it is easily mounted directly on a tractor. The sled-type digger (fig. 19) can be pulled by a tractor or it can be drawn through the beds by means of a winch and cable. The latter method affords better control of the tool and an additional advantage is gained through making the tractor easily and quickly available for other work. This tool does a better job of stirring up the soil and loosening the trees if short pieces of flat steel are attached to the blade.

The separate unit sled-type lifter can be mounted on wheels or supported on an easily removable skid-shoe for transportation from one point to another. The latter scheme has proved more convenient. Another type of carrier consists of a unit of channel iron on the back of the tractor on which the lifter can be suspended.

Where wide spacing is used in propagating hardwood seedlings, the single-row, U-blade lifter has proved more satisfactory than the multiple-row tree lifter. Since the crowns of most hardwood species are larger than those of conifers and slightly longer roots are required, the digging tool should provide for greater crown clearance and greater cutting depth.

The tools used for lifting are not entirely satisfactory for root pruning seedlings in place, because a thin, sharp blade is required. A tool that has been used in the Lake States nurseries with some success is a U-shaped blade mounted on a sled-type frame similar to one on which the tree lifter blade is mounted. The horizontal section of the blade is made of high-grade steel (bandsaw steel) and is bolted to the vertical sections with cap



F-476-83, 476384

FIGURE 17.—Rotary weeders for seedbeds sown in drills. A, Overall view; B, closeup of rotary hoe units.

screws. The blade is 52.4 inches long, 1.75 inches wide, and 0.08 inch thick. Two holes are drilled 0.75 inch from each end of the blade into which the cap screws fit. It is kept taut by a brace between the upright sections about one-third of the distance from the top of the vertical sections, and by means of a rod equipped with a turnbuckle that connects the side pieces.

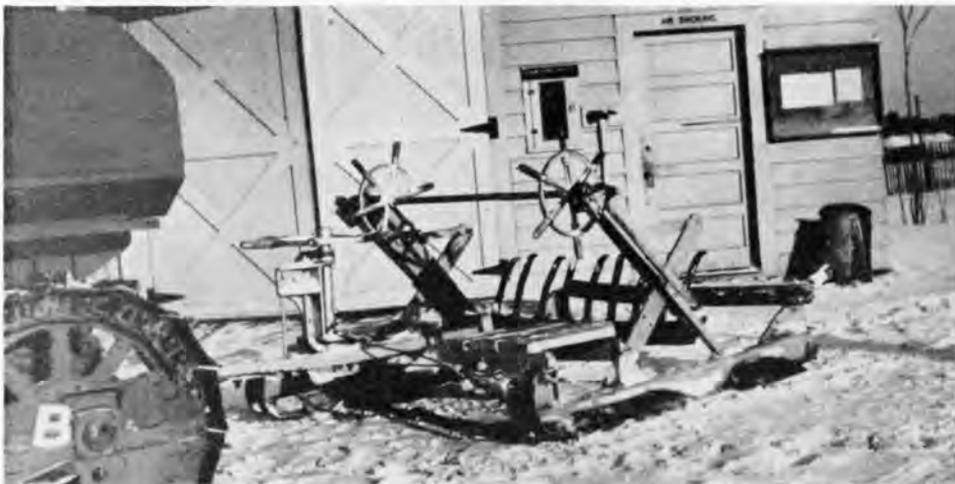
SPRAYERS

Several types and models of spraying equipment for herbicides and insecticides are available commercially. Some nurserymen in the Lake States mount a small pressure pump and a spray boom directly on a tractor and carry the herbicide in a container on the rear of the machine. Forest Service nurseries use a commercial skid-type sprayer. This compact and efficient unit is carried on a light tractor trailer wide enough to straddle the beds. Although it requires loading and unloading from the trailer and the transfer of the herbicide from the shipping container to the tank on the sprayer, it eliminates much of the strenuous work and hazards connected with carrying herbicides on a tractor.



F-153298, 464642

FIGURE 18.—A, A horse-drawn tree lifter in operation. B, A sled type lifter.



The skid-type sprayer has an adjustable boom that permits treating 3 beds in 1 operation. The boom is made in three sections, each of which can be shut off as desired. Each section is equipped with three mist-spray nozzles that give a uniform coverage, and the rate of application as well as pressure can be controlled accurately.

This sprayer can also be used for treating insect infestations where contact sprays and liquid stomach poisons are recommended, and for spraying noncorrosive fungicides. It can be used for other spray work by removing the horizontal boom and fitting the unit with the proper type of spraying attachments.

Commercial hand sprayers are not recommended because they are undependable for uniform coverage and are relatively inefficient when large acreages and frequent sprayings are involved.

Special equipment is required for handling sulfuric acid and corrosive fungicides. Although a wooden barrel equipped with a lead-pipe boom is an inexpensive piece of equipment for applying acids, a lead-lined wooden tank with a lead-pipe boom is more satisfactory. The size of the tank required will depend to some extent upon the amount of seedbed area to be treated annually.

A wooden tank with an approximate 200-gallon capacity, mounted on a chassis equipped with a tractor hitch, is a safe and dependable piece of equipment for applying chemical solutions. The tank, filled from the top through an opening 18 by 18 inches, is fitted with a tight lid to prevent the fungicide from splashing when the sprayer is being used. The discharge pipe is a 1½-inch galvanized pipe and the sprinkler pipe is a 1- by 49-inch lead pipe. The latter has ⅛-inch outlets drilled 1 inch apart to permit even and uniform distribution of the fungicide. A 1½-inch gate valve is used as a shutoff and to regulate the flow. The unit is also equipped with a platform on which the operator may ride.

SEEDBED BOARDS

Seedbed boards serve as a barrier to the action of sand across the surface of the beds during the period of germination and early seedling stages. They also serve as frame supports for seedbed screens. The seedbed boards in Forest Service nurseries are 1- by 4-inch 12-foot boards, and strap iron stakes are used to hold them in place (fig. 20).

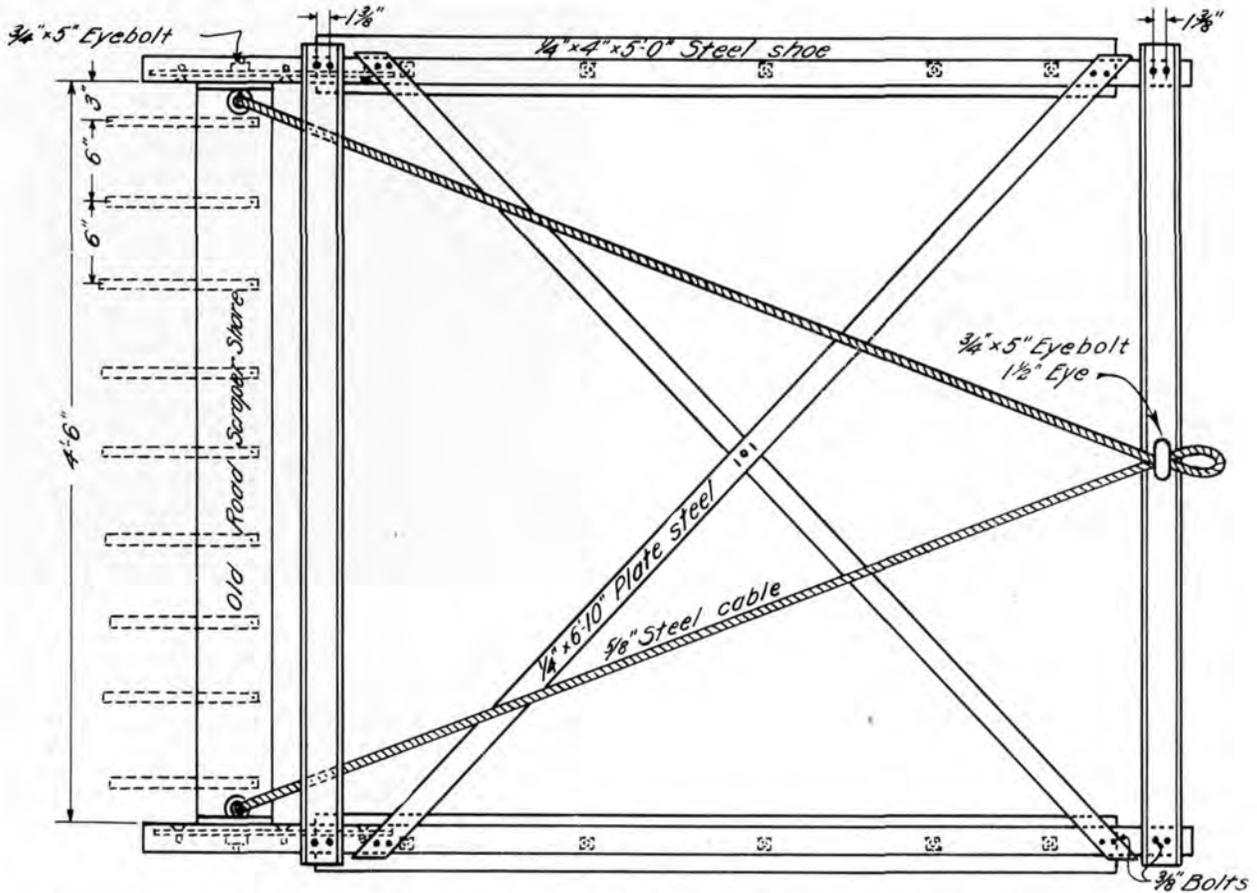
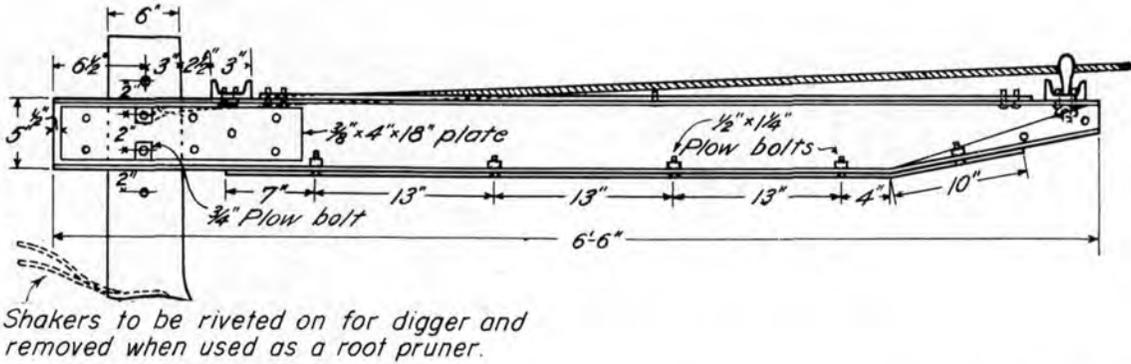
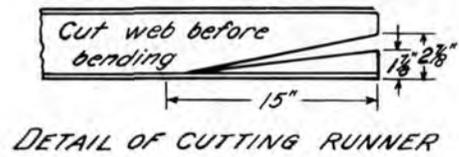
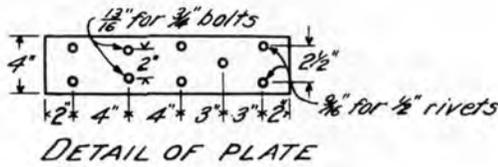


FIGURE 19.—Details of construction of a sled-type tree lifter. This lifter can be used for root pruning when the nine soil breakers are removed.

Although pine lumber is sometimes used for seedbed boards, white-cedar gives longer service. Rough material is favored over surfaced material because it gives added strength and greater rigid-

ity. If pine lumber is used, preservative treatment will increase its service life. Boards treated with creosote in the early thirties (74) have given 20 years of service and are still usable. Because

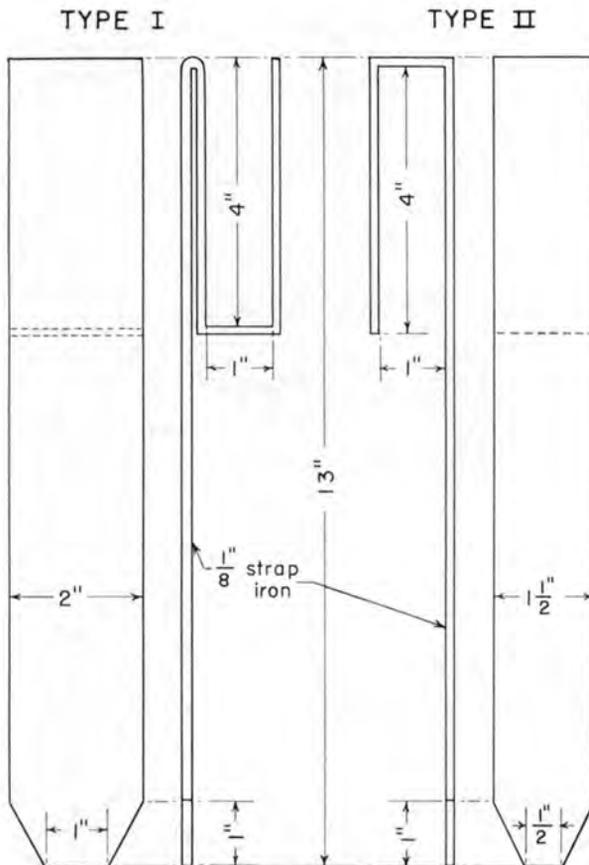


FIGURE 20.—Iron bedboard stakes: Type I (U-type) is used where ends of boards meet; type II (clip type) is used at midpoints. Some nurseries use type II exclusively.

creosote and pentachlorophenol are toxic to small seedlings, treated seedbed boards should be stacked with spacers and not used until at least the second season following treatment.

SEEDBED SCREENS

Most forest nurseries in the Lake States use hardware cloth screens to protect the seedbeds from birds and rodents. The hardware cloth, 48 inches wide, is best handled in 33- to 50-foot-long sections rolled directly on the 1- by 4-inch bedboards. The rolls are overlapped about 6 inches and held with a turn of wire. For placing and

removing the screen, a bed-straddling, tractor-drawn trailer is a useful labor-saving device. To help hold the screen in place and to prevent its becoming bent out of shape, 1- by 2- by 49-inch slats are stapled at 3- or 4-foot intervals across the width of the cloth. The screens are tacked to the bedboards, slat side up, so that they will lie flat.

A few nurseries use the 4- by 12-foot Pettis seedbed frame with screened sides that support a covering screen, but their bulk in storage and cost of maintenance, and the time-consuming effort in installation and removal, make them somewhat more expensive and less desirable than longer screens used in roll form. Some nurseries use lath racks with attached legs.

HANDTOOLS

A nursery, of course, needs the usual complement of handtools such as rakes, spades, hoes, and rotary hand weeders. The latter are especially useful in keeping paths clean (fig. 21).



F-473979

FIGURE 21.—A 10-inch-wide rotary hand weeder suitable for weeding paths and rows of broadleaves or transplants at 12- to 14-inch spacing in sandy nursery soils. The blade at the lower left cuts weed roots horizontally and the angled blades on the revolving reel pulverize the soil.

SOIL MANAGEMENT

One of the important steps in successful nursery practice is proper management of the soil. Its maintenance in a condition of proper fertility, acidity, tilth, and drainage will pay big dividends. In the Lake States, nurseries cut out of existing forest land produce excellent stock for about 4 years. Thereafter the size and quality of stock decline and it is necessary to add compost or peat and commercial fertilizer. Even after treatment, however, the quality of stock produced is seldom as good as that of the first crop or two. Cultivated areas, old fields, or former pastures usually must be fertilized heavily from the very start.

Continuous nursery production creates a considerable drain on the soil nutrients because of the closeness at which the plants are grown and the fact that the entire plant growth is later removed from the soil. Based on chemical analyses of red pine nursery stock of several age classes, Lunt (86) calculated the annual nutrient intake per acre in terms of nitrogen (N), phosphorus (as P_2O_5), and potassium (as K_2O) as follows: 41, 14, and 18 pounds for 1-0 stock; 154, 32, and 59 pounds for 2-0 stock; and 84, 23, and 41 pounds for 2-1 stock. He concluded that 10 parts of total N, 4 parts of P_2O_5 , and 5 parts K_2O would provide a good balance of soil nutrients.

An analysis of 27 samples of 2-0 jack pine from the Hayward Nursery in Wisconsin showed the following percents of nutrients in the plants, including needles, stem, and roots: average nitrogen, 1.65—range from 1.48 to 1.76; average phosphorus (as P_2O_5), 0.245—range from 0.213 to 0.275; and average potassium (as K_2O), 0.727—range 0.572 to 0.968. The calculated per-acre drain of nutrients by removal of the crop of 2-0 jack pine, weighing 3,740 pounds per acre (ovendry), was 61.7 pounds nitrogen, 9.2 pounds phosphorus (as P_2O_5), and 27.2 pounds potassium (as K_2O).

The amount of nutrients actually supplied in fertilizer must greatly exceed that found in tissue analysis, because of loss by leaching and capacity of certain soils to fix, in unavailable form, a substantial amount of nutrients, especially phosphorus. It is not uncommon for some nursery soils to fix several hundred pounds per acre of 20-percent superphosphate or its equivalent. Therefore, actual observation of trends in stock development in nurseries and of response to fertilizers affords a more direct and reliable approach to the problem of soil management than does tissue analysis.

The chief elements that need to be supplied to Lake States nursery soils are nitrogen, phosphorus, potassium, magnesium, and occasionally calcium. The latter is needed particularly for broadleaf

species and occasionally for conifers on strongly acid soils. A general sulfur deficiency is suspected in a considerable area of northern Minnesota, including parts of the Chippewa and Superior National Forests. If there is a sulfur deficiency in nurseries situated there, it probably can be corrected by the standard treatment of one-eighth fluid ounce of sulfuric acid per square foot.

FERTILITY OF NURSERY SOILS

Minimum levels of soil fertility.—Soil tests will indicate the approximate amount of fertilizers needed, if any, to correct soil deficiencies. Quick chemical tests can be made on-the-ground with special kits (143, 168), or soil samples can be taken for testing by private or public testing agencies.

Standards of fertility satisfactory for growth of the more common Lake States tree species were determined by S. A. Wilde (190) by analyses of surface soils from typically well-developed natural stands (table 10). In actual nursery practice these standards are quite satisfactory, except that excellent 2-2 red pine, white pine, or white spruce transplants can be produced by reducing the indicated levels of total nitrogen by one-fourth. Areas that test below these minimums and are devoted to the production of seedlings or 1-year transplants should be fertilized.¹⁰

When soil analyses show that nutrient levels already are adequate, the addition of more fertilizer may result in top-heavy, succulent plants that do not survive well in fall plantings (fig. 22). Such overfertilization is most likely to occur in 2-0 jack pine, and to some extent in 3-0 red pine and 3-0 white pine.

Acidity.—Under most nursery conditions in the Lake States, adjustment of acidity is not a problem. A problem may exist, however, if the soil is highly acid or definitely alkaline, because these extremes in pH result in malnutrition of nursery seedlings. In extremely acid soils (pH 4.0 to 4.5) there is a sharp reduction in the availability of potassium, phosphorus, calcium, and magnesium (174). Also, soils of high acidity have a low capacity to retain nutrients such as potassium and ammonia nitrogen, and the danger of loss by leaching is correspondingly higher (181). Where soils are rather limy (pH 7.7 to 8.5), chlorosis

¹⁰ A map record of soil fertilizer applications, cover crops used, the dates they were applied or sown and the amounts per unit of area, chemical treatments for white grub control, weed reduction, and similar practices is worthwhile (106). It gives the nurseryman a quickly grasped picture of the status of treatment without his laboriously sifting through a mass of written records. The base map should show the area of each unit and the length of beds.

TABLE 10.—Standards of nursery soil fertility for several representative Lake States tree species¹

Species	Reaction, pH	Base exchange capacity per 100 gm. soil	Total nitrogen	Available per acre			Replaceable per 100 gm. soil	
				Nitrogen	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)	Calcium	Magnesium
		Milli-equivalents	Percent	Pounds	Pounds	Pounds	Milli-equivalents	Milli-equivalents
Jack pine.....	5.6	5.0	0.10	20	40	100	2.0	0.5
Red pine.....	5.4	8.0	.12	30	50	150	3.0	1.0
Scotch pine ²	5.4	8.0	.12	30	50	150	3.0	1.0
White pine.....	5.4	10.0	.14	35	80	200	5.0	1.5
White spruce.....	5.2	15.0	.25	45	100	250	6.0	2.0
Norway spruce ²	5.2	15.0	.25	45	100	250	6.0	2.0
Yellow birch.....	5.3	12.0	.16	35	60	175	5.0	1.5
Sugar maple.....	5.8	14.0	.20	45	150	275	8.5	2.5
Basswood.....	5.8	14.0	.20	45	150	275	8.5	2.5
White ash.....	6.2	16.0	.22	55	185	300	11.0	3.0

¹ Reprinted by courtesy of *Chronica Botanica* from *Forest Soils and Forest Growth*, by S. A. Wilde, 1946.

² Standards extended on the basis of practical nursery experience.

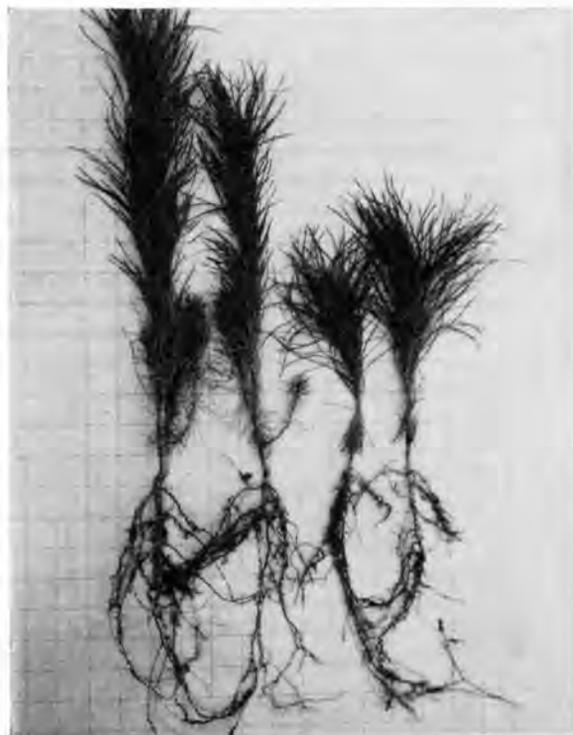
develops because of the limited availability of elements such as iron, manganese, boron, zinc, and copper. Phosphorus also is less available, damp-

ing-off and root rot diseases are accentuated, and mycorrhizal development is poor.

Old well-established nurseries in the forested northern parts of Wisconsin, Michigan, and Minnesota have a tendency toward somewhat too low a pH. Repeated use of rather acid peats, or of a dilute sulfuric acid or other acidifying materials, has in many instances lowered the average original level of pH from about 5.5 to as low as 4.0 in the most acid spots in the nursery. For example, in a northern Wisconsin nursery the original pH of the soil was 5.3 to 5.5, but in 18 years soil treatments with dilute sulfuric acid and acid peat (pH 4.4 or lower) had lowered it to about 4.0 in some spots. Jack pines and red pines grew poorly and the outer third of their needles became bright yellow orange, a symptom of magnesium deficiency (11, 193). Dolomitic limestone applied at 1,000 to 1,500 pounds per acre brought the pH at the 0- to 4-inch depth from 4.1 up to 5.0 or more, improved the needle color, and increased growth (table 11). When the pH values given in table 11 are plotted graphically over the amounts of limestone applied, the result is a curve of almost perfect correlation.

In another test the application of 1,000 pounds of ground limestone to a light sandy soil with a silt-plus-clay content of around 12 to 14 percent increased the pH from 4.0 to about 4.9 (table 12). However, ground limestone should not be applied just before conifer seed are sown because it may result in heavy damping-off. Where both soil tests and foliage symptoms indicate excessive acidity, limestone should be added to the compost that is applied to a cover crop, to transplant areas, or to localized areas of off-color seedlings beyond the succulent stage.

Applications of dolomitic limestone may be followed by reduced growth of acidophilic conifers unless soluble nitrogen is added (190).



F-372135

FIGURE 22.—The 2 top-heavy, poorly balanced 2-0 jack pines at the left were grown on a fertilized plot, the 2 at the right, on an unfertilized plot. The trees from the fertilized plot would not survive as well in fall planting or after a serious drought following spring planting. This demonstrates the value of determining the need for fertilizer applications through soil tests.

TABLE 11.—Effect of application of ground limestone on first-year jack pine seedbeds in areas of excessive acidity¹

Ground limestone per acre (pounds)	Trees with yellow foliage because of excessive initial acidity			Total green weight of 100 trees as 1-0 stock	Soil reaction Sept. 28, 1948
	July 27, 1948	Oct. 6, 1948	Oct. 5, 1949		
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Ounces</i>	<i>pH</i>
0.....	32.6	56.2	27.5	8.00	4.11
500.....	39.8	29.0	13.7	9.50	4.60
1,000.....	42.4	19.3	12.5	10.10	5.03
1,500.....	42.9	17.4	12.5	11.20	5.25
2,000.....	34.4	12.6	11.2	8.85	5.51

¹ Treated with limestone on July 28, 1948.

TABLE 12.—Changes in pH in the surface 4 inches of a sandy nursery soil 2 months after treatment with ground limestone

Initial pH	Changes in pH value when application level of limestone was—			
	500 pounds	1,000 pounds	1,500 pounds	2,000 pounds
	4.0.....	+0.5	+0.9	+1.2
4.5.....	+ .4	+ .7	+ .9	+1.0
5.0.....	+ .3	+ .5	+ .6	+ .7

¹ Value estimated.

In the prairie part of Minnesota, and in southern Wisconsin and Michigan, the soil pH may become alkaline from irrigation water heavily laden with carbonates. Also, the use of a sand cover that is alkaline in reaction can create a problem. These prairie soils may shift in pH from 6.0 to 7.5 in 4 to 5 years from applications of slightly alkaline water. Their pH must be lowered to 5.5 or 6.0 if reasonably satisfactory growth is to be attained.

Species that are especially sensitive to soil alkalinity in the seedling stage include jack pine, red pine, Scotch pine, blue spruce, western white spruce, white spruce, and, to a lesser extent, ponderosa pine. Junipers have done rather well in soils that are neutral or slightly alkaline up to pH 7.5 to 7.6.

The alkalinity of conifer seedbed soils cannot be corrected satisfactorily by the usual fertilization practices. The soil must be acidified. Such treatment will greatly enhance the effects of fertilizers applied later, and will improve the rate of spread of beneficial mycorrhiza.

A sample of soil can be easily tested for alkalinity with a few drops of dilute (10 percent) hydrochloric or sulfuric acid. If it effervesces readily, the pH will be above 7.0. In an actual case, a nursery soil in North Dakota, similar to what

might be encountered in western Minnesota, had built up from its normal pH of 6.8 to 7.5 to 7.8 in 4 years. Damping-off increased and stock of jack pine, Scotch pine, and spruces, and to a lesser extent ponderosa pine, was very poor in vigor, needle length, bud development, weight, and height. Phosphorus assimilation was very poor.

Applications of a 2-percent solution of sulfuric acid, using about 1 pint of water per square foot of bed, resulted in doubling the weight of spruce stock. In some instances it doubled or trebled the number of usable plants where one-fourth ounce of concentrated acid per square foot was used, diluted with water. Higher dosages may cause damage when the beds dry out unless they are watered very heavily following application.

Nurserymen confronted with alkalinity problems may find the following tabulation useful. It indicates the probable shift in pH of moderately alkaline, sandy prairie soil by various levels of treatment of sulfuric acid.

Concentrated sulfuric acid used per square foot (fluid ounce) ¹	Soil tested at depth of—	
	0-4 inches (pH)	0-8 inches (pH)
0.....	7.5	7.3
1/8.....	6.8	6.8
1/4.....	6.2	6.5
3/8.....	5.8	6.2
1/2.....	5.6	6.0

¹ Before dilution to about 2-percent solution. Soil was treated in the spring and tested in the fall of the same year.

The difference in values for 0- to 4-inch level, as compared with the full 0- to 8-inch shows that there is a more marked change in the surface 4 inches than in the top 8 inches.

A standard practice in many Lake States nurseries is to apply commercial sulfuric acid, diluted to 2 percent by volume, at the rate of 1/16 to 3/16 fluid ounce per square foot immediately after the seed are sown. Its purpose is to control damping-off, but it has also been of some value in weed control (173). Turner (177) found treatments of 1/16 to 3/16 fluid ounce per square foot very beneficial but observed no appreciable carryover benefit from one crop to another. He also found that spring application of the acid on fall-sown beds was successful, the stand per square foot in treated beds being 77.1 trees while in untreated beds it was only 30.1 trees. Others, however, have found some danger of acid injury by this practice.

If sulfuric acid does not remedy soil alkalinity, commercial-grade flowers of sulfur (3/8 to 1/2 avoirdupois ounce per square foot) may be raked into the soil to a depth of about 4 inches several months to a full year ahead of seeding. This reduces pH somewhat more than does the usual sulfuric-acid treatment and there is less risk of injury, especially if applied a year in advance of seeding. In terms of equivalent effectiveness in acidifying power, every 3 avoirdupois ounces of flowers of sulfur is about equivalent to 5 fluid ounces of sulfuric acid (39).

Nitrogen.—The addition of peat or muck will supply nitrogen to the soil. Well-rotted animal manures used at 10 tons or more per acre also are a good source of nitrogen and organic matter, but they may increase the damping-off and, in newly prepared seedbeds, weed problems. Animal manures have been used with considerable success, however, on transplant areas or with cover crops.

If the percent of total nitrogen in the nursery is at the standard prescribed for the species (table 10, p. 42), the addition of inorganic sources of nitrogen as a top dressing or so-called "liquid fertilizer" usually is not necessary. However, if symptoms of deficiency of nitrogen show up, particularly in spruces in the form of short yellowish-green needles, a treatment of liquid fertilizer consisting of 200 to 300 pounds per acre of 20-percent ammonium sulfate is helpful. Other readily soluble nitrogen carriers may be used instead, such as ammonium nitrate at 100 pounds per acre.

Phosphorus.—Some soils rich in iron have the capacity to fix a considerable amount of phosphorus, thus making it unavailable for plant growth. In one northern Wisconsin nursery with a strong phosphate deficiency, the first application of 200 pounds of 20-percent superphosphate resulted in no benefit because of iron fixation. The addition of 400 pounds, however, greatly improved the growth of jack pine stock. Extensive experience with experimental plots in northern nurseries shows that for tested soils having a phosphate deficiency the minimum treatment is 300 pounds of 20-percent superphosphate or its equivalent for jack and red pines, and 400 pounds for white pine, spruces, or hardwoods. Amounts of 400 to 600 pounds per acre gave good results in numerous nursery fertility trials.

Phosphoric acid may deserve more trials as a fertilizer. In one test at the Hugo Sauer Nursery, the application of 0.8 fluid ounce of the material per square foot gave a 32-percent increase in weight of 3-0 white spruce. Heavier treatments gave even greater contrast (table 13). Applications made in the fall at the time of seeding increased the stand 6 to 19 percent compared with the checks, while treatments applied in the spring decreased the stand by 9 to 21 percent, probably because of acid injury.

Since phosphoric acid tends to lower the pH of the soil, treatment may be undesirable where the pH is lower than 5.0. However, for moderately acid or neutral soils (pH 6.0 to 7.5), treatment may be worth testing at a dosage of about $\frac{1}{2}$ to $\frac{1}{4}$ fluid ounce per square foot, applied in a dilute solution. Phosphoric acid in liquid form, obtained in connection with superphosphate production, is now marketed in tank-car quantities to California agriculturists. It has significant amounts of iron, magnesium, sulfur, manganese, and other elements that may enhance crop response.

Replaceable bases.—Most nursery soils are usually supplied well enough with replaceable bases, such as calcium and magnesium, to grow satisfactory conifer crops. Hardwoods have a higher requirement. Deficiencies can usually be corrected by applications of about 10 tons of manure, or duff and humus collected under hardwood stands. The addition of $\frac{1}{2}$ to 1 ton of ground limestone may be necessary in strongly acid soils (pH 4.0 to 4.5) to produce good growth in blocks devoted exclusively to hardwoods.

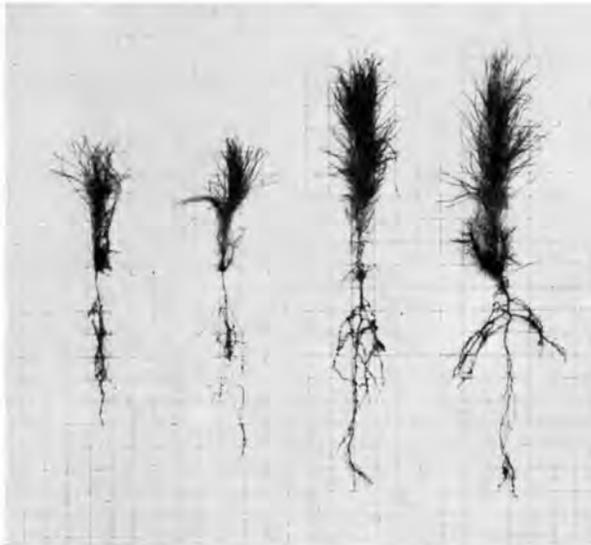
FERTILIZERS

Peat.—Because of its high water-holding capacity, moderate nitrogen content, and capacity to improve base-exchange relations and carryover effects of commercial fertilizers, peat is a valuable soil amendment in forest nurseries (fig. 23). Fortunately, huge deposits of peat occur in the sphagnum swamps of the Lake States and are readily accessible. Many nurseries, therefore, develop their own sources of peat. Before a swamp is developed for this purpose, a survey should be made. Depths of peat at a dozen or more places should be recorded and a rough estimate made of the amount available. For economical operation, at least 5 to 10 thousand cubic yards of peat should be present on any site where mechanical excavation is intended.

From 6 to 10 samples should be taken from different depths to determine if the peat has a pH between 4.5 and 5.5 (up to 6.5 or 7.0 is satisfactory for hardwood nurseries), a total nitrogen content of 2.0 percent, and a base-exchange capacity of 70 milliequivalents per 100 grams (190).

TABLE 13.—Effects of phosphoric acid soil treatment on 3-0 white spruce

Phosphoric acid applied per square foot of bed (fluid ounces)	Length		Stem diameter	Green weight			Top-root ratio
	Top	Root		Top	Root	Total	
	Inches	Inches	$\frac{1}{4}$ inch	Grams	Grams	Grams	
0	4.8	6.00	7.7	2.48	1.22	3.70	2.03
$\frac{1}{4}$	5.4	4.70	7.9	3.12	1.15	4.27	2.71
$\frac{1}{2}$	5.5	4.75	8.2	3.55	1.32	4.87	2.69
$1\frac{1}{2}$	5.4	6.40	8.6	3.63	1.72	5.35	2.11
2	6.0	6.20	8.8	4.08	1.75	5.83	2.33



F-389108

FIGURE 23.—Peat enhances the effect of commercial fertilizers. This 2-0 jack pine was grown on an area that had been fertilized 3 years earlier and had produced a crop of 1-0 jack pine. *Left*, 2 plants from the area where only commercial fertilizers had been used; *right*, 2 plants from area treated with commercial fertilizer plus 20 tons of dry peat per acre. Fertilizer in each case was 400 lbs. of 20-percent ammonium sulfate, 600 lbs. of 20-percent superphosphate, and 160 lbs. of 50-percent muriate of potash per acre.

Mechanical excavation reduces the cost of peat by 50 to 75 percent over that dug by hand. Several methods have been developed by Lake States nurserymen by which peat has been excavated at a cost of \$0.25 to \$0.60 per cubic yard. Most of these methods utilize a dragline (fig. 24). How-

ever, steam or diesel shovels, such as those used by contractors, are effective for excavating peat about 3 feet deep. When close to the nursery, the peat can be stockpiled on the edge of the swamp. If the swamp is at some distance, the peat usually is hauled by tractor to the nursery and stockpiled or used in compost pits.

It is well to remember the following:

1. The use of large amounts of raw peat, especially if applied in the surface layers, may cause potash and phosphate starvation (191).

2. Peat should be thoroughly and uniformly combined with the soil by tilling it in as deeply as possible and it should be supplemented by mineral fertilizers.

3. If peat is applied on a weight basis, a large part of the total weight is water. For example, H. A. Barton of the U. S. Forest Service found that a cubic yard of peat, stockpiled in a well-drained site for several months and weighing 850 pounds, had an oven-dry weight of only 134 pounds.

4. Where no rototillers are available and the peat is in rather large chunks, it should be shredded before spreading. A shredder can be made from the cylinders and concaves of an old threshing machine mounted on the chassis of an old truck and with a 20-hp. motor with 11-inch pulley for power, a 10-inch pulley on the shredder, and an endless conveyor belt to carry the shredded peat directly to a stockpile or into a manure spreader (29).

The method of mixing and applying peat or compost varies with the equipment and facilities available. The simplest method is to apply about 50 to 100 cubic yards of peat per acre directly on the nursery site with a manure spreader. Neces-

F-373049

FIGURE 24.—A dragline set-up used in removing peat from spruce swamps. (Hugo Sauer Nursery, Rhinelander, Wis.)



sary amounts of mineral fertilizers, based on soil analyses, may be applied with the peat or separately. Because stockpiled peat may remain frozen late into the spring, it is desirable to spread the peat in the fall.

Duff.—Duff is a highly prized material for nursery fertilization. It is rich in organic matter, high in water-holding capacity and beneficial microorganisms, and well balanced as regards content of nitrogen, phosphorus, potash, lime, and minor elements (table 14) (2, 87, 105, 190). A factor that usually prevents its extensive use is the high cost of labor required to rake it into piles and then carry it on trays or litters to nearby trucks. Sometimes the long haul involved is also expensive. Although northern hardwood stands of sugar maple, yellow birch, basswood and hardwood-hemlock are the preferred source for duff, aspen or aspen-paper birch stands may provide a cheaper source because of their abundance and wide distribution.

Some nurseries may be close enough to larger towns to make arrangements with city officials to obtain the leaves swept up from the streets in the fall. Such an arrangement, made by the nursery at Winona, Minn., produced from 400 to 600 tons of dry leaves a year; the nursery paid for hauling the material from the city to its compost pile.

Ordinarily, duff is used in composts, but it has also given excellent results when applied directly to the soil with other fertilizers. In most cases, 5 to 10 tons of duff, along with peat and commercial fertilizers, are adequate. Excellent results were obtained at the Butternut Nursery in Wisconsin by using 20 cubic yards of hardwood-hemlock duff and 40 yards of raw peat per acre (80).

Compost.—Many Lake States nurseries have concrete compost pits where they retain specified mixtures of peat, hardwood duff, and mineral fertilizers for 1 to 2 years. Sometimes these materials are placed in alternate layers. At other nurseries, measured materials are shoveled into a peat-shredding machine from which they drop directly into the compost pit (fig. 25).

A rather well-balanced mixture for an acre of badly depleted nursery soil consists of 50 cubic yards of peat, 5 cubic yards of duff, 300 pounds of 20-percent ammonium sulfate, 500 pounds of 20-percent superphosphate, and 200 pounds of 50-percent muriate of potash. First, the three commercial fertilizers are mixed. Then, to get a reasonably good mixture, 10 cubic feet of peat, 1 cubic foot of duff, and 7 pounds of the mixed commercial fertilizer are proportioned roughly as they are shoveled into the hopper. By the time they have passed through the shredder and dropped into the pit, they are rather well mixed. For best composting action, the organic material must be moderately moist, but not wet; if too dry, it should be sprinkled.

As an economy measure, many nurserymen now make up a concentrated compost. For example, in the compost mentioned in the preceding paragraph, there are roughly 20 pounds of commercial fertilizers per cubic yard of organic matter. In the concentrated compost, there are 60 pounds of commercial fertilizer per cubic yard of peat, plus 0.3 cubic yard of duff; only 17 cubic yards of this triple-strength compost is applied to the nursery together with 33 cubic yards of peat. The material is worked in by rotary tiller.

Cover crops.—Cover crops are desirable in Lake States nursery culture for the purpose of

TABLE 14.—Analysis of surface soil layers in aspen stands in the Lake States

SOIL CHARACTERISTICS							
Soil horizon	Average thickness	Organic matter	Total nitrogen	Replaceable calcium per 100 grams	Base-exchange capacity per 100 grams	Available potash	Available phosphorus
	Inches	Percent	Percent	Milli-equivalents	Milli-equivalents	Parts per million	Parts per million
Duff ¹	0.55	50.2	0.938	27.1	52.2	1,240	161
Humus ²65	26.4	.529	21.8	44.4	790	105
A ₁	1.20	7.5	.216	7.5	16.9	73	23
A ₂	3.40	1.1	.035	1.4	5.9	54	34
RATIO OF VALUES TO THOSE IN A ₂ LAYER							
Duff ¹		46	27	19	9	23	5
Humus ²		24	15	16	8	15	3
A ₁		7	6	5	3	1	1
A ₂		1	1	1	1	1	1

¹ Partially decomposed leaves.

² Black layer of humus below duff.



F-373025

FIGURE 25 —Filling a compost pit. Peat, hardwood-hemlock duff, and commercial fertilizers are shoveled into the peat shredder in proper proportion. (Hayward Nursery, Wis.)

crop rotation and to add some bulk organic material to the soil. As early as 1909 Pettis (113) suggested that one-third of the nursery area should be in cover crop. Pieters and McKee (114) state that the chief purpose of green manure is to maintain organic matter, and that many legumes under good conditions may add from 120 to 200 pounds of nitrogen to the soil per acre. They list hairy vetch, Austrian winter peas, *Crotalaria*, alfalfa, sweetclover, and crimson clover as the most important cover crops in the United States.

Among cover crops used in Lake States forest nurseries are rye, oats, soybeans, and field peas. Commercial nurseries usually located on better, less acid soils may use alfalfa or clover seeded at 8 to 12 pounds per acre, or hairy vetch at 3 to 4 pecks per acre. The clovers and alfalfa usually require a soil pH of about 6.5 or higher (24).

Since most large-scale producers of pine and spruce for reforestation in the Lake States are located on soils with pH in the range 4.8 to 6.2, they have depended on rye as a standard cover crop. Soybeans have been used in the southern part of these States. Rye will grow fairly well in moderately acid soils with pH range of 5.2 to 6.2. It tolerates more acid soils than oats or

soybeans which prefer a pH of 6.0 or slightly higher (25).

Tests of six different species of lupine at the Hugo Sauer Nursery, Rhineland, Wis., indicate that several of them have real possibilities as leguminous cover crops even on soils with pH of about 5.0. Blue annual bitter lupine produced from 4,260 to 6,510 pounds of oven-dry material per acre on unlimed and limed plots respectively, with a total nitrogen contribution to the soil of 66 to 102 pounds per acre. Sweet yellow lupine, a nonalkaloid species suitable for livestock feed, produced from 5,450 to 5,570 pounds of oven-dry material per acre on unlimed and limed plots, respectively, with a total nitrogen contribution to the soil of 82 to 84 pounds per acre.

Finely ground dolomitic limestone was added at the rather mild rate of about 1,000 pounds per acre in the above experiments. The lupine seed was treated with special lupine inoculum before seeding in June, and was harvested in the fall. The lupines out-produced rye by about 3 to 1 in terms of organic matter and total nitrogen content. Lupine seed is available from commercial seed houses in the Southeast.

Lupines have also done well when spring-seeded in cool-climate areas lying at high elevations, particularly at Savenac Nursery, Haugan, Mont., and Mt. Shasta Nursery, McCloud, Calif. They are used extensively in southeastern United States as winter-sown cover crops.

Legumes and other cover crops afford maximum addition of bulk organic matter when the entire crop, including both root and top, are plowed under. Legumes are plowed under shortly after they have attained full flower or are starting to form pods or seeds, while rye or oats are plowed under just as seed heads start to form. The tops contain the bulk of the organic matter and a large part of the total nitrogen. Some Lake States nurserymen mow legumes in the summer and let them lie until fall to reduce soil blowing.

Manure.—Manure has not been used to any great extent in public nurseries in the Lake States but has for years been a favorite in commercial nurseries for lining out areas. It improves tilth, water-holding capacity, aeration, and temperature relations (134), and often doubles or trebles the number of useful soil organisms in the top 9 inches of soil (133).

The chief problems with manure are frequent loss of the valuable liquid part that contains much of the nitrogen, volatilization of the ammonia as it ferments, and improper time and rate or manner of application. It is generally deficient in phosphate. A good treatment for transplant areas or ornamental blocks is 8 to 10 tons of manure per acre supplemented by 250 to 300 pounds of 20-percent superphosphate.

Manure generally is considered to promote damping-off and hence is not recommended for areas that are to be seeded to conifers. It often contains considerable weed seed. In general order of decreasing nutrient value, the manures rate as follows: chicken, sheep, hog, horse, and cattle.

Liquid fertilizers.—Although a number of liquid fertilizers have been used in Lake States and other nurseries to correct nutrient deficiencies, commercial nurserymen have long preferred nitrophoska (15-30-15)¹¹ (151). It is often used at the rate of 4 ounces per 3 gallons of water applied per 4- by 12-foot bed.

In an experiment at Hugo Sauer Nursery in 1937, and followed into the field, fertilization with nitrophoska increased the amount of plantable 2-0 red pine stock by 30 percent and second-year field survivals by 3.0 to 7.5 percent (table 15). The length of needles and terminal buds nearly doubled and stem caliper increased by this treatment (fig. 26). Considering both costs and results obtained, a treatment of 400 pounds per acre of 15-35-15 fertilizer gave best results.

Since straight phosphate fertilizers are not readily soluble in water, combined fertilizers, such

¹¹ Three values used in connection with fertilizers, for example 15-30-15, refer to percent of nitrogen, phosphorus (as P₂O₅), and potash (as K₂O) respectively.

TABLE 15.—Effect of liquid fertilizers on the grade, size, and field survival of 2-0 red pine

Amount of nitrophoska applied (pounds)	Classification of nursery stock ¹			Green weight of average 2-0 seedling	Field survival	
	Plantable	Good	Excellent		First year	Second year
	Per-cent	Per-cent	Per-cent	Grams	Per-cent	Per-cent
0	64	14	4	1.55	71.6	54.7
200	76	16	10	1.79	72.8	62.2
400	94	48	24	2.73	80.4	58.9
800	94	54	36	3.14	72.4	57.7

¹ In classifying nursery stock, trees with a caliper of $\frac{3}{64}$ inch and over were considered plantable; $\frac{5}{64}$ inch and over, good; $\frac{7}{64}$ inch and over, excellent. All stock had fairly good balance. Trees not meeting the caliper specifications were discarded.

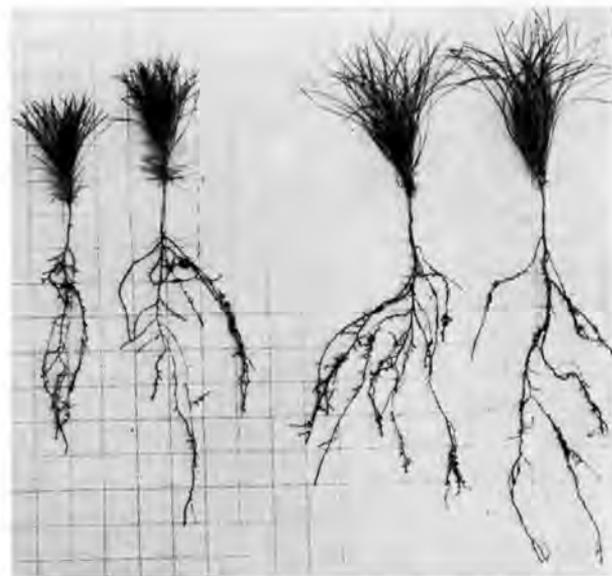


FIGURE 26.—Liquid fertilizers greatly improve growth and color. These are 2-0 red pine. The two trees at the left received no treatment. The two trees at the right received 400 pounds per acre of 15-35-15 nitrophoska. (Background is 1-inch squares.)

as ammo-phos (11-48-0) or nitrophoska (15-35-15), are used at rates of 200 to 400 pounds per acre. Potash, readily soluble in water, can be applied in 50-percent muriate of potash or 50-percent sulfate of potash at the rate of 150 to 200 pounds per acre. An alternative is to use a combined fertilizer, such as potassium nitrate (13-0-44), at 200 to 300 pounds per acre. Liquid fertilizers can be applied in late May and again in June or early July.

In small nurseries liquid fertilizers are applied with a tank or drum mounted on wheels, such as an acid cart. In large-scale operations, they can be pumped directly out of a tank into the overhead

pipeline (30), run into the sump in which the pump intake is located (138), or forced into the pipeline with an injector (fig. 27) or by means of a venturi tube near the oscillator while the water system is in operation (82). The venturi-tube method is advantageous in that no outside sources of power or pumps are necessary. As the overhead is turned on, fertilizer automatically is drawn into the overhead line from a tank located on a pickup truck or on skids and connected with two hoses to the tube.

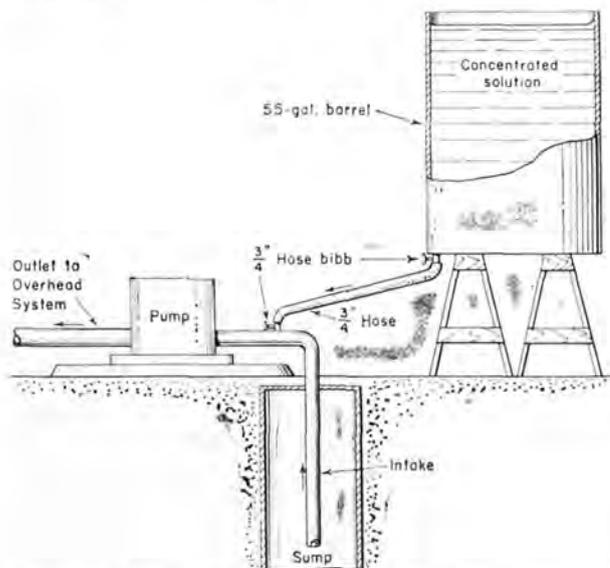


FIGURE 27.—Injector for forcing liquid fertilizers into overhead irrigation systems. (Manistique Nursery, Manistique, Mich.)

Commercial fertilizers.—A few of the principal commercial fertilizers that supply various elements are listed below. There are, of course, many more. The 1938 Yearbook of Agriculture or any standard textbook on fertilizers, such as that by Collings (33), lists these in more detail.

Nitrogen (N)

- Ammonium sulfate, 20 percent
- Ammonium nitrate, 33–35 percent
- Sodium nitrate, 16 percent
- Dried blood, 6–14 percent
- Urea, 46 percent
- Calurea, 34 percent
- Calcium nitrate, 17 percent

Phosphorus (as P_2O_5)

- Superphosphate, 16–20 percent
- Treble superphosphate, 45–48 percent
- Basic slag, 5–20 percent

Potassium (as K_2O)

- Potassium sulfate, 48 percent
- Potassium chloride, 48–62 percent

Mixed fertilizers supplying two or more elements

- Nitrophoska, 15–30–15¹² or 15–35–15

- Ammonium phosphate, 11–45–0 or 16–20–0
- Potassium nitrate, 13–0–44
- Animal tankage, 5–9–0 to 10–14–0
- Bonemeal, 3–20–0
- Milorganite, 6–2.5–0

MALNUTRITION SYMPTOMS

Malnutrition often can be detected if some of its symptoms, such as abnormal foliage color and bud development, are present in the stand. Symptoms of malnutrition are described in table 16 and the following paragraphs. Although certain treatments may give short-term relief for the affected crop, remedial measures should be applied before the area is seeded again.

1. Potash deficiency in red pine in one study was marked by a stunting of growth; the needles turned bluish green and became necrotic (tan to copper in color) at the ends, especially those at the base of the plant (70). In another study there was general chlorosis, browning and death of the needles, and decreased growth and needle persistence (68).

2. Potash deficiency in white pine was evidenced by necrosis at the tips of the needles all over the plant, and the needles were slightly copper colored (70). Purpling of white pine needles also has been noted as a symptom of phosphate deficiency.

3. Magnesium deficiency in several of the pines is indicated by a yellowing of the needle tips (94). In several instances, particularly where there was considerable calcium in the irrigation water, chlorosis of ponderosa pine, Douglas-fir, jack pine, and lodgepole pine has been corrected by use of a 1-percent spray of ferrous sulfate applied at 10-day intervals in the growing season (78).

DIVIDENDS FROM NURSERY FERTILIZATION

There is probably no cash outlay in nursery operation that pays such large and consistent dividends as maintenance of the proper fertility level of the soil. Studies at the Lake States Forest Experiment Station show that the percent of plantable stock often can be raised from 70 or 80 in unfertilized beds to 90 or more in treated beds (fig. 28).

Each 10-percent increase in plantable stock may be equivalent to a gain of several hundred dollars obtained by spending a fraction of that amount for fertilizers. For example, an acre of nursery area will produce about 750,000 2–0 red pines, grown at the usual density. The value of such a crop is at least \$5 per 1,000 trees, or \$3,750 per acre. If the number of plantable trees per square foot is boosted 10 percent by fertilization, the value of such increased production is \$375 per acre. The combined cost of fertilizers and their application in the nursery usually will be from \$50 to \$100 per acre, or less if liquid fertilizers are used. Therefore, the net profit from nursery fertilization in

¹² See footnote 11, p. 48.

TABLE 16.—*Symptoms of malnutrition in forest nursery stock*¹

Deficiency or excess	Symptoms	Class of stock and species	Treatment required per acre
Nitrogen deficiency	Pale yellowish-green, short foliage.	2-0, 3-0, and transplant white pine and white spruce.	300 pounds per acre of 20 percent ammonium sulfate, or 200 pounds in each of 2 successive treatments at 4-week intervals in solution. For next crop use compost and peat abundantly.
Phosphorus deficiency	Purplish-bronze needles. Needles very short, buds unusually short at end of season.	1-0, 2-0 white spruce	400 pounds of ammonium phosphate or nitrophoska in solution. For next crop use 600 pounds per acre of 20-percent superphosphate before seeding.
Potash deficiency	Entire needles often yellow; tips often dead.	1-0 jack pine	200 pounds of 50-percent sulfate of potash in solution. For next crop use 240 pounds of potash per acre before seeding.
Excessive soil acidity (pH 4.0 to 4.5) resulting in magnesium deficiency.	Golden yellow color of outer third of needle. Remainder of needle normal or deep green. (Symptom may also result from use of ammonium sulfate, sulfuric acid, or very acid peat on rather acid soils).	1-0 and 2-0 jack pine, and 2-0 or older red pine.	Rake 1,000 pounds of dolomitic limestone between drills on badly affected spots. Work in with cultivator. For next crop, use 500 pounds dolomitic limestone per acre, if devoted to transplants or a cover crop.
Excessive soil alkalinity (pH 7.7 to 8.8). Western part of Minnesota.	Pale yellow foliage. Short needles. Short terminal bud. Lateral bud development poor.	2-0 jack pine, 2-0 Scotch pine, 2-0 ponderosa pine, 2-0 red pine.	Rake 1 to 1½ ounces per square foot of aluminum sulfate between drills and work into soil. Water. Or apply 1 ounce in weak solution and water afterward.
Deficiency of beneficial mycorrhizae on roots. Prairie soils.	Extremely patchy, uneven size of trees in beds. Ends of foliage often are brown or dried up. Terminal buds short. Very heavy mortality in second-year seedbeds.	2-0 ponderosa pine, 2-0 Scotch pine, 2-0 and 3-0 spruce (blue, white, western white).	Too late to salvage much from 2-0 or 3-0 beds. For next crop, grow transplants on area with seedlings from well-established nursery; or haul in soil from old nursery at ½ pound per square foot. Acidify surface soil to pH 6.0.
Iron deficiency. Mostly alkaline prairie soils with pH 8.0 to 8.8 or higher.	Yellow splotches devoid of chlorophyll on leaves.	1-0 and 2-0 Siberian elm, American elm, and other hardwoods.	Rake 1 ounce per square foot of iron sulfate into soil between drills. For next crop, use flowers of sulfur at ½ ounce per square foot to acidify soil and increase availability of iron.

¹ Based on observations of the Lake States Forest Experiment Station in Wisconsin, Michigan, Minnesota, and North Dakota.

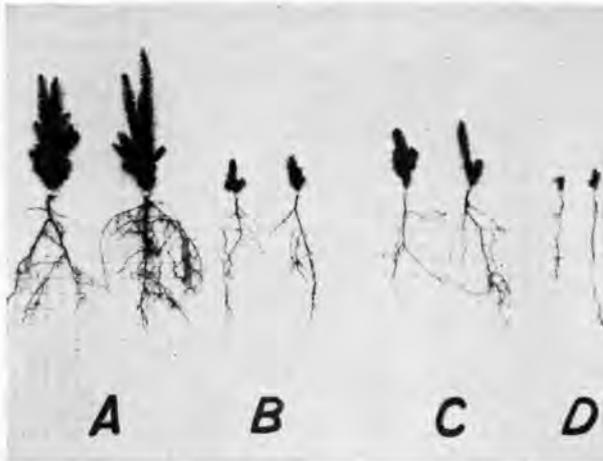
this instance would be from \$275 to \$325 per acre for every 10-percent increase in production of plantable trees.

In one nursery, the amount of plantable 1-0 jack pine was increased 27 to 40 percent by fertilization. A slight but consistent gain in second-year field survival was not significant statistically (table 17). The cost of fertilization per acre was \$30 to \$80 in 1937 and the increase in value of the stock produced was \$150 per acre for each 10-percent increase in amount of plantable stock.

Occasionally, an extreme deficiency of one fertilizer element causes actual starvation and mortality of trees in the nursery. In one area where there was a strong phosphate deficiency—only 23 parts per million of available phosphorus (as P₂O₅)—white spruce seedlings in unfertilized beds were very short, purplish bronze in needle color, and many died the second season (fig. 29). In adjacent fertilized beds, the needle color was normal and there was no heavy second-year loss. Fertilizers that are slow to dissolve provide a good

source of phosphorus in very sandy soils subject to leaching. In one experiment the size of stock was increased by the use of 20 tons of dry peat along with 1,000 pounds of bonemeal per acre.

Based on a large number of nursery fertilization tests, the average gain in field survival 5 to 8 years after planting was only between 1.5 and 2.3 percent. However, the best treatments gave increases in field survival of 3.9 to 14.0 percent 2 to 3 years after planting and 3.0 to 16.9 percent about 7 years after planting (table 18). Since gain or loss from best treatments where more than one field test plot was involved is compared with the average survival in the check plots for that individual test and not with the average survival for all check plots combined, the average gain based on all treated plots provides a better although somewhat conservative figure for the probable gain in field survival. These results refute the theory that stock produced for droughty or difficult planting sites should be sharply restricted in nutrients while in the nursery. In the



F-389110

FIGURE 28.—Effect of fertilizer on 3-0 white spruce produced on a soil of low fertility. Fertilization was as follows: A, 400 lbs. ammonium sulfate, 600 lbs. superphosphate, 160 lbs. 50 percent potash, and 14 tons of peat per acre; B, 200 lbs. superphosphate per acre; C, 400 lbs. ammonium sulfate, 600 lbs. superphosphate, and 80 lbs. muriate of potash per acre; D, none. (Background is 1-inch squares.)



F-372125

FIGURE 29.—Bed of 2-0 white spruce at right received 200 lbs. of ammonium sulfate and 80 lbs. of potash per acre; lack of phosphates in this bed was acute and there was outright starvation of the plants. Bed at left received 400 lbs. of 20-percent ammonium sulfate, 400 lbs. of 20-percent superphosphate, and 80 lbs. of 50-percent muriate of potash per acre.

tests, the effect of nursery fertilization on increased height growth largely disappeared 5 to 8 years after the trees were planted (table 19).

When both height and survival are considered, the addition of peat alone in the nursery was of little value, probably because the raw peat absorbed part of the soil nutrients. However, peat applied with mineral fertilizer or in compost form gave better results. Mineral fertilizers alone gave surprisingly good results, although in the long run their use without occasional additions of organic matter probably would result in gradual reduction of the nursery soil's capacity to produce prime stock.

TABLE 17.—Increase in field survival and production of plantable 1-0 jack pine by fertilization in the nursery

Nursery treatment per acre	Proportion of trees rated as ¹ —			Second-year field survival (thrifty trees)
	Plantable	Good	Excellent	
No treatment-----	60	12	7	69.6
8 tons compost ² (ovendry basis)-----	92	45	22	73.0
20 tons peat (ovendry basis)-----	87	30	10	77.3
20 tons dry peat + 400 pounds 20-percent ammonium sulfate + 600 pounds 20-percent superphosphate + 160 pounds 50-percent potash-----	100	67	47	77.0
400 pounds 20-percent ammonium sulfate + 600 pounds 20-percent superphosphate + 160 pounds 50-percent potash-----	95	22	12	70.7

¹ In rating the nursery stock, plantable trees had a stem caliper of $\frac{3}{16}$ inch or greater; good, $\frac{1}{8}$ -inch caliper or greater; and excellent, $\frac{5}{16}$ -inch caliper or greater. All stock had good balance.

² Compost consisted of hardwood-hemlock duff, acid peat from spruce swamps, and complete N, P, K commercial fertilizers.

THE MYCORRHIZA PROBLEM

Mycorrhiza are beneficial fungi that live in association with conifers (89) and some hardwoods. They aid the plants in the assimilation of phosphate, nitrogen, and potash, and perhaps of other nutrients as well (49, 90, 91, 128). Their lack or scarcity, especially in nonforest soils such as prairie land, or in former forest land now in agricultural crops or grass, can spell partial (187) or complete failure of subsequent seedlings or plantings of conifers. In former forest soils mycorrhiza disappear rapidly for lack of host plants and, perhaps, moisture (75). The presence of humus may extend their survival beyond the usual span of 1 to 2 years.

Lack of mycorrhiza has not been a particular problem in newly established nurseries in the Lake States because many of these were located on recently cleared forest land. In several instances, however, parts of nurseries were placed in old fields or pastures. In these areas the first crop of seedlings was decidedly uneven in size and development in spite of heavy fertilization. Patchwise, this was attributed to uneven distribution of mycorrhiza living on spottily distributed organic matter. After two crops of trees had been harvested, tree size became quite

TABLE 18.—Effects of nursery fertilizers on survival of field-planted conifers in the Lake States

Species	Age class	Age of plantation when counted		Average survival in untreated check plots	Gain or loss in survival compared with check plot when treatment was—								Basis	
		Range	Average		Peat only		Mineral only		Compost		Peat and mineral		Field test plots	Trees
					Average	Best treatment	Average	Best treatment	Average	Best treatment	Average	Best treatment		
Years	Years	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Number	Number	
Jack pine	1-0		3.0	77	+2.0	+2.0	0	0	+3.0	+3.0	+1.0	+1.0	1	4,000
Do	2-0	1-3	2.6	76	+1.1	+1.1	+2	+13.6	-6	+3.8	+6	+4.0	18	76,500
Do	2-0	5-8	7.0	78	+6	+6	+5	+13.1	+2.8	+3.8	+1.8	+2.0	14	61,300
Red pine	2-0		3.0	77	+5.0	+5.0	+2.0	+2.0	+3.0	+4.0	+3.0	+3.0	1	2,400
Do	2-0		8.0	73	+4.0	+4.0	0	0	+3.0	+3.0	+3.0	+3.0	1	2,400
Do	3-0	1-2	1.8	72	-8.0	-8.0	+10.3	+26.5	+3.0	+5.0	+13.0	+13.0	4	17,700
Do	3-0	5-6	5.7	60	-7.0	-7.0	+15.5	+46.0	-4.0	-2.0	+2.5	+7.0	3	11,300
White pine	2-0		3.0	82	+6.0	+6.0	+1.0	+1.0	+3.0	+7.0	+2.0	+2.0	1	2,400
Do	2-0		8.0	77	+5.0	+5.0	+4.0	+4.0	-2.0	+1.0	+4.0	+4.0	1	2,400
Do	3-0		2.0	88	-4.0	-4.0	+1.0	+11.0	-6.0	-2.0	+1.0	+1.0	3	15,200
Do	3-0	6-7	6.5	78	0	0	+5.5	+19.0	+1.0	+2.0	+2.0	+2.0	2	8,800
White spruce	3-0		2.0	87	+1.0	+1.0	+2	+7.0	+2.0	+5.0	-6.5	-6.5	4	20,550
Do	3-0		7.0	70	-2.0	-2.0	+2	+18.5	+2.5	+9.0	+5.0	+5.0	4	20,550
Weighted average, all 1- to 3-year plantings				78	+3	+3	+1.6	+14.0	+5	+3.9	+8	+4.0	32	138,750
Weighted average, all 5- to 8-year plantings				75	+3	+3	+2.3	+16.9	+1.5	+3.7	+2.3	+3.0	25	106,750

TABLE 19.—Effects of nursery fertilizers on height of field-planted conifers in the Lake States

Species	Age class	Age of plantation when measured		Average height of trees in check plot	Gain or loss in height compared with check plot when treatment was—			
		Range	Average		Peat only	Mineral only	Compost only	Peat and mineral
Years	Years	Feet	Feet	Feet	Feet	Feet	Feet	
Jack pine	2-0	5-8	7.0	7.8	-0.1	+0.2	+0.1	+0.1
Red pine	2-0		8.0	3.1	+1	-1	-2	-1
Do	3-0	5-6	5.7	2.1	+1	-1	-1	-1
White pine	2-0		8.0	2.8	-2	-6	0	-3
Do	2-0	6-7	6.5	3.3	+1	-2	+2	+2
White spruce	3-0		7.0	1.3	+1	0	0	0
Weighted average, all species		5-8	6.9	5.34	-.04	+.05	+.03	+.04

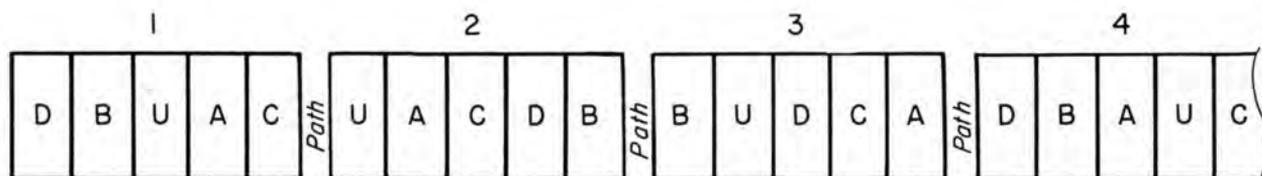


FIGURE 30.—An experimental bed with 4 replications, each of which has 5 plots. A, B, C, and D in each instance represent the 4 materials under test, and U the untreated check plot.

uniform. Mycorrhiza has spread because of the presence of host pines, good moisture conditions, and such operations as floating, dragging, disking, cultivating, and lifting.

In prairie soils such as those in western Minnesota and small areas of Wisconsin, lack of mycorrhiza could be a serious problem in newly established conifer nurseries, and inoculation would have to be made. The most feasible method is to incorporate topsoil and duff from nearby planted stands of pine or spruce into the top 2 to 3 inches of the seedbed. Another method is to line out or transplant seedlings from an old established nursery that produces large, thrifty seedling conifers of uniform size in a soil obviously well supplied with mycorrhiza.

These methods have the theoretical disadvantage of introducing damping-off or other disease organisms into a new nursery site, but appear to be the only ones yet feasible for large-scale operations. If the soil in the new site is about neutral (pH 7.0), treatment with sulfuric acid, or other acidifying materials, is absolutely necessary to lower the pH to about 5.5 or 6.0 because mycorrhiza spread faster in a moderately acid soil than in one which is neutral or alkaline.

EXPERIMENTAL PLOTS

There may be occasions when the nurseryman will wish to make tests of fertilizers, fungicides, or weed killers. For such purposes, experimental plots 4 by 4 feet in size are recommended, and they are best laid out in one or more long beds that provide for 4 or 5 contiguous replications (fig. 30). Such a bed samples more variation of soil than a square or nearly square test area. However, replication blocks may be scattered over as many as 4 locations separated by as much as 100 or 200 yards.

The plots in an experiment should be handled as uniformly as possible. Where the experiment involves pretreatment with a fertilizer or other soil amendment, a fungicide, or a weed-seed killer, it is best to mix the tree seed thoroughly and then weigh out the exact amount for each plot on a reasonably sensitive scale. Seeding should be done by hand at a uniform depth (fig. 31), and seed covered by sifting soil over the depressed seeded drills and smoothing it off carefully with a board or the back of a rake. In some instances the experimental beds may need screening against rodents, birds, or larger animals.

Experiments involving trials of weed control or liquid fertilizers may be superimposed on an existing bed of uniformly stocked first- or second-year seedlings or transplants. Counts can then be made of weeds before and after treatment and of trees injured or killed by the treatment.

In some experimental beds, counts of seedlings are required in late spring and in the fall. In others, only one final count before or after lifting may be necessary. At the end of the trials or tests, samples of the seedlings should be taken after lifting by selecting mechanically every 5th, 10th, or 20th seedling. The sample should be large enough to provide 25 or 50 trees out of each small bed. These sample seedlings provide a basis for determining percent of plantable and premium stock produced, total fresh or oven-dry weight, top-root ratio by weight, etc. Normally, the results of any four like treatments are pooled by average stand per square foot, number of plantable trees produced per square foot, number of premium-grade or undiseased trees produced per square foot, or average fresh or oven-dry weight per tree. If there are large and consistent differences in averages, the results of the experiment are quite apparent. If the differences are small, the data can be analyzed by statistical methods (32, 55, 147, 171). For this, assistance can be obtained from a United States Forest Service Forest Experiment Station or an individual familiar with mathematical procedures.



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FIGURE 31.—A closeup of a 4- by 4-foot experimental plot and a flanged wooden roller that assures uniform depth of seeding.

Hartley (66) recommends a procedure that will often add to the general observational picture in routine nursery operations. He suggests leaving a few check areas that are treated differently than the remainder of the nursery; for example, small shaded or unshaded units, and units treated differently as to watering, fertilization, or weed killers. This should provide clues to the relative effectiveness of certain treatments, aid in isolating possible causes of death, and help to explain differences in stand density or size.

AGE CLASSES OF STOCK NEEDED FOR REFORESTATION

The age classes to be produced at a nursery will depend on several factors. The most important is the kind of stock required to assure good survival in most years on the field planting sites (table 20). Older age classes or transplants often are recommended for the more difficult sites and for windbreaks.

Many studies conducted in the Lake States (57, 131, 132, 142, 159, 160) and in other areas (104, 146) indicate an advantage in first-year field survival of 10 to 40 percent for transplants over seedlings. On the more difficult sites, transplants may be necessary for good results and this fact has a bearing on the age class grown in the nursery.

TABLE 20.—Age classes of stock to use in reforestation and windbreak planting in the Lake States ¹

Species	For reforestation on—		For windbreaks
	Average to easy sites	Difficult sites	
Conifers:			
Douglas-fir			2-2, 2-3, 3-2
Fir, balsam	2-2, 3-0, 4-0	2-2, 2-3, 3-2	3-2, 2-3, 3-3, 2-2
Hemlock, eastern ²	2-2	2-2, 2-3	2-3, 3-2
Larch, European	2-1, 2-0	2-1, 1-2	2-1, 2-2, 1-2
Pine, Austrian			2-2, 2-1, 1-2
Pine, jack	2-0, 1½-0, 1-0	1-1, 2-0	1-1, 1-2, 2-0
Pine, ponderosa			2-2, 1-2, 2-1
Pine, red	2-1, 3-0, 2-0	2-2, 1-2, 2-1	2-2
Pine, Scotch ³	2-0, 2-1	2-2, 2-1	2-2
Pine, white	3-0, 2-0, 2-1	2-2, 1-2	2-2
Redcedar, eastern	2-1, 3-0, 2-0	2-2, 2-1	2-2
Spruce, black	2-1, 3-0	2-1, 2-2	2-2, 2-1
Spruce, blue			2-2, 2-3, 3-2
Spruce, Norway ³	2-1	2-2, 2-1	2-2
Spruce, western white			2-2, 2-3, 3-2
Spruce, white	2-2	2-2, 2-3, 3-2	2-3, 2-2, 3-2
Tamarack	2-0	1-1, 2-0	1-1, 1-2, 2-1
White-cedar			2-2, 2-3, 3-2
Broadleaves:			
Ash, black ²	2-0	2-0, 3-0	3-0, 2-0
Ash, green			2-0, 3-0
Ash, white	2-0	3-0, 2-0	3-0, 2-0
Aspen, quaking ⁴	2-0	1-1, 2-0	
Basswood	2-0	2-0, 3-0	3-0, 1-2
Beech, American ²	2-0, 1-0	3-0, 2-0	
Birch, paper ⁴	2-0	3-0, 2-0	3-0, 2-0
Birch, yellow ²	2-0	3-0, 2-0	
Cherry, black ²	2-0	3-0	
Cottonwood, eastern			
Elm, American	2-0, 1-0	2-0, 3-0	2-0, 3-0
Elm, rock ²	2-0	3-0, 2-0	3-0
Locust, black	1-0, 2-0	2-0, 1-0	2-0, 1-0
Maple, red	2-0	2-0, 3-0	3-0, 2-0
Maple, silver	1-0	2-0	2-0
Maple, sugar ²	2-0, 3-0	3-0	3-0
Oak, red ⁵	1-0	1-0, 2-0	1-0, 2-0
Oak, white ⁵	1-0	2-0, 1-0	2-0
Walnut, black ⁵	1-0	1-0	1-0

¹ Age classes are listed in each category in preferred order.

² Rarely used in reforestation because of difficulty of successful establishment due to deer, rabbits, site requirements, or costly aftercare.

³ Special care must be taken to assure proper seed source, adaptability to climate, and good form when mature.

⁴ Planting of this species is largely experimental as yet.

⁵ 1-0 or wildings, or 1-year rooted cuttings.

⁶ 1-year rooted cuttings or 2-0, or wildings.

⁷ 2-0 or 1-year rooted cuttings, or wildings.

⁸ Often established by direct seeding.

Extensive observations in shelterbelt and farmstead windbreak planting have shown that transplants of conifers are necessary to obtain uniformly good survival, especially on soils that are rather fertile or where weed growth is likely to engulf the trees unless they are cultivated. Small, spindly trees are easily buried in cultivation or smothered out by weed competition. The most favored age class is 2-2 conifer stock, although for the slower growing spruces 2-3 stock is sometimes necessary to get a tree of sufficient height, thickness of stem, and adequate root system to give uniformly high survival.

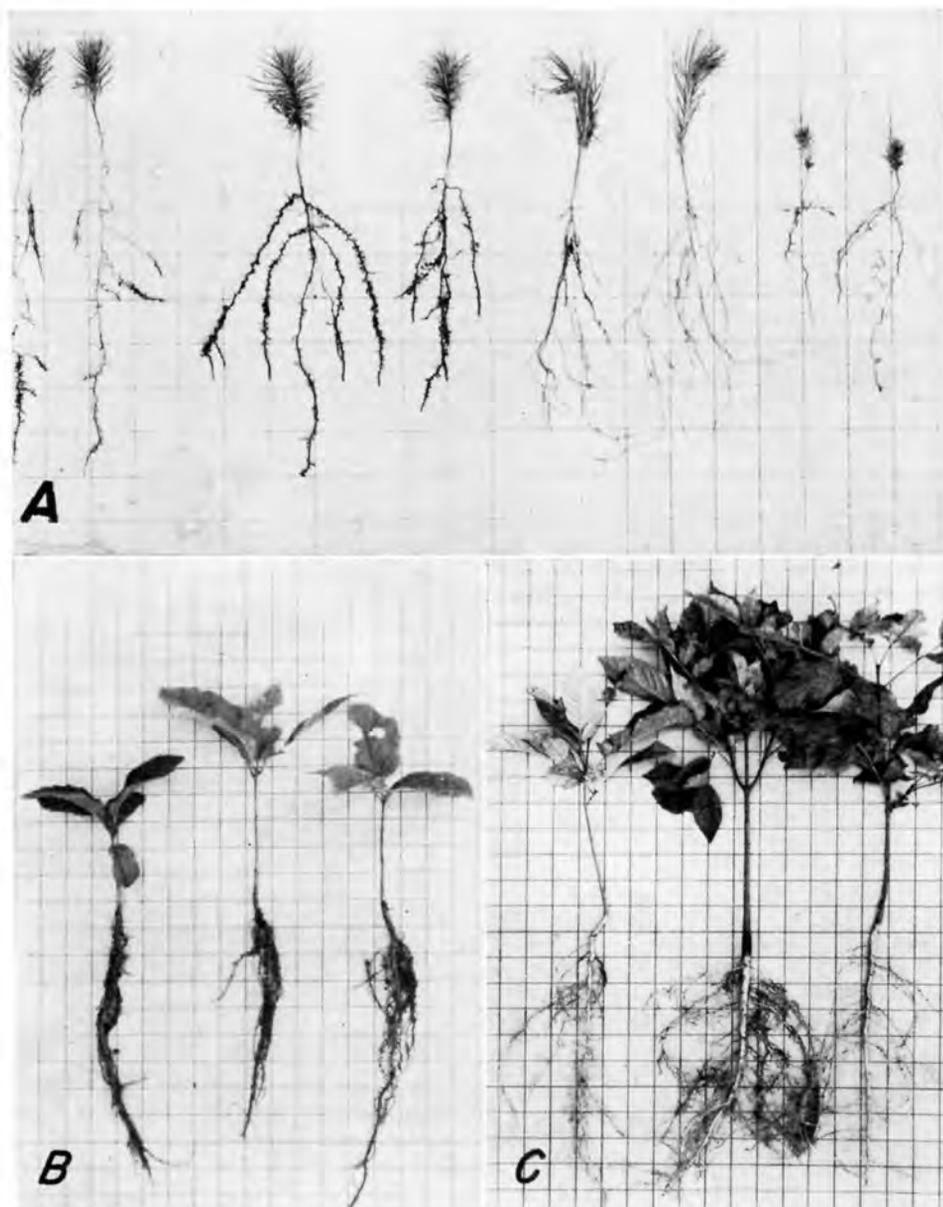
Other factors that govern the classes of stock to be produced are (1) the length of growing season

and the relative fertility level in the nursery, both of which affect the size of stock produced; (2) the inherent growth characteristic of the different species and age classes (fig. 32); (3) season of seeding; and (4) the time of transplanting. The effect on stock size from these sources may be great enough at some nurseries to call for adjustment in the age classes recommended in table 20.

Some nurseries are able to produce 2-0 red pine and 2-0 white pine that are practically as large and which will survive as well as 2-1 stock from other nurseries. Transplants of some species, such as red pine, grow well and increase very appreciably in size during the first year in the transplant beds. White spruce, on the other

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FIGURE 32.—A, Typical 1-year-old nursery seedlings. From left to right the sets of two seedlings are red pine, white pine, jack pine, and white spruce. B, Typical 1-0 red oak. C, Typical 2-0 white ash. (Background is 1-inch squares.)



hand, grows very slowly the first year in transplant beds in most Lake States nurseries, and only in its second year does it put on good growth. It usually increases in weight during its 4th year as much as or more than it did the previous 3 years. Hence, white spruce usually is grown to 2-2 age, which produces an excellent tree of good size, fine root system, and good balance; it survives and grows well under adverse field conditions. Older white spruce stock may be required for especially difficult planting chances, such as those commonly encountered in shelterbelt establishment.

In some nurseries 2-0 jack pine tends to become rather topheavy, so seeding is delayed until June to produce a shorter, well-balanced tree referred to as 1½-0 age class (fig. 33).

Fall-sown seedbeds invariably produce stock superior in size to spring-sown beds. This is especially striking and of importance for certain age classes that are difficult to develop to adequate size for field planting as seedling stock. Among these critical age classes are 1-0 jack pine, 2-0 red pine, and 2-0 white pine. For these age classes, fall seeding may result in sufficient size increase to produce 10 to 30 percent more plantable stock, largely because more of the trees will come up to the minimum caliper specification.

Stock measurements vary considerably by species and age classes (tables 21, 22, 23, and 24). For this reason, some species can be grown to plantable size in 1 or 2 years whereas others require 4 or 5 years.



F-380614

FIGURE 33.—Size of jack pine can be regulated by age class and time of seeding. At left are 2 1-0 seedlings; center 2 seedlings are 1½-0 age; at right are 2 seedlings of 2-0 age.

TABLE 21.—Measurement of jack pine and red pine stock from Lake States nurseries

Species and age class (years)	Density per square foot	Length		Stem caliper	Fresh weight			Top-root ratio by weight	Trees measured
		Top	Root		Top	Root	Total		
Jack pine:	<i>Number</i>	<i>Inches</i>	<i>Inches</i>	<i>¼ inch</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>		<i>Number</i>
1½-0	170	1.2	3.5	2.1	0.64	0.48	1.12	1.33	30
1-0	70	2.8	6.4	4.7	1.52	.57	2.09	2.67	150
1-0	60	4.7	9.5	5.3	1.95	.46	2.41	4.24	
1½-0	70	3.8	9.4	8.0	4.48	1.42	5.90	3.15	30
2-0	48	7.4	7.1	9.8	8.24	1.58	9.82	5.22	30
2-0	65	4.0	8.6	6.0	2.66	.70	3.36	3.80	50
1-1	16	3.6	10.6	7.4	4.24	1.82	6.06	2.33	60
1-1	16	5.1	12.1	10.7	10.47	2.85	13.32	3.67	80
1-2	16	13.7	11.7	13.8	19.71	3.23	22.94	6.10	10
1-2	16	7.2	17.6	12.0	15.44	5.00	20.44	3.09	50
Red pine:									
1-0	16	2.2	6.1	3.6	.42	.26	.68	1.62	10
1-1	16	1.6	10.4	7.0	1.12	.89	2.01	1.26	50
2-0	50	2.9	7.9	5.7	2.63	.70	3.33	3.76	80
2-0	60	3.4	10.4	7.6	3.63	.86	4.49	4.22	
3-0	45	6.3	9.3	9.6	9.67	1.59	11.26	6.08	250
3-0	48	6.6	9.4	7.3	5.47	.83	6.30	6.59	30
2-1	15	4.1	10.6	9.4	5.91	2.89	8.80	2.04	60
2-1	16	4.0	10.6	9.0	5.15	2.23	7.38	2.31	160
2-1	16	7.3	9.6	13.4	10.90	7.02	17.92	1.55	30
1-2	16	5.1	11.3	9.0	10.72	2.23	12.95	4.81	50
3-1	16	6.9	11.0	11.8	8.24	3.60	11.84	2.29	60
2-2	16	8.1	14.0	13.3	20.72	4.99	25.71	4.15	90

¹ Estimated density.

TABLE 22.—Measurement of white pine and white spruce stock from Lake States nurseries

Species and age class (years)	Density per square foot	Length		Stem caliper	Fresh weight			Top-root ratio by weight	Trees measured
		Top	Root		Top	Root	Total		
White pine:	<i>Number</i>	<i>Inches</i>	<i>Inches</i>	$\frac{1}{64}$ <i>inch</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>		<i>Number</i>
1-0-----	¹ 70	2.0	6.7	3.3	0.33	0.34	0.67	0.97	30
2-0-----	50	3.3	9.0	6.0	1.07	.66	1.73	1.62	50
1-1-----	16	3.6	11.9	6.9	1.74	1.96	3.70	.89	50
2-1-----	16	4.4	10.9	8.1	2.77	2.30	5.07	1.20	60
2-1-----	16	4.7	10.5	8.7	3.95	2.58	6.53	1.53	110
3-1-----	16	7.1	14.7	9.7	5.87	4.38	10.25	1.34	30
1-3-----	16	11.5	14.0	14.7	18.59	8.50	27.09	2.19	30
2-2-----	16	10.3	8.1	12.7	16.09	7.26	23.35	2.22	20
2-3-----	16	15.3	14.7	18.7	38.57	16.80	55.37	2.30	30
White spruce:									
1-0-----	¹ 80	1.2	4.0	1.9	.09	.09	.18	1.00	10
2-0-----	¹ 80	2.8	9.6	4.0	.57	.35	.92	1.63	290
3-0-----	¹ 70	4.7	8.0	6.4	2.11	.83	2.94	2.54	160
4-0-----	30	6.0	4.6	11.8	9.69	3.28	12.97	2.95	80
2-1-----	16	4.6	8.9	4.5	2.54	2.00	4.54	1.27	80
2-2-----	16	5.9	11.3	10.4	7.46	3.33	10.79	2.24	80
2-2-----	16	8.1	5.9	13.1	12.82	4.72	17.54	2.72	20
3-1-----	16	6.4	9.6	10.5	3.77	2.68	6.45	1.41	80
3-1-----	16	5.5	9.1	9.0	3.43	2.33	5.76	1.47	50
3-2-----	15	7.6	7.8	16.2	14.56	8.28	22.84	1.76	30

¹ Estimated density.

TABLE 23.—Measurement of miscellaneous conifers from Lake States nurseries

Species and age class (years)	Density per square foot	Length		Stem caliper	Fresh weight			Top-root ratio by weight	Trees measured
		Top	Root		Top	Root	Total		
Black spruce:	<i>Number</i>	<i>Inches</i>	<i>Inches</i>	$\frac{1}{64}$ <i>inch</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>		<i>Number</i>
2-0-----	50	6.7	5.9	9.2	6.44	2.63	9.07	2.45	20
2-1-----	18	10.4	9.3	14.5	13.06	7.06	20.12	1.85	30
Norway spruce:									
3-1-----	16	5.6	9.1	8.0	3.48	2.70	6.18	1.29	50
3-2-----	16	7.2	6.0	10.9	10.64	4.42	15.06	2.41	20
2-4-----	16	11.6	7.5	17.6	32.03	8.41	40.44	3.81	30
Scotch pine:									
2-1-----	16	5.1	10.6	7.0	4.27	1.69	5.96	2.53	50
2-1-----	16	5.5	10.9	11.0	6.57	4.43	11.00	1.48	50
White-cedar:									
2-0-----	45	3.0	2.7	3.1	7.70	1.90	9.60	4.05	20
3-2-----	12	7.3	10.9	13.4	18.80	6.40	25.20	2.94	30
Hemlock:									
3-1-----	16	6.8	4.9	6.9	3.84	2.33	6.17	1.65	16
Balsam fir:									
2-2-----	¹ 16	5.0	8.9	7.7	5.48	2.22	7.70	2.47	10
Tamarack:									
2-0-----	¹ 16	6.2	7.0	7.7	1.92	2.36	4.28	.81	10

¹ Estimated density.

TABLE 24.—Measurement of broadleaf stock from Lake States nurseries

Species and age class (years)	Density per square foot	Length		Stem caliper	Fresh weight			Top-root ratio by weight	Trees measured
		Top	Root		Top	Root	Total		
Sugar maple:	<i>Number</i>	<i>Inches</i>	<i>Inches</i>	$\frac{1}{64}$ <i>inch</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>		<i>Number</i>
1-0-----	¹ 15	3.3	6.0	6.3	1.09	1.18	2.27	0.92	80
2-0-----	10	3.6	10.8	10.6	.52	3.60	4.12	.14	30
3-0-----	¹ 10	9.6	13.2	13.7	2.58	6.71	9.29	.38	520
1-0 wildings	¹ 5	2.0	3.3	4.7	.51	.61	1.12	.84	30
Yellow birch:									
1-0-----	¹ 15	3.6	6.1	6.3	.63	.56	1.19	1.12	230
2-0-----	17	11.4	9.4	12.5	2.68	2.71	5.39	.99	30
3-0-----	¹ 15	20.5	12.6	18.7	14.32	9.26	23.58	1.55	780
Red oak:									
1-0-----	¹ 10	3.8	11.4	12.1	4.26	6.34	10.60	.67	30
2-0-----	¹ 10	7.9	13.2	13.7	3.38	14.75	18.13	.23	60
Basswood:									
1-0-----	¹ 10	3.2	8.5	11.7	3.19	3.73	6.92	.86	130
2-0-----	¹ 10	5.8	9.4	17.0	3.16	15.80	18.96	.20	30
White ash:									
1-0-----	¹ 10	4.5	9.7	6.0	.28	.45	.73	.62	50
2-0-----	¹ 10	9.7	10.8	11.9	4.95	5.97	10.92	.83	30
Black ash:									
1-0-----	6	2.0	4.6	5.3	.10	.59	.69	.17	30
Rock elm:									
1-0-----	15	.9	5.3	3.2	.60	.40	1.00	1.50	30
1½-0-----	38	4.1	7.9	6.5	1.49	2.34	3.83	.64	30
2½-0-----	¹ 15	8.5	8.6	13.4	5.32	10.58	15.90	.50	60
Beech:									
1-0-----	¹ 5	3.5	6.4	6.2	1.21	1.54	2.75	.79	30

¹ Estimated density.

SEEDBED PREPARATION AND SOWING

The success of either broadcast or drill sowing depends to some extent upon the thoroughness of ground preparation. To obtain the good tilth that is essential, the nurseryman must use proper equipment and carefully plan and time the various phases of the job. The equipment and its uses are discussed in an earlier section (p. 33). All ground preparation should be completed early enough so that the soil can settle before sowing is done.

Prospective nursery areas that support a soil-improvement crop require a slightly different method of preparation than areas that are fallow. If the nursery is to be seeded in the fall, the green cover crop should be turned under early enough so that it can decompose before seeding is begun. Soil-improvement crops commonly sown in the fall reach the optimum stage for turning under about the middle of June or early July. Spring-sown crops tend to mature later and do not require turning down until about the last week in July. After plowing, the area should be disked.

A seedbed surface as near level as possible facilitates a good job of sowing. Therefore, after initial ground preparation, and when the seedbed boards are in place or the sides of the beds delineated by wire, it is good practice to cut down the high points in the beds and fill the depressions. A bed leveler is useful for this purpose (fig. 34). If a high water table exists in any part of the nursery, or if there is a drainage problem, the beds should be higher than the paths. Usually, the weight of the tractors used in the nursery depresses the paths sufficiently. If necessary, however, the paths can be lowered easily and quickly with a roundpoint shovel or corn tiller. Some nurserymen have found it convenient to shape the seedbeds with a special tool designed for this purpose (fig. 35).

In fall seeding, seedbed boards are placed on one side of the bed only to simplify rolling out the screen or snow fence that is used to hold the mulch in place over winter. The remaining bedboards are put up in the spring after the mulch has been removed and the seeds start to germinate.

F-243213

FIGURE 34.—A hand-drawn bed leveler equally well adapted for drill- or broadcast-sown beds.





FIGURE 35.—A seedbed shaper of commercial manufacture.

F-473834

Drill seeding has quite generally replaced broadcast seeding by hand in Lake States nurseries. Although it does not afford as uniform distribution of seed per given area as does broadcasting, it is the most economical method. It eliminates the cost of sand covering and permits mechanical cultivation. However, opinion differs as to the relative merits of drill versus broadcast seeding. At fairly high seedbed density (150 or more per square foot), broadcasting probably consistently produces slightly larger and more uniform stock with lower cull percent. This is attributed to a better distribution of the plants over the entire growing space and greater uniformity of depth of the sand cover. But with the trend toward rather low seedling density (often only 50 to 60 per square foot), there is less advantage for the broadcasting. Turner (178) found the average dry weight of 2-0 red pine seedlings nearly the same in drill and broadcast beds grown at rather low densities.

For many years conifers were sown in 10 drills per 4-foot-wide bed with a space of 4.6 inches between rows, center to center. In 1938, Lanquist (79) introduced the 7-drill bed that left a 4¾-inch space between outer edges of adjoining drills. This made it easier to cultivate between the rows, and with less damage to the trees, and also simplified vertical root pruning.

An experiment conducted at Hugo Sauer Nursery, Rhinelander, Wis., involving several methods of seeding jack pine did not show any advantage in first-year field survival of 2-0 stock for broad-

cast seeding over drills or bands. If anything, the narrow drill seeding had some advantage, as shown in the following tabulation:

<i>Spring-planted 2-0 jack pine</i>		
Method of sowing:	<i>Trees per square foot (number)</i>	<i>Field survival (percent)</i>
Broadcast-----	40	88. 8
Do-----	80	83. 2
Drills 1 inch wide, 4½ inches apart, center to center----	40	96. 0
Do-----	80	93. 8
Drills 2 inches wide, 4½ inches apart, center to center----	40	96. 8
Do-----	80	91. 5
Bands 4 inches wide, 12 inches apart, center to center----	40	90. 5
Do-----	80	81. 1
Bands 16 inches wide, 12 inches apart, center to center----	40	91. 2
Do-----	80	81. 2
Least significant mean difference at 5-percent level-----		7. 80
Least significant mean difference at 1-percent level-----		10. 37

BROADCAST SEEDING

Where hand methods are used, the seed should be measured out in small quantities and broadcast by an experienced man. The smaller the unit sown with each measure of seed, the more even will be the distribution; 100-square-foot units are a convenient size. A graduated container facilitates rapid handling of the seed. The sower carries the

seed in a pail and scatters them from the margin to the center of the bed with his free hand as he moves along the path.

Broadcast seeding by mechanical methods is preferred by some nurserymen. Manually operated lawn seeders equipped with hopper and slotted bottom have proved satisfactory for this purpose. The Nekoosa-Edwards Paper Company Nursery, Port Edwards, Wis., uses a Scott lawn seeder that is about 18 inches wide. The seeder is run with 1 wheel on top of a vertically set 1- by 4-inch bedboard placed on two sides of the bed. A trip is made down one side of the bed and back on the other. This leaves an unseeded strip about 10 inches wide down the middle of each bed. The strip, to a large extent, does away with the depression of growth often found in densely sown beds that are broadcast to their full 4-foot width.

The mechanical seed drill (fig. 13, p. 34) can also be adapted for broadcast seeding by removing the seeder assemblies and replacing them with a baffle-board on which the seed strikes as it falls to the ground.¹³ The baffleboard is mounted at an angle to the surface of the bed with the tubes directly above it. Since the direct-force feed device can be regulated to deliver a constant and uniform flow of seed, distribution is better than that ordinarily obtained by hand methods.

When seed are sown broadcast, either by hand or mechanically, they must be pressed lightly into the soil with a roller and covered with $\frac{1}{4}$ to $\frac{1}{2}$ inch of nonalkaline sand.¹⁴ The sand can be applied by sifting it through a tray that has a bottom of 4-mesh hardware cloth. Two men, facing each other across the seedbed, hold the handle-equipped tray. A third man shovels the sand into the screen. The screened part of such a tray is usually 40 inches long by 30 inches wide with handles 12 inches long. On larger operations, a special sanding machine can be used which carries the sand on an endless belt device similar to that on a manure spreader.

At the Bessey Nursery, Halsey, Nebr., a hand-drawn sand spreader was devised which in appearance is like a medium-sized lime spreader; it consists of a trough the width of a bed mounted on two wheels. An adjustable, rotating, vane-equipped shaft in the bottom of the trough pushes out a uniform layer of sand onto the bed. Great care should be taken to use lime-free sands, because limy sands can cause much damping-off and retard growth, especially of the pines grown in Lake States nurseries (38). If lime-free sand is not available, burlap mulch or sawdust may be used to cover broadcast-sown seed.

¹³ A blueprint of the Bessey Nursery seed sower can be obtained from U. S. Forest Service, Federal Center, Bldg. 85, Denver 7, Colo.

¹⁴ Seeds of a few species, notably aspen and cottonwood (19), are sown directly on the surface and not covered. For the first 2 or 3 days the beds are watered several times daily to keep the surface continually moist. Seeding on a $\frac{1}{4}$ -inch layer of screened peat aids germination because of retention of moisture.

DRILL SEEDING

When a mechanical seed drill is used, the nurseryman should make sure that it is adjusted to deliver the proper amount of seed per unit of seedbed. A simple method for adjusting the machine is to place a wide piece of canvas on the ground and operate the seeder over it. Changing sprockets on the feed and drive shafts will cause different amounts of seed to be delivered. The seed falling onto the canvas at each trial should be accurately weighed or counted to check delivery rate, and the testing continued until the right combination of sprockets is found. Since the drill seeder is equipped with a device for covering the seed and also with a roller that compacts the soil, the need for applying sand and then rolling the beds is eliminated.

Beds with hand-sown drills must be floated to cover the seed and then rolled to firm the soil. In long, continuous beds, the drills usually are made lengthwise to facilitate later mechanical operations. However, crosswise drills are appropriate to 4- by 12-foot seedbeds, and a drill board is a useful tool for their preparation. It can be made by tacking wood strips of the desired width and thickness, $4\frac{1}{2}$ inches apart, onto a 20- by 46-inch board.

Seeds that are large or difficult to de-wing usually are sown by hand in shallow drills. The sower should measure and distribute them with the same care that is required in handling smaller or de-winged seeds. A semimechanical method for handling seed of any size and shape, which is much faster than the usual method of hand sowing, was developed by nurserymen of the Prairie States Forestry Project (47). Two to four men ride a sled-type furrowing device and distribute the seed by hand in drills as the machine is drawn over the prepared bed.

DENSITY OF SEEDING

Since it is the general aim to produce a maximum number of premium-grade trees per unit of seedbed area, optimum density should be determined for each species, taking into consideration the age at which the stock is to be removed from the beds and the purpose for which it is to be used. A better quality of plant is required for outplanting as seedlings than for transplanting in the nursery. Although top and root length must be considered in evaluating the quality of seedlings, stem diameter is the most useful criterion. This latter characteristic usually is influenced by density more than by other factors. Recommended seedbed densities for conifer and hardwood stock are given in table 25.

The changes adopted in seeding densities in recent years reduced by about half the densities used several decades ago. This reduction was especially necessary for field planting stock because high densities result in small-caliper, spindly, and,

on occasion, topheavy stock that is easily matted down. The root systems of such trees often are undersized and in periods of drought are unable to supply enough moisture to keep the plant alive. Furthermore, in high-density beds, trees of inferior genetic quality are more difficult to grade out than they are in medium- or low-density beds where the contrast in size is more apparent.

TABLE 25.—Recommended seedbed density per square foot, by species, for stock that is to be field planted or transplanted in nursery¹

Species	Density when stock for field planting is—				Density when stock for transplanting is—		
	1-0	1½-0	2-0	3-0	1-0	2-0	3-0
	No.	No.	No.	No.	No.	No.	No.
Douglas-fir			30	40		75	75
Fir, balsam			50	40		75	75
Hemlock, eastern						65	65
Larch, European			40		60		
Pine, Austrian			50		65		
Pine, jack	55	50	50		65	65	
Pine, ponderosa			50		65	65	
Pine, red			50	40	65	65	
Pine, Scotch			50		65	65	
Pine, white			50	40	65	65	
Redcedar, eastern			30	30	50	45	
Spruce, black, blue, Norway, white, and western white			50	40		75	75
Tamarack			40		60		
White-cedar, northern						65	65
Ash, black, green, and white			15		25	25	
Basswood			15		25	25	
Birch, paper and yellow			15	15			
Cottonwood	10				25		
Locust, black	15	15	20				
Maple, red, silver, and sugar			15				
Oak, red and white	10		10				

¹ Since permissible densities are affected by soil-fertility level, length of growing season, and frequency of watering, the figures given here might be raised by 20 or 30 percent under exceptionally favorable conditions.

The chief reason for using lower seedbed densities for stock to be transplanted in the nursery is to reduce cull percent not only in the stock to be transplanted, but also in the transplants themselves. The latter point is of especial moment in the case of 2-1 transplants. Since they are left in the transplant bed only 1 year, fairly good-sized 2-0 stock is necessary if an adequate size transplant is to be produced. With 2-2 conifer stock, there can be much more tolerance of higher seedbed densities because deficiencies in the 2-0 size usually are made up by the time the plants have completed 2 full years in the transplant bed.

In a number of experiments, the general trend in response of trees to increasing density of stand

was a marked and consistent decrease in average stem diameter and a decrease in average total weight per tree (table 26). For white pine grown at densities of 20 to 80 per square foot, there was roughly a decrease of 0.5 gram in average total fresh weight per seedling for every increase of 10 in density. Quadrupling density from 20 to 80 per square foot resulted roughly in reducing by half the average green weight per plant. For a somewhat faster growing species, such as red pine, the average green weight was reduced by nearly 60 percent by a density increase from 20 to 80. For sugar maple, the quadrupling of density from around 5 to 20 per square foot resulted in about a 70-percent reduction in average seedling weight. For hardwoods in general, there is a more marked reduction in tree height as density increases than there is in conifers. Increased densities in 3-0 conifer beds tend to increase the ratio of top to root on a weight basis.

Red pine 3-0 stock is quite satisfactory for spring planting if grown at a density of 40 to 50 per square foot, and it is becoming a favored stock for use in machine planting. In a spring planting, stock grown at about 45 trees per square foot showed less than 5 percent first-year mortality in the field. Mortality in fall-planted stock doubled when the density in the beds was increased from 25 to 80 trees per square foot. In the former, mortality was 25 percent; in the latter it was 50 percent. These differences are highly significant. Densities in 3-0 red pine beds may be considerably higher if the stock is to be planted in the spring than if it is to be planted in the fall.

A separate experiment with stock from a different nursery, and planted on a different forest, brought out the general superiority of 2-1 transplants of red pine over 3-0 seedlings for fall planting. First-year survival of the transplants was 93.2. For the 3-0 red pine seedlings grown at nursery densities of 15, 33, 48, 75, 84, and 101 per square foot, the first-year field survivals were 80, 53, 61, 52, 46, and 51 percent, respectively. These differences are highly significant statistically in favor of the lowest density class.

The 2-0 class of white pine stock is seldom suitable for field planting regardless of the density at which it is produced. 2-0 stock grown at densities of 60 to 70 seedlings per square foot produces a maximum number of plants for transplanting. If grown at densities of 40 to 45 plants per square foot, well-balanced 3-0 can be produced without top and root pruning. For fall planting, somewhat lower densities, preferably 25 to 35 seedlings per square foot, are required for 3-0 white pine to yield good survival.

In an experiment on white pine, 3-0 stock grown at 26 trees per square foot gave 89 percent second-year survival in fall plantings, or nearly as good as 2-1 transplants which had 91 percent survival. In spring plantings, first-year survivals of more than 90 percent were obtained with stock grown as dense as 50 trees per square foot.

TABLE 26.—Effect of density of seedling stand on size of stock

Class of stock and species ¹	Actual density per square foot	Average length		Average stem diameter	Average green weight			Average top-root ratio
		Top	Root		Top	Root	Total	
	Number	Inches	Inches	$\frac{1}{64}$ inch	Grams	Grams	Grams	
2-0 jack pine	18	6.4	7.8	11.4	10.40	1.90	12.30	5.47
Do	29	7.2	7.8	9.8	7.30	1.40	8.70	5.21
Do	49	5.8	8.4	8.4	5.30	1.00	6.30	5.30
Do	59	5.1	7.9	7.8	4.10	.80	4.90	5.12
Do	74	5.1	7.5	7.4	3.80	.80	4.60	4.75
3-0 white pine	13	3.4	12.2	8.0	4.73	1.97	6.70	2.40
Do	26	4.1	10.7	7.4	4.68	1.54	6.22	3.04
Do	47	4.9	10.4	6.8	3.70	1.07	4.77	3.46
Do	59	4.5	10.2	6.3	2.85	.89	3.74	3.20
Do	81	5.0	9.8	6.0	2.78	.74	3.52	3.76
3-0 red pine	15	7.3	11.8	11.1	14.51	2.62	17.13	5.54
Do	33	6.6	10.3	8.3	8.01	1.29	9.30	6.21
Do	48	6.6	9.4	7.3	5.47	.83	6.30	6.59
Do	75	6.3	9.7	7.4	5.25	.83	6.08	6.33
Do	84	5.9	9.4	6.8	4.70	.78	5.48	6.03
Do	101	6.6	8.6	6.7	4.30	.66	4.96	6.52
3-0 sugar maple	3	14.4	14.7	17.8	5.81	14.79	20.60	.39
Do	8	11.2	12.7	14.9	3.28	8.21	11.49	.40
Do	11	9.2	12.5	13.4	2.88	6.74	9.62	.43
Do	20	7.6	11.1	12.8	1.84	3.74	5.58	.49

¹ Jack pine and sugar maple grown at the Hugo Sauer Nursery, Rhinelander, Wis. White pine and red pine stock grown at the Hayward Nursery, Hayward, Wis.

A series of 5 separate experiments, each involving nearly 10 thousand 3-0 red and white pine trees, showed highly significant differences in survival, in each case in favor of trees grown at low density compared with high density. The density markedly affected diameter and, to some extent, top-root ratios as shown in table 26 for 3-0 age classes.

With 2-0 jack pine, no significant difference was observable in field survival in two separate tests involving thin and moderate sowing. A poor first-year survival of 56 percent was noted in fall-planted 2-0 jack pine. These seedlings were grown on soil that had an excessively high fertility level which resulted in unusually tall, heavy foliated trees with tops averaging more than 8 inches. The top-root ratio was 5.3 to 1 on the basis of fresh weight. Other age classes of better balanced stock had a first-year survival of 82 to 94 percent. The same general trend of poor survival in fall planting held for poorly balanced 3-0 red pine when compared with other classes of stock that had a better relation of tops to roots (160).

COMPUTING THE AMOUNT OF SEED TO SOW

Accurate information should be available regarding the germination percent and total number of seed per pound for each lot of seed to be used. This information, and the desired density per unit of area, can be used to compute the amount of seed to sow. The formula follows:

$$P = \frac{A \times D}{G \times S \times Y}, \text{ when } P = \text{pounds of seed; } A =$$

area in square feet; D = density, that is, desired number of seedlings per square foot; G = germination percentage of the seed, expressed as a decimal; S = number of seed per pound as they come from the container; and Y = survival factor, variable by species, based on the percentage of viable seed that will produce seedlings which survive at end of the first year, expressed as a decimal.

For example, suppose that the amount of red pine seed to sow per 100 square feet to produce 55 seedlings per square foot is to be determined. The seed to be used run 45,000 to the pound, have a germination of 90 percent, and a survival factor of 0.65. The formula becomes:

$$P = \frac{100 \times 55}{0.90 \times 45,000 \times 0.65}$$

$$P = 0.209 \text{ pounds}$$

The number of seed to sow per linear foot of drill can likewise be computed. The formula follows:

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

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

For example, if the desired stand is 10 seedlings per linear foot, and the seed has a germination percentage of 60 and a survival factor of 40 percent, the formula becomes:

$$N = \frac{10}{0.60 \times 0.40}; \text{ or}$$

$N = 41.67$ seed per linear foot of drill.

The following tabulation may be useful to nurserymen in judging roughly how much seed must be sown to meet certain production goals, or in gaging how much seed to sow in the absence of a germination test. It is based on experience tables for the more important species grown in the Lake States.

Species:	Trees produced per pound of seed of average germination capacity (thousands)
Douglas-fir	11.00
Fir, balsam	8.20
Hemlock, eastern	24.00
Larch, European	10.80
Pine, Austrian	9.10
Pine, jack	38.00
Pine, ponderosa	4.80
Pine, red	28.00
Pine, Scotch	19.00
Pine, white	11.00
Redcedar, eastern	3.80
Spruce, black	50.00
Spruce, Norway	16.00
Spruce, white	43.00
Tamarack	60.00
White-cedar, northern	12.00
Ash, black	1.20
Ash, green	4.70
Ash, white	3.10
Aspen, quaking	36.00
Basswood	.30
Beech, American	.80
Birch, paper	25.00
Birch, yellow	9.20
Cherry, black	1.20
Cottonwood	25.00
Elm, American	5.50
Elm, rock	1.90
Locust, black	6.40
Maple, red	4.20
Maple, silver	.34
Maple, sugar	1.20
Oak, red	.07
Oak, white	.10
Walnut, black	.04

In every lot of seedlings, and to a minor extent in transplants, there are cull trees that must be discarded. Generally, from 5 to 20 percent of the seedlings and 1 to 3 percent of the transplants are culls. Cull percent varies by density of sowing, soil fertility, class of stock produced, and rigidity of culling standards. To compensate for expected cull, an additional area should be seeded.

DEPTH OF SEEDING

Since depth of seeding influences the establishment of an even and uniform stand of seedlings, its importance cannot be emphasized too strongly. Each species has an optimum seeding depth that

varies with the size of seed, soil texture, and the season of sowing (18, 174). Although large seeds may be sown more deeply than small seeds, deep sowing increases the liability of injury from damping-off fungi, and makes emergence more difficult. Seeding depth can be about one-third greater in the light, sandy soils than in the heavier, loam soils because of the comparatively greater ease of emergence in the former. Experience has also shown that in the fall seeds should be sown slightly deeper than in the spring to prevent their being thrown out by frost action or uncovered by wind erosion.

TIME OF SOWING

Since seed dormancy and optimum germination temperature vary by species, the time of sowing to assure prompt and complete germination also varies. In general, seed of the conifers commonly produced in the Lake States can be safely and often advantageously sown in the fall. When sown in the spring, seeds of some species require pretreatment for best results. Stratification for 30 to 60 days of 40° F. has proved to be a good method for breaking embryo dormancy of several species. Seeds that do not keep well in storage, or those that can germinate within a few days after they ripen, should be sown immediately after collection. Silver maple and white oak seeds are in this category.

Local climatic conditions must be taken into account in setting up seeding practices, particularly those for fall sowing. While fall sowing in the Lake States region should be done during late September or October, injury and losses from premature germination may result if temperatures are unseasonably warm. Therefore, at nurseries in areas where fall weather conditions are variable, seeding should be postponed until temperatures conducive to premature germination have passed.

Premature germination of fall-sown seed, with subsequent freezing and mortality, apparently is most likely to occur in the more southerly nurseries in the Lake and Central States. This is particularly true of nurseries in a latitude of about 44° or farther south, or where the frost-free period is 140 days or more. For example, Chittenden Nursery reports that jack pine has, on occasion, tended to germinate prematurely; hence, sowing there is delayed until late in October. Fall germination of ponderosa pine, Scotch pine, and Norway spruce has also been reported.

Fall-sown seedlings commonly are larger and better developed at the end of the first season than spring-sown seedlings, because of the longer growing season available to them. For instance, in a lot of 2-0 jack pine grown at the Hugo Sauer Nursery, Rhinelander, Wis., the average fresh weight per fall-sown seedling was 8.2 grams as compared to 5.3 grams per spring-sown seedling. Second-year red pine often shows the same general relationship.

Because fall-sown beds must be protected from seed-eating birds and rodents, wind erosion, and frost heaving, the cost of completing the work, per square foot of seedbed, is slightly higher than for spring sowing. However, because of more complete germination, better development, and a higher percentage of plantable trees obtained from fall sowing, the unit cost per thousand plantable trees normally is less than for spring sowing.

Spring seeding should be done as early as the ground can be worked. Early seeding gives the young plants the advantage of a longer growing season, an important factor in the development of conifer seedlings.

In producing 1½-0 stock in the Lake States, seeding must be postponed until June 10 to 15, which allows only a short growing season the first year. Sowing at this late date exposes the seedlings to high air and ground temperatures during the period of germination and frequently results in high, early mortality. The remaining stand also is subject to heavy loss over winter by frost heaving and winter injury. Nevertheless, late spring sowing for the production of 1½-0 jack pine has been successful. Because of its better top-root ratio, this class of stock sometimes has been used in preference to 2-0 unpruned jack pine. However, since a very satisfactory type of seedling for field planting can be obtained by top-pruning 2-0 jack pine, the practice of raising 1½-0 stock is recommended only in case of emergency where fall or early spring seeding cannot be accomplished.

The general practices relative to season of sowing discussed here for conifers also are applicable to the hardwoods. Although the seeds for many of the species whose fruits ripen in the fall can be stored over winter and seeded in the spring, fall seeding or stratification of the seed over winter has given better results than sowing unstratified seed in the spring.

SEEDBED MULCHES

Mulches generally are used to protect newly sown seedbeds from wind erosion, frost heaving, and premature germination in the spring, and to conserve moisture. Frequently mulches also are used to protect spruce, white-cedar, and other slow-growing species during the first winter following germination. Mulches also offer some control against pilfering of the seeds by birds, and retard weed growth during the pregermination period. Several materials, including burlap, light woven cotton cloth, straw, marsh hay, and sawdust, have been used for this purpose. Each nurseryman should decide from his own experience whether the benefits obtained from using a mulch more than offset the cost of the material and labor.

Burlap or cotton cloth strips, wide enough to cover the beds and fastened with wire pins 4 to 6 feet apart, are the most desirable mulches for spring-sown beds. Although initial cost and a relatively short life are objectionable features,

these materials can be applied and removed at a minimum labor cost. Since excessive moisture and contact with the soil tend to hasten their disintegration, they are not particularly satisfactory as overwinter mulches. To extend their life, it is highly important that they be thoroughly dry before they are rolled and stored (fig. 36). Southern nurseries have been treating burlap with copper naphthenate to improve resistance against rotting (183).

Clean straw and marsh hay with a high percentage of sedge have proved satisfactory for protecting fall-sown beds. They are much cheaper than burlap and can be applied at a reasonable cost if the work involved is adequately organized. Material free of weed seeds should be used. It can be obtained by cutting and gathering the hay when its seed is in the milk stage and the crop is immature. Rye straw has also proved to be a good mulch material in Forest Service nurseries. Its long stems, large yield per acre, and the fact that it is ready for cutting at an early date makes rye a very desirable crop to produce for a mulch. If properly handled, it can be used several years. When removed from the beds in the spring, it should be stacked in a pile where it can be kept dry.

In Lake States nurseries, a layer of straw ½ to 1 inch deep when compressed has been found to be sufficient for mulching newly prepared seedbeds. A slightly deeper layer is required for 1-0 stock since the purpose here is to reduce as much as possible the alternate freezing and thawing of the soil, the action of which heaves the small seedlings out of the ground. The mulch is spread on the beds from a small moving trailer that straddles the beds. Two to four men working from the

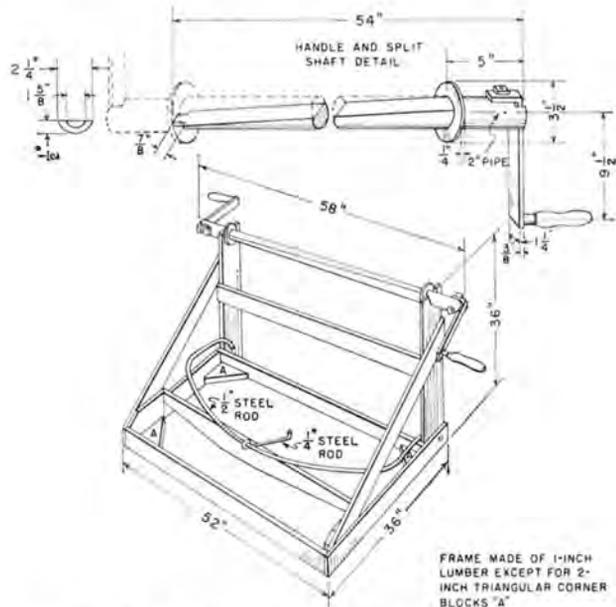


FIGURE 36.—A reel is an efficient tool for rolling and storing burlap.

paths shake out the material and spread it by hand as evenly as possible. After the mulch has been spread, hardware cloth or snow fence is rolled out over it to hold it in place (fig. 37). Where it is necessary to mulch 1-0 stock, one edge of the cloth or snow fence is rested on the seedbed board to provide aeration and prevent compaction of the mulch under weight of snow.

Other organic mulches, including hardwood leaves and pine needles, have proved effective at some nurseries. Because these materials usually are expensive to collect and difficult to remove from the beds in the spring, they are not used as extensively as straw mulches. Furthermore, there is risk of bringing in needle blight. Softwood and hardwood sawdust have also been used to a limited extent, but this type of mulch is difficult to remove in the spring and, because of the quantities required, cannot safely be left on the bed during the period of germination and early seedling development.

Mulches delay germination for 10 to 14 days. Hence, they may be useful in retarding too early germination in sections where unseasonable warm spells frequently occur. The removal of mulches is discussed on p. 71.

Some nurserymen have found that a snow blanket obtained with a series of snow fences is very effective in protecting seedlings. It reduces soil erosion from wind action and the accumulated

snow is an additional source of moisture. Labor costs for this method are ordinarily less than for mulching.



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FIGURE 37.—Rolling out hardware cloth to hold mulch in place on recently seeded beds.

SOIL MOISTURE AND IRRIGATION

Every soil has a maximum water-holding capacity. This field capacity usually is from 12 to 15 percent for loamy sand soils containing 15 to 20 percent of silt-plus-clay; the water applied to the root zone (usually the surface 8 inches) should bring the moisture content up to about field capacity. Application of more water merely results in loss by percolation and is hence a waste of power in applying the excess.

Together, percolation, evaporation, and plant use often cause a rapid loss of water from the soil surface (fig. 38). In one instance there was a drop from 23 percent total moisture directly after a rain ending at 8 a. m. to about 15 percent in a brief period of 6 hours (fig. 38). Thereafter, it leveled off at about 14.5 percent by 8 a. m. the following day. This value apparently is the approximate field capacity for this type of soil. Similar results were noted by Turner (176) in the Beal Nursery at East Tawas, Mich.

During the germination period, and for about 2 months thereafter, irrigation is necessary in Lake States nurseries, particularly for conifer seedbeds. The critical surface inch of soil must be kept moist by daily watering or rain, except in days of low evaporation. In periods of extreme heat or drought, especially in June and July, or when strong drying winds result in sand blowing, two waterings a day may be needed in order to avoid tremendous losses. Considerable supplemental moisture also must be supplied to seedbeds older than 2 months.

Properly watered stock will be larger and more vigorous than unwatered stock. However, no rigid rule can be prescribed as to frequency of watering. It will depend on rainfall, air temperatures, humidity, and the tree species and its stage of development. For seedbeds at the critical germination stage, it is safer to overdo the watering, perhaps wasting some, than to use too little and risk the loss of part of the stand. Once the trees are past the succulent stage, 1 or 2 waterings a week are usually adequate for seedbeds. At this stage, it is satisfactory to maintain the available soil moisture at 4 to 8 percent for the top 8 inches in jack and red pine beds, and at 5 to 10 percent in beds of white pine, spruces, and hardwoods. One watering every week or 10 days usually suffices for transplants. Although transplant beds do not require as frequent watering as seedbeds, larger amounts are needed in a single watering.

Records of the Hugo Sauer Nursery, Rhineland, Wis., illustrate the use of water at a typical Lake States nursery. In 1937 and 1938, 3,798,000 and 2,231,000 gallons of water, respectively, were applied to some 30 net acres of producing seed and transplant beds. May to Sep-

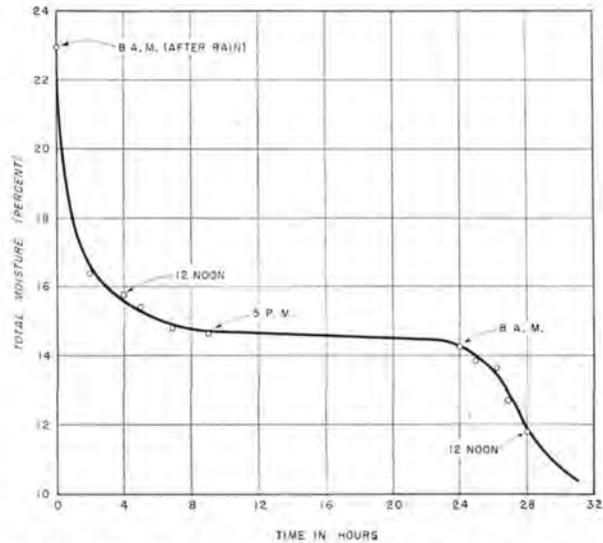


FIGURE 38.—The drop in soil moisture content in a loamy sand nursery soil is very rapid after a rain. The drain of soil moisture by transpiration and evaporation is at a minimum at night.

tember rainfalls for the 2 years were 12.3 and 24.8 inches, respectively, the former representing a drought season (62 percent of normal rainfall) and the latter a favorable season (127 percent of normal rainfall). This nursery is located in an area with a normal precipitation of 30.9 inches, of which about 70 percent falls from April to September, inclusive. Water was furnished by three 200-gallon centrifugal pumps whenever total soil moisture dropped below about 8 percent (equivalent to 4 percent available moisture).

The irrigation record showed that the water supplied in the dry season ranged from 4.0 to 9.1 inches depending on class of stock, while in a season of above-normal rainfall it varied from 0.1 to 3.4 inches (table 27). Although 70 percent more irrigation water was required in 1937 than in 1938, even the latter season of above-normal rainfall required 21 waterings on first-year seedbeds. This was necessary because the rapid drying of the surface of sandy soil hampers germination.

While overhead irrigation systems generally give excellent coverage, on occasion it may be necessary to water the ends of beds with a hose if winds carry the spray away from them. Snow fences or windbreaks also have an effect on water distribution. Rindt (124) observed that snow fence on pipe supports had some tendency to intercept water, and that in drought years first-year seedlings in the beds adjacent to them sometimes suffered mortality.

TABLE 27.—Irrigation record for May–September in two successive years, Hugo Sauer Nursery, Rhinelander, Wis.

Class of stock	1937 (dry season)			1938 (season of abundant rain)		
	Waterings	Irrigation water applied	Total water received ¹	Waterings	Irrigation water applied	Total water received ²
	Number	Inches	Inches	Number	Inches	Inches
First-year conifer seedlings.....	29	9.1	21.4	21	3.4	28.2
Second-year conifer seedlings.....	19	5.8	18.1	14	2.2	27.0
First-year conifer transplants.....	21	6.5	18.8	12	1.9	26.7
Second-year conifer transplants.....	9	4.0	16.3	8	1.3	26.1
First-year broadleaf seedlings.....	15	4.4	16.7	1	.1	24.9

¹ Including 12.3 inches of natural precipitation.

² Including 24.8 inches of natural precipitation.

METHODS FOR MEASURING SOIL MOISTURE

The top few inches of soil in newly germinating beds and the 2- to 8-inch levels in the interior of second- or third-year seedbeds or transplant beds must be kept quite moist. This is particularly true in periods of extreme drought or heat when the evaporation rate is so high that there may be little or no penetration of moisture below the surface inch or two in spite of considerable watering. Patches of seedlings may die out for lack of water. Such a situation occurred throughout the Lake States during the 1936 drought.

Soil moisture content can be determined by any one of the methods described in the following paragraphs. It is also possible, with a little training, for the nurseryman to estimate moisture content within a few percent, especially in the critical, drier range.

1. *Ovendry method.*—A soil auger or tube is used to collect a soil sample from the bed. The sample is then placed in a tight can, weighed, dried in an oven for 12 to 24 hours at 105° C., then reweighed. Total moisture is computed by the following formula:

Total moisture in percent =

$$\frac{(\text{Fresh weight of soil}) - (\text{Ovendry weight of soil})}{\text{Ovendry weight of soil}} \times \frac{100}{1}$$

Available moisture can be determined by subtracting the wilting coefficient of the soil from the total moisture. Typical wilting points of soils over a range of textures are as follows:

Texture	Total silt-plus-clay content (percent)	Computed wilting coefficient (percent)
Sand.....	9.4	2.2
Loamy sands.....	15.3	4.6
Sandy loams.....	26.8	7.7
Silt loam.....	65.6	10.4

Although a fairly close approximation of the wilting coefficient is obtained from the formula

$$\text{Wilting point in percent} = \frac{\text{Moisture equivalent}}{1.84}$$

a more accurate determination can be made by direct observation of the moisture content left in dried-down, well-rooted potted plants at time of wilting.

2. *Evaporation method.*—This method is faster than the owendry method and is well adapted to sandy mineral soils containing comparatively small amounts of organic matter. It consists of weighing a freshly collected sample in a screen-bottom metal container set in a metal cap; alcohol is then poured over the soil and ignited to drive off the moisture (14). The sample is then reweighed and the available moisture content computed by the formula given for the owendry method.

3. *"Soil points" method.*—This is a simple and effective method. A "soil point" is a hollow, tapered porcelain cone about 3 inches long with an absorptive surface of 12 square centimeters (85). The points are dried in an oven or over calcium chloride; then the open end is plugged with a cork and the point inserted in the soil at the desired depth, usually 2 to 4 inches. After an hour's time the points are removed, placed in a can with a tight lid, and reweighed. Available moisture is then computed.

In a trial at the Hugo Sauer Nursery, Rhinelander, Wis., it was found that under 3 conditions of total moisture described as moist (13.5 percent), fresh (9.5 percent), and dry (6.0 percent), the amount of water absorbed per cone was 2.0, 1.0, and 0.1 grams respectively (152). Since the wilting coefficient of the soil was approximately 4 percent, the available soil moisture for these 3 conditions was 9.5, 5.5, and 2.0 percent respectively.

4. *Tensiometers (127, 157).*—A tensiometer consists of a porous clay element attached to a mercury manometer or dial gage indicator. The porous clay element is placed in the soil at a depth where moisture status is desired, and the system is filled with cooled water that has been boiled to remove air.

Compact, sturdy tensiometers cost approximately \$22 and have given good service in the field. The 6- and 12-inch models are best adapted to forest nurseries. They have a graduated scale of 0 to 100 to indicate relative state of soil dryness, the "100" representing 1 atmosphere or 76 centimeters of mercury suction pull of the soil. Appropriate parts of the scale are labeled wet, medium, or dry. When the needle enters the dry range, irrigation is recommended.

Tensiometers do not work well when suction pull exceeds about 60 centimeters of mercury because air bubbles get into the system; however, in sandy forest nursery soil the suction pull will generally be in the range of 10 to 35 centimeters. Some unavoidable fluctuations in readings occur due to daily changes in temperature (58), but these can be ignored.

With some experience in the use of tensiometers, nurserymen will probably find them to be a useful guide to prevent overwatering. Likewise, this instrument may furnish some warning as to the need of watering, particularly for fairly well-established plants with at least 4-inch roots. It is less likely to be a reliable guide to watering needs in newly germinating seedbeds that must be kept quite moist at the surface. This is because it is difficult, if not almost impossible, to measure instrumentally the moisture content of surface layers of soil only $\frac{1}{2}$ - to $\frac{1}{4}$ -inch thick.

The relation of tensiometer readings to comparative status of soil moisture as read on one of the instruments in commercial production is as follows for the general run of crops and soils:

Soil moisture status	Scale reading in terms of atmospheres of suction pull	Equivalent in terms of centimeters of mercury	Remarks
Wet.....	0-0.30	0-22.8	Adequate to abundant moisture.
Medium..	0.30-0.70	22.8-53.2	Usually adequate. Very sandy soils may require irrigation.
Dry.....	.70-1.00	53.2-76.0	Requires irrigation.

5. *Electrical resistance method* (15, 16, 109).—This method is well adapted to soils with average salt content. It consists of burying a special plaster of Paris block or Fiberglas unit in the soil at a desired depth (usually 2 to 3 inches for first-year seedlings, and 6 inches for older trees) and measuring the electrical resistance with a meter that costs about \$75. With the plaster of Paris block a resistance of 2,800 ohms or more indicates that the soil will shortly require irrigation to bring it to optimum growing condition. The need for irrigation is shown directly on the dial of the meter in terms of relative soil moisture conditions, 100 representing a fully saturated soil. Irrigation is recommended when the meter readings drop below 50 (16).

A half dozen blocks, each buried in large units where class of stock or soil conditions are repre-

sentative, will give good coverage of the moisture conditions in an average nursery and warn of need of irrigation. The blocks can be left buried in place with their lead wires placed on permanently marked stakes so that workmen will not damage the block or its leads with tools or machinery. The meter itself can be quickly attached to the leads, a reading taken, and then moved to the next moisture station.

For very precise work in soil moisture determination, a moisture bridge costing about \$165 is recommended (15), along with a nylon resistance unit in place of the plaster of Paris block. Some investigators prefer Fiberglas units to plaster of Paris blocks because such units are more sensitive and accurate when the soils are quite moist.

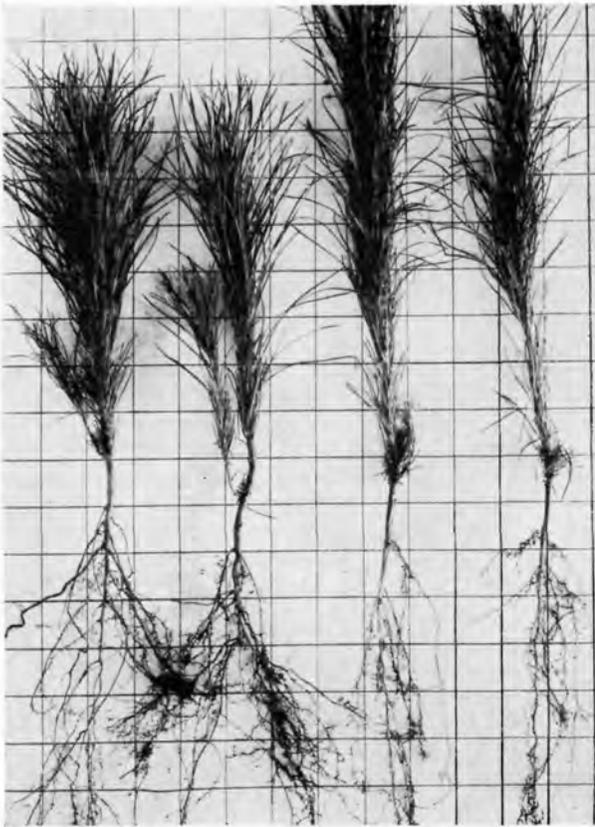
Light, highly portable models of electrical moisture meters are now on the market, costing slightly over \$200. This includes the tapered gage stakes and tapered auger necessary for setting the gage stakes in selected crop areas. Gage plugs with 48-inch leads can be used instead of gage stakes and are somewhat cheaper. If gage plugs are used, the average nursery will probably need from 6 to 10 sampling areas involving different classes of stock and variable soil types. One gage plug should be buried at appropriate depth—probably at 2 inches in newly germinating beds and 6 inches in other beds. The manufacturers' directions should be followed in placing the gage stakes or plugs, and also in interpreting electrical resistance readings.

IMPROVING DROUGHT RESISTANCE BY REGULATED WATERING

Jack, red, and Scotch pine, and eastern red-cedar often are planted on sandy or shallow soils or exposed sites, such as south or southwest slopes. On these droughty sites, mortality can be minimized by planting well-rooted, moderately thick-stemmed, well-balanced stock with rather small tops to cut down transpiration as much as possible. One way of obtaining drought-hardy plants, besides selection of the proper class of stock, is to apply water rather sparingly during the year before field planting so that they become hardened (fig. 39).

In a test of "drought hardening," 2-year-old jack pine seedlings given only 2.25 inches of water in 3 waterings were more drought resistant than seedlings receiving no supplemental irrigation and those receiving 4.75 and 7.00 inches. Excessive irrigation tends to reduce drought resistance, but too little watering actually weakens the plants.

The total percent of moisture in the surface 4 inches of typical loamy sand nursery soils at the start of irrigation in first-year seedbeds commonly is at least 8 percent. Therefore, 1 or 2 hours of watering are sufficient. Second-year seedbeds or transplant beds usually are allowed to dry down



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FIGURE 39.—2-0 jack pine. Two plants on left are from plot subjected to normal watering conditions. Two plants on right are from plot receiving excessive water throughout the growing season. (Chittenden Nursery, Wellston, Mich.)

to about 7 percent total moisture (or 3 percent available moisture) before water is applied. To soak up the top 8 inches of soil adequately will require 4 to 6 hours of irrigation with a sprinkler system that applies 0.125 inch of water per hour (fig. 40).

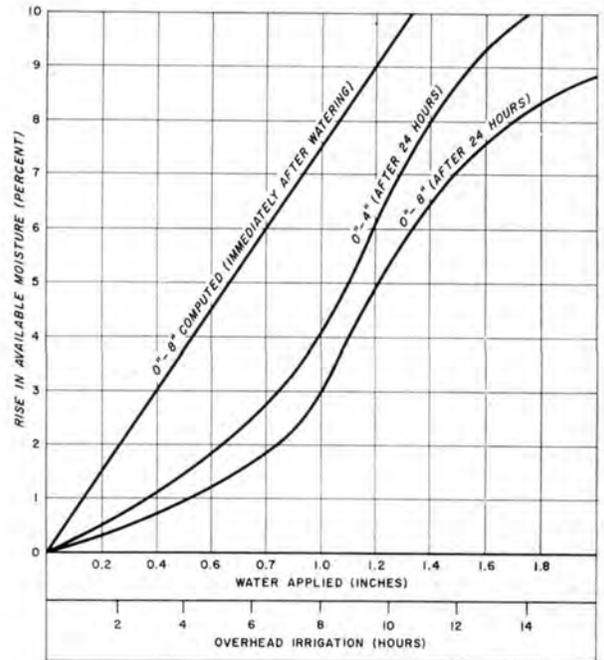


FIGURE 40.—Computed and actual rise in soil moisture content of a loamy sand nursery soil after various intensities of irrigation. The difference between computed and actual soil moisture content is due to losses by evaporation, transpiration, and underdrainage.

SEEDBED CARE DURING GERMINATION AND THE SEEDLING STAGE

The germination stage of 10 to 30 days or more is most critical because the tender seedlings are easily injured. Mulches should be removed in the spring when conditions are favorable and the danger from killing frosts has passed. Although they can be left on the beds until after the seeds have germinated, they should be removed before the seedcoats appear above the ground; otherwise, the seedlings may be seriously injured at the time the mulch is removed.

To prevent undue injury to the seedlings, great care should be used in taking up burlap or in raking straw mulches from the seedbed. Fiber or wire-tine rakes are better than ordinary garden rakes for removing straw mulches. It is also important that all of the mulch be removed. If it is not removed completely, losses are apt to occur as a result of excessive moisture and of root rot disease that was stimulated by decomposition of the mulch.

Hardware cloth screens (p. 40) should be kept in good condition by careful handling and replacement of broken cross slats. This will prevent openings through which rodents and birds can gain access to the seedbed; it will also prevent damage to the seedlings from sagging screens. The screens should be left on the seedbeds until germination is complete and nearly all of the seedlings have shed their seedcoats.

HALF-SHADE

In Lake States nurseries such species as the spruces, balsam fir, Douglas-fir, hemlock, northern white-cedar, and sugar maple develop better seedling stands if they are grown under half-shade the first season. Other species may require shade if grown south of the 70° F. average July temperature isotherm, which includes, roughly, the southern halves of Minnesota, Wisconsin, and the Lower Peninsula of Michigan. Here even white pine may require shade in the first season. Half-shade is usually put on in late spring and left until late August or early September.

Half-shade from the right height may increase the stand of white spruce seedlings by 20 to 50 percent. Trials at the Hugo Sauer Nursery in Wisconsin indicated that the shade fence should be placed 8 to 12 inches above the seedbed surface for this species (table 28). Where the half-shade was only 4 inches high, the stand was actually poorer than without shade because of stagnation and heating of the air. When the shade slats ran north and south, results were slightly better than when they ran east and west.

The most efficient method of providing half-shade is to use 48-inch-wide slat-wire snow fence supported on 2 strands of No. 9 wire placed about 40 inches apart. The wires in turn are supported on 13- to 14-inch-high wooden horses placed across the beds at intervals of 12 feet. These horses, made entirely of 1- by 2-inch creosote-treated stock, have an overall width of 48 inches, and their legs are 15 inches long with a base spread of 17 inches. Because they are made without cleats for bracing, they can be stored compactly by nesting one on top of the other.

The wire rests on top of the horse in a small notch cut 4 inches from each end in the cross member. Each pair of wires runs the full length of the seedbed unit, usually 200 to 500 feet. They are drawn taut by a block and tackle and fastened to 3-inch-diameter stakes driven in at an angle at each end of the bed. A modification of this method is to support the wire on 1- by 2- by 48-inch crossbars tacked to posts or stakes placed at 12.5-foot intervals on each side of the beds (fig. 41).

A second method involves supporting the rolls of snow fence on horizontal wooden stringers of 1- by 2-inch or 1- by 4-inch material nailed to stakes driven at 4- to 6-foot intervals on each side of the bed. One method at the Chittenden Nursery in Michigan utilizes a 15-inch-long iron bedboard stake placed upside down and hooked underneath the 1- by 4-inch bedboard. The shades used are handmade in sections 4½ by 12

TABLE 28.—Effect of height of half-shade and orientation of the beds and drills on a stand of white spruce, Hugo Sauer Nursery, Wis.

Direction of seedling drills ¹	Direction of slats in shade frames ¹	Height of slats above ground	Trees per square foot	
			As 2-0 stock	As 3-0 stock
		<i>Inches</i>	<i>Number</i>	<i>Number</i>
N to S	E to W	4	35.1	31.1
N to S	E to W	8	48.9	43.6
N to S	E to W	12	48.1	44.8
E to W	N to S	4	33.8	32.8
E to W	N to S	8	60.6	54.4
E to W	N to S	12	53.9	48.1
E to W	N to S	16	42.3	39.4
N to S	No shade	(²)	41.6	39.4

¹ N, S, E, and W refer to North, South, East, and West respectively.

² No shade.

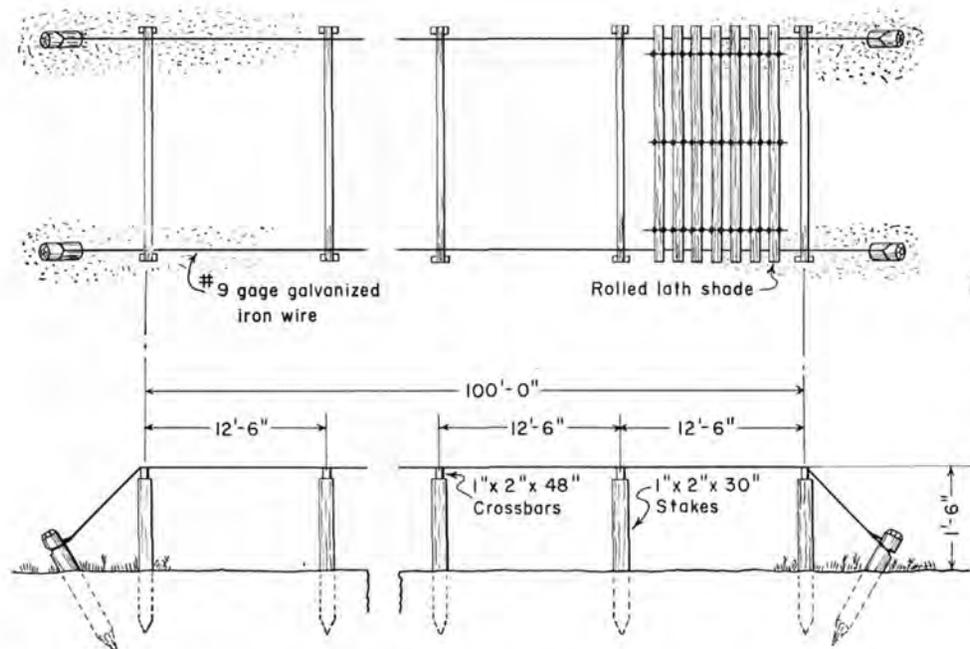


FIGURE 41.—Method of supporting slat-wire snow fence used as half-shade.

feet. Lath racks are used by some nurseries as a support for half-shade. When not in use, the slat-wire snow-fence shade should be stored in rolls outdoors, with the bottom layer of rolls resting on poles to minimize rotting of the lath.

THINNING

Occasionally, a seedling stand may be overdense. This is more likely to occur in small-seeded broad-leaf species such as paper birch or elm than in conifers. The surplus seedlings may be pulled out or, in the case of conifers, cut off with shears when their roots are not more than 3 inches long. The beds should be well moistened before thinning and again afterwards. Studies on thinning 2-0 white pine stock in the spring of the third growing season indicated that relatively early thinning, preferably in midsummer or late summer of the first year, is required to produce the maximum benefit.

WATERING

After seeding and during the germination period, nursery beds require frequent, often daily, light watering except when there is enough rain to keep them moist at all times. Usually, from 0.10 to 0.25 inch of water, or about 1 to 2 hours' application from an overhead system, is sufficient. In periods of extreme heat or strong, drying winds, two waterings daily may be necessary. When the seedlings are 6 weeks old, watering need be done only twice a week, applying 0.25 to 0.50 inch of water in 2 to 4 hours of overhead irrigation. Details on regulation of watering, and instruments and methods of measuring moisture, are given in another section (p. 67).

Watering also is a defense against late spring frosts which may damage newly germinating trees or succulent growth on such stock as first-year spruce. Water systems usually are turned on in the late evening or during the night as soon as temperatures drop to 30° F. The watering prevents freezing of the plant tissue because the water temperature is higher than that of the air. When temperatures have dropped as low as 20° to 22° during watering, a thin sheet of ice forms but this promptly melts the following morning and the tender spruce seedlings generally are undamaged except for occasional breakage.

CULTIVATION AND WEED CONTROL

To remove weeds and to prevent compaction of the surface soil, it is necessary to cultivate, especially in second-year seedbeds or transplant beds. First-year seedbeds of conifers generally are hand-weeded or treated with mineral spirits to control weeds. However, some nurserymen use bed-straddling, tractor-drawn machines, beginning about midsummer, to cultivate the soil between rows of first-year pines. This practice reduces the cost of hand weeding. Usually, a few cultivations a year suffice unless weeds are especially bad. Broadleaves, handled in more widely spaced drills, can be cultivated readily with a two-wheeled garden tractor or larger rubber-tired tractors equipped with cultivating tools.

Probably no phase of nursery work has changed as rapidly in the past decade as has chemical weed control. Before 1940, sulfuric acid and zinc sulfate were used (182), but since that time several newer chemicals have been employed. There are

two general classes of chemicals: (1) those to be applied before or immediately after seeding as a pre-emergent control; and (2) those to be sprayed on the tree crop after it has emerged; they kill the weeds but do not injure the trees.

Among the chemicals used for pre-emergent treatment are methyl bromide, sulfuric acid, zinc sulfate, allyl alcohol, chlorobromopropene, para-chlorophenyl dimethylurea, sodium chlorate, carbon disulfide, and chloropicrin. The chief post-emergent sprays used are mineral spirits (known as white spirits of petroleum in some European countries) that can be purchased from leading oil companies under a variety of trade names. See p. 118, Safety Rules and Precautions in Handling, Mixing, and Applying Chemicals.

Sulfuric acid.—Sulfuric acid, usually applied as a control for damping-off immediately after seeding, has a supplemental value in reducing the number of weeds that appear in seedbeds in the 2- to 4-week period after treatment. The reduction in number of weeds may be as much as 50 to 80 percent in this period. Usually, concentrated commercial sulfuric acid is applied in about a 2-percent solution with water, using from $\frac{1}{16}$ to $\frac{1}{8}$ fluid ounce of the concentrated acid (before dilution) per square foot of seedbed.

Zinc sulfate.—When applied at the rate of 8 grams ($ZnSO_4 \cdot 7H_2O$) in 250 cubic centimeters of water per square foot immediately after seeding the beds, zinc sulfate has reduced the weed stand some 80 percent (182). A new application must be made with every new crop; on the second tree crop, the amount of chemical can be cut in half. Because there is some danger of creating a toxic condition for trees with zinc sulfate, other herbicides are favored in Lake States nurseries.

Methyl bromide.—Methyl bromide is a gas toxic to weed seed, and its use is especially adaptable to small nurseries having no more than a few acres in seedbeds. It is applied to prepared seedbeds at the rate of 1 pound per 100 square feet a few days before seeding. By means of a special injector, the gas is forced under waterproof paper or plastic material that is rolled out on the beds and the edges held down with soil. The covers are removed after they have been in place for about 24 hours. Seeding can take place 2 to 3 days later.

In tests made in 1950 at the Hugo Sauer Nursery, there was complete lack of weeds for at least 22 days after treatment (155). At the end of 36 days there was only 0.5 weed per square foot in treated beds compared with 7.7 weeds per square foot in check beds. The average weight of 2-0 seedlings was nearly identical in both treated and untreated beds (0.075 and 0.073 ounce, respectively). However, the foliage of trees in treated beds was slightly off-color. The cost of treatment on a larger scale in a Missouri nursery was \$335 per acre in 1951, including amortization of vinyl plastic covers (76). Hand weeding in this nursery, where weeds were an

especially serious problem, would have cost \$550 per acre.

Methyl bromide functions best if applied when soil temperatures are 50° F. or higher. Besides its weed-control value, it may also have some value as a damping-off and insect control. Clifford (31) noted a complete kill of white grubs in beds after application of this chemical. Two pounds per 100 square feet are generally recommended for damping-off control.

Allyl alcohol ($CH_2=CH-CH_2OH$).—This weed-killer has shown excellent results in trials at the Hugo Sauer, Wis., and Eveleth, Minn., Nurseries (161). Application of a 0.2-percent solution at the rate of 5,000 to 10,000 gallons per acre in trial beds reduced the weed stand 81 to 89 percent of that in check beds at the end of 2 months. The trial beds were thoroughly prepared for seeding and treated a week to 10 days prior to sowing when the soil temperatures were at least 60° F. The soil was disturbed as little as possible in the seeding operation.

Allyl alcohol is used as a standard weed control at Mt. Shasta Nursery in California (81). There, 4.5 gallons of this product are mixed with 45.5 gallons of water in a tank and this solution is forced under high pressure into the overhead sprinkling system while it is in operation. With a 400-foot pipeline unit, about one-half acre can be treated in 15 to 20 minutes. Costs per acre are approximately \$27 for chemicals and \$3 for labor.

The toxic nature of this chemical and precautions needed in its handling (144) have acted somewhat as a deterrent to its wide-scale use. It has the further disadvantage that when applied through the overhead system, drift of spray may injure adjoining beds of seedlings or transplants.

Chlorobromopropene.—This chemical destroys weed seeds in about the same manner as allyl alcohol. However, results obtained with it were not as good as those obtained with allyl alcohol in tests run in 1951 at the Hugo Sauer Nursery, Wis. Its toxicity to humans and precautions required in handling have, as with allyl alcohol, been a deterrent to its wide-scale use.

Other chemical controls for weeds.—Another pre-emergent, pre-seeding treatment employs carbon disulfide in 2-ounce doses placed in holes 6 to 8 inches deep and spaced 18 inches apart (59). Each hole must be sealed with soil. As little as 1,600 pounds of carbon disulfide per acre may be satisfactory on a sandy soil, but heavy soils require 2.5 to 3.0 times that much. Summer treatment has been found best. Carbon disulfide is used chiefly to kill deep-rooted, perennial weeds. When applied as a weed killer, it has other values, such as control of white grubs and nematodes. This chemical is explosive in the presence of flames and should be handled with care.

Sodium chlorate has been applied in spray form for deep penetration, using 3 pounds in 3 gallons of water.

Chloropicrin has been used experimentally at the rate of 7 cubic centimeters of chemical per cubic foot of soil, covered with light paper, and left for 3 days (126).

Hydrin, a hydrocarbon obtained from coal, is a good weed-seed killer when applied at 10 gallons per acre, along with ample water, immediately after seeding. It was used successfully in tests at Hugo Sauer Nursery, Wis., in 1953 on jack and red pines and black locust but larger scale trials are needed.

Mineral spirits or white spirits.—Mineral spirits are the most widely and successfully used herbicides in conifer nurseries in the Lake States as well as elsewhere in the United States (fig. 42). They are not used to any extent in broadleaf nurseries because hardwoods, with some exceptions, are generally injured or killed by the spray. Made from petroleum, mineral spirits have an initial boiling point of 300° to 320° F., API gravity of 48 to 50, and an aromatic hydrocarbon content of 10 to 20 percent.

Mineral spirits are especially effective on small weeds $\frac{1}{2}$ to 2 inches in height or spread. Within 3 to 12 hours after being sprayed, many turn light gray or brown and die within a few days. However, some weeds, notably purslane, Canada thistle, quackgrass, and larger clover plants, resist treatment. Mineral spirits used in the Lake States generally contain 10 to 12 percent of aromatic hydrocarbons and are usually applied full strength at the rate of 25 to 75 gallons per acre, at pressures ranging from 50 to 100 pounds per square inch (table 29). Three or four applications per season are generally made. Some nurserymen use as many as 6 to 8 per season.

Weed kill appears to be approximately proportional to the content of aromatic hydrocarbons in the mineral spirits used. For instance, in 1950

it was observed that a treatment of 80 gallons per acre with mineral spirits that had a 12 percent aromatic content gave approximately the same kill as 45 gallons per acre of spirits with 22 percent of aromatics (156).

Pre-emergent spraying of 50 gallons per acre on jack pine beds immediately after seeding in late June gave 86 percent weed reduction; spraying 100 gallons gave 92 percent weed reduction. According to observations by A. L. Nelson, pre-emergent sprays at the Griffith State Nursery in Wisconsin were effective in May but were ineffective in April, probably because weed seeds in April were somewhat dormant and more resistant to the sprays.

Although pines, spruces, firs, and junipers tolerate mineral spirits and a few closely allied petroleum products (35, 44, 125, 153, 154) other conifers, notably the larches, do not tolerate mineral spirits. Some tree species are moderately sensitive and may show injury if more than about 40 gallons per acre are applied in any one treatment. Still other species, such as red pine and jack pine, appear to tolerate as much as 80 to 100 or more gallons per acre of spray with little or no harmful effect.

Young seedlings are somewhat susceptible to injury during the first 3 or 4 weeks after germination. Consequently, spraying during this period should be avoided except for such resistant species as red and jack pines which may be given very light dosages of 20 to 30 gallons per acre. Mineral spirits are not likely to damage older conifer seedlings when sprayed at air temperatures under 80° F. Likewise, they show less damage in beds of spruce, balsam fir, and white pine, where the half-shade is replaced shortly after spraying, than in beds open to full sunlight.



FIGURE 42.—Spray rig for applying mineral spirits.

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TABLE 29.—Safe dosages of mineral spirits for conifers in Lake States nurseries, using material containing 10 to 12 percent of aromatic hydrocarbons

Species	Safe dosage per acre ¹ for trees that are—		
	4 to 6 weeks old	6 weeks to 1 year old	1+ year old
	Gallons	Gallons	Gallons
Douglas-fir.....	0	40	50
Fir, balsam.....	30	40	50
Juniper, Rocky Mountain.....	30	40	60
Pine:			
Austrian.....	40	50	60
Eastern white.....	40	60	75
Jack.....	50	60	75
Mugho.....	40	50	60
Ponderosa.....	40	60	75
Red (Norway).....	50	60	75
Scotch.....	40	50	60
Western white.....	35	40	60
Redcedar, eastern.....	30	40	60
Spruce:			
Black.....	30	50	60
Blue.....	25	30	40
Norway.....	25	40	60
White.....	30	50	60
White-cedar, northern.....	0	30	40

¹ First spraying of first-year beds should be done after a few of the trees have emerged, or before emergence if weeds have germinated. Thereafter, no spraying should be done until the seedlings are about 4 weeks old.

The usual cost for labor and chemicals (with labor at about \$0.80 per hour and mineral spirits at \$0.25 per gallon) is \$18 to \$20 per acre for 1 application. Hand weeding in the Lake States costs 3 to 4 times this amount. Considering all spraying costs and hand mopup of weeds escaping kill, spraying with mineral spirits reduces overall weeding costs by 50 to 60 percent compared with hand weeding. In the South, Cossitt (35) reports savings up to 90 percent. The superintendent of the Wisconsin Conservation Department nurseries, W. H. Brener, reported an annual saving of about \$18,500 after mineral spirits were adopted as a standard weed control method in 1949.

Some nurserymen have used gasoline weed burners to destroy weeds about 10 days after seeding and just before tree emergence. Wells (186) reports cutting weeding costs in half by this procedure.

TOP AND ROOT PRUNING AS A SUBSTITUTE FOR TRANSPLANTING

Top and root pruning of seedling conifers has been used to some extent in the Northeast (50) and in the Lake States as a substitute for transplanting. Top pruning has been practiced largely on second-year jack pine that often becomes 8

to 14 inches high in nurseries of good fertility. On droughty sites where this species commonly is planted, these topheavy seedlings survive poorly—especially if fall-planted. Although top pruning is viewed to some extent as an emergency measure, it may improve field survival of topheavy, fall-planted jack pine as much as 15 percent. It is of less advantage in spring plantings.

Normally, the tops of 2-0 jack pine are pruned in May or early June of the second year while the new growth is expanding rapidly. The tops are cut 1 to 2 inches above the end of the previous season's wood, usually removing 1 to 3 inches of new growth. The treatment does not adversely affect subsequent bud formation or the normal development and form of the tree. By the end of the second year the tree is shorter, has better balance (a more favorable top-root ratio), is less spindly, has less transpiration surface, and generally is a sturdier, more drought-hardy plant. Moreover, under field planting conditions the plants are less likely to be flattened down by snow, wind, or heavy, beating rains, or to be frost-heaved.

A pair of hedge shears with blades 10 to 12 inches long or a sharp, thin-bladed scythe in the hands of a skilled workman is satisfactory for top pruning on a small scale. The preferred method for large-scale operations is a power mower of the type normally used in cutting hay. It is pulled by a rubber-tired tractor that straddles the bed, and an entire 4-foot-wide bed is pruned at once. The end of the bar is usually supported on a shoe or small "sled" to hold it at the desired height above the beds. Some nurserymen use a small, one-wheel, power mower with a bar 2½ feet long. With this device, 2 trips are made for each 4-foot-wide bed, taking about half the width of the bed at one time.

Top pruning of 2-0 jack pines when they are dormant or when the stems are woody has proved harmful. For example, in 1937 a lot of 2-0 jack pine was pruned while dormant. On some of the trees, the tops were severed one-half inch below the terminal bud; others were pruned to a 3-inch length, removing perhaps 1 inch or more of the top; the remainder was not pruned. Shortly thereafter the trees were field-planted in replicated plots. Field survivals at the end of the first year were reduced 15.4 to 21.1 percent by top pruning (table 30).

Root pruning in place in the spring has also been used to some extent on 2-0 jack pine in an attempt to develop a more fibrous, compact root system and to reduce top length (fig. 43). The best results in such cases have come from root pruning at a depth of 3 to 5 inches in the spring of the second year. Sometimes root pruning combined with top pruning fosters good field survival, especially in very top-heavy stock scheduled for fall planting.

The effects of root and top pruning, and of coating the needles with a wax substance just before

TABLE 30.—*Effect on field survival of top pruning dormant 2-0 jack pine just before planting*

Treatment in nursery	First-year field survival ¹	Causes of mortality			Basis, trees
		Grubs	Drought	Competition and other	
	Per- cent	Per- cent	Per- cent	Per- cent	Num- ber
Not pruned.....	73.0	1.5	22.2	3.3	1,000
Pruned to point ½ inch below terminal bud.....	57.6	1.0	25.0	16.4	978
Pruned to a 3-inch top.....	51.9	1.4	28.9	17.8	1,000

¹ Least significant mean difference at 1-percent level is 9.85. Both pruning methods proved harmful at odds of 99 out of 100.

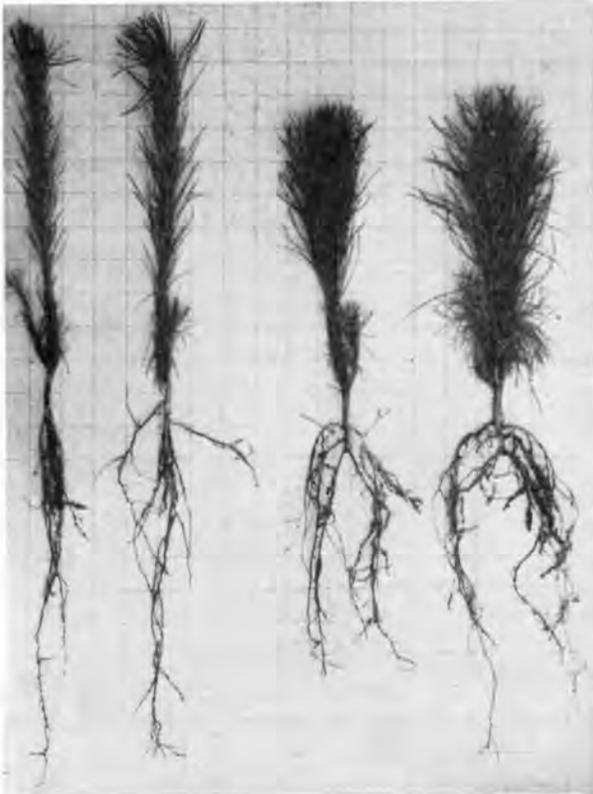
shipment to the field planting site, were tested on the Nicolet National Forest in northeastern Wisconsin and on the Upper Michigan National Forest in the fall of 1940 and spring of 1941 (table 31). This study brought out the following results: (1) Spring-planted trees of several species survived better than those planted in the fall, especially if the stock was unpruned; (2) root pruning, particularly when done both horizontally and vertically, markedly improved survival of fall-planted stock; (3) top pruning alone appeared to reduce survival, even when done in late spring when the new growth was still succulent; and (4) wax dips to cut down transpiration were of no benefit.

Fall-planted 3-0 white and red pine stock, root pruned both horizontally and vertically, survived 23 and 16 percent better, respectively, than untreated stock (table 31). This result would seem to warrant pruning trials on a larger scale because of the relative cheapness of 3-0 stock and its adaptability to machine planting. Such root pruning can be done mechanically for as little as

TABLE 31.—*First-year field survival in eight separate trials of root or top pruning in conifers (all stock planted by hand)*

Treatment in nursery	First-year field survival of—								Overall evaluation of treatments, based on statistically valid increase in survival
	3-0 white pine			3-0 red pine			2-0 jack pine		
	Fall-planted	Fall-planted	Spring-planted	Fall-planted	Fall-planted	Spring-planted	Fall-planted	Spring-planted	
None.....	Percent 65.0	Percent 65.7	Percent 89.0	Percent 62.6	Percent 51.0	Percent 94.0	Percent 55.8	Percent 83.6	Beneficial in 2 of 8 trials. Beneficial in 1 of 8 trials. Harmful in 3 of 8 trials. Beneficial in 3 of 8 trials. Beneficial in 2 of 8 trials. No effect. Beneficial in 3 of 8 trials.
Root pruned horizontally.....	73.8	†79.8	88.2	*80.6	56.6	93.2	70.8	83.2	
Root and top pruned.....	*78.3	74.7	89.3	72.0	48.0	92.2	61.0	75.8	
Top pruned.....	62.8	66.7	§75.5	§41.6	42.0	90.0	61.4	†74.0	
Root pruned horizontally and vertically.....	†87.0	†90.2	94.8	75.4	†70.8	97.2	62.8	86.6	
Root and top pruned, and liquid fertilizer.....	66.7	†83.2	89.7	†87.0	57.2	94.8	73.6	82.8	
Tops dipped in wax.....	73.8	68.0	87.8	62.0	54.4	89.8	58.2	85.2	
Root pruned, tops dipped in wax.....	*76.2	†81.8	94.2	63.4	†70.4	96.0	64.2	76.2	
Average.....	72.9	76.3	88.6	68.1	56.3	93.4	63.5	80.9	
Least significant mean difference in column at 5-percent level.....	10.8	9.28	8.3	15.4	12.46	4.6	-----	8.36	
Least significant mean difference in column at 1-percent level.....	14.47	12.43	11.1	20.8	16.78	-----	-----	11.28	

*= Significantly better than untreated check plot at 5-percent level.
 †= Significantly better than untreated check pilot at 1-percent level.
 ‡= Significantly poorer than untreated check plot at 5-percent level.
 §= Significantly poorer than untreated check plot at 1-percent level.



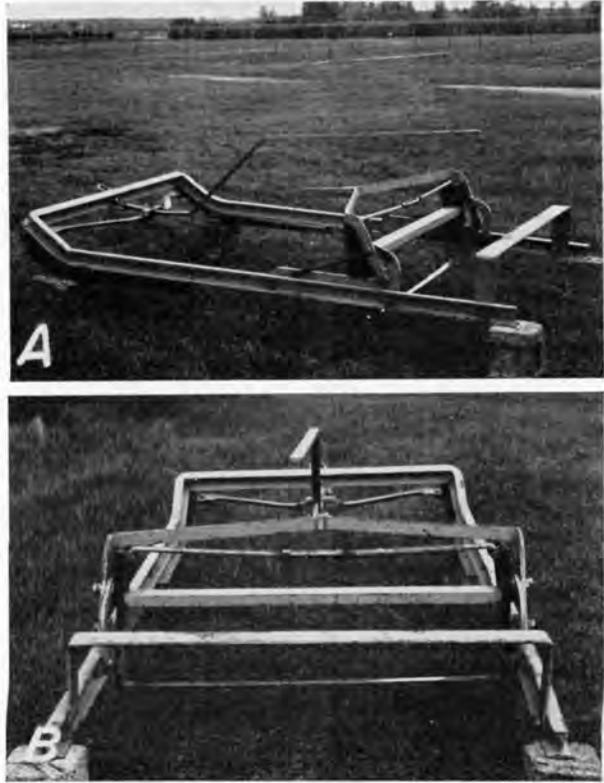
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FIGURE 43.—Root pruning of 2-0 jack pine in the spring of the second growing season improves balance, reduces spindliness, and produces a more fibrous root system. Left, 2 unpruned trees; right, 2 trees root pruned at a depth of about 2.5 inches. (Background is 1-inch squares.)

10 cents per 1,000 trees compared with a transplanting cost of \$1 or \$2.

The denser, more fibrous root system caused by root pruning results in a better balanced tree at the time of digging. Such trees, because of greater compactness of the root system, are easier to field plant. Vertical pruning should, by all means, be done on the path side of each outer row of a bed because these two rows particularly tend to develop rather widespreading, lateral roots running into the paths. Many of these roots are lost in 3-0 stock of red and white pines unless root pruning in place is used to create a more compact root system.

The Barton root pruner does excellent work in light, sandy, nursery soils that are quite free of old tree roots left from land clearing, and that have little or no stone over one-quarter inch in diameter. This horizontal pruner consists of a thin blade of bandsaw steel held under tension with a turnbuckle and mounted on a Wind River lifter frame (fig. 44). On heavier soils where the thin blade may tend to buckle, or on newly cleared sandy soils with considerable stone, sticks, or old roots, it is advisable to use an ordinary tree lifter with the lifter shoes removed and the blade set at



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FIGURE 44.—Barton root pruner mounted on a Wind River lifter frame. The cutting element is a thin blade of bandsaw steel 52.4 inches long, 1.75 inches wide, and 0.08 inch thick, held under high tension by a turnbuckle. It has a depth adjustment and a steering handle. A, Side view; B, rear view.

a horizontal or slight forward inclination. The blade should be hollow ground and kept sharp.

One horizontal root pruner that is suitable for small-scale experimental trials consists of a thin, 2-inch-wide blade, 52 inches long, bolted horizontally on the bottom of a steel bucksaw-type device. Lengths of $\frac{3}{4}$ -inch iron pipe are laid in a trench to act as a rail or depth guide for the pruner. A small block and tackle is fastened near the ground line in each path to stakes driven in about 12 feet ahead of the pruner. The pruner is then drawn along by two men pulling on the rope, while a third man holds it in an upright position. Vertical pruning can be done with a sharp spade or a small, sharpened, rolling coulter. The job accomplished is similar to that performed by the Barton root pruner.

For stock grown in drills, vertical pruning can best be done with sharp, rolling coulters mounted on an axle and located at the midpoint between rows. The rolling coulter has an advantage—in keeping free of refuse and tree roots—over vertical individual knives even when these were slanted downward and backward. Beds containing only 5 to 7 drills and having a space between drills of 6 to 10 inches can be pruned vertically with less

damage than the 10-row beds with only 4.5 inches, center to center, between drills.

Vertical pruning with vertically placed knives has been done simultaneously with horizontal pruning. However, there was a distinct tendency for tree roots and other refuse to collect at the slotted junction of the horizontal and vertical blades. This choke-up resulted in lost time while the bed was dug up at that point and the refuse removed.

The beds should be watered thoroughly shortly after root pruning to prevent temporary wilting

of the trees. Based on extensive observations of a number of nursery experiments, root-pruned stock may tend to show a slight nutritional deficiency. Application of a complete liquid fertilizer, totaling about 300 pounds per acre of 15-30-15 fertilizer or its approximate equivalent, within a week or two of root pruning will aid in maintaining normal, healthy foliage color and obtaining somewhat higher field survival. The symptoms of malnutrition are no doubt due to the severance of about half of the root system.

TRANSPLANTING OPERATIONS

Transplanting, as the term is applied to nursery management, means to remove small seedlings from a crowded seedbed and line them out where they will have more room to develop. Seedlings held in transplant beds for 1 to 2 years are better balanced plants than those produced by root pruning in place. Because of the added expenditures involved in transplanting and subsequent care, the cost of transplant stock generally is much higher than for stock that has not been transplanted.

Conifers ordinarily are transplanted in the early spring while they are still dormant. The work should be started as early as conditions permit. Normal losses are 1 to 3 percent.

A relatively high mortality can be expected when seedlings are transplanted between June 1 and August 15. Digging the seedlings before active growth starts in the spring and holding them in cold storage until transplanted will prevent some mortality. Even with cold storage, however, the warm temperatures and dry winds that commonly occur during June and July may injure or kill the plants before they become established.

Transplanting has been done successfully from mid-August to fall in U. S. Forest Service nurseries in the Lake States when ground moisture conditions were satisfactory. The former Soil Conservation Service nursery at Winona, Minn., had good success in transplanting from August 1 to September 6. Ordinarily, late season transplanting should not be started until about the middle of August after the stock has nearly completed its summer's growth. Normal losses from late summer and fall transplanting are 5 to 10 percent of the trees.

Fall transplants usually require more attention than early spring transplants because of the less favorable soil moisture and air temperatures that normally occur in the fall. If the soil is at all dry, it should be irrigated before transplanting to create optimum soil conditions for operating mechanical trenchers, and to avoid the heavy losses from planting the trees in dry soil. The nurseryman will also need to provide adequate moisture by sprinkling or furrow irrigation immediately after transplanting.

Ordinarily, transplanting should be terminated by September 20 in order to allow sufficient time for the soil to settle and the trees to become partially established before severe winter weather. If the trees are transplanted in the late fall, or a blanket of snow cannot be expected to protect them, the beds should be mulched. (See *Seedbed Mulches*, p. 65.)

Where trees are to be distributed after only 1 year in the transplant beds, it is essential that the transplanting be done in the fall or early spring so that the trees will have the benefit of a long growing season. This is not so important if the stock is to remain in the transplant beds for two seasons.

LIFTING STOCK FOR TRANSPLANTING

To insure a minimum of injury in digging the stock, ground moisture conditions should be favorable, and men assigned to the work should be experienced and dependable. The practice of digging the trees with a spade or fork has been replaced by more modern and efficient methods in practically all Lake States nurseries. (See p. 37 for a description of mechanical lifters.) However, where only small numbers of trees are involved and the investment in heavy equipment cannot be justified, lifting can be accomplished with handtools. A spading fork is preferred to the ordinary spade for this work since it is lighter in weight, can be forced into the ground with less effort, and does less severing of lateral roots.

When a mechanical lifter is used to dig stock for transplant purposes, the lifter blade usually is set for a depth of about 7 inches and "dug in" at the end of the bed to insure proper and uniform depth of cutting. The lifter should be drawn slowly through the bed so that it can be controlled adequately and do a better job of breaking and crumbling the soil (fig. 45). The lifting of stock



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FIGURE 45.—Tree lifter loosening roots of nursery stock. This particular lifter is operating on a cable and winch system. (Chittenden Nursery, Wellston, Mich.)

should be correlated with the pulling operation, and only sufficient beds lifted ahead of the pulling crew to keep it busy. If too much time elapses between the two operations, the soil tends to settle and become compact. This makes the job of removing the trees more difficult and increases the amount of mechanical injury to their roots.

To provide good quality stock, it is important that the pulling crew be thoroughly trained in the method of pulling trees. Ordinarily, additional spading to loosen the trees is unnecessary

if the tree lifter is properly adjusted to soil conditions. However, if the trees cannot be removed easily, it is good practice to loosen them with a spade or fork. The crew can work most effectively if it starts on the outside of the bed and proceeds toward the center. Individual pullers should be so spaced that they are not working in close quarters. This will minimize the danger of flying dirt particles striking neighboring workers in the eye, and it will also make it easier for the crew foreman to check the work of each individual.

The plants are less subject to injury if a small bunch at a time is firmly grasped and removed from the soil with a steady pull. A light shake ordinarily dislodges any dirt that clings to the roots. Undersized or mechanically injured plants are then discarded, and when a bunch of the proper size has been obtained, it is heeled in behind the worker with a handful of moist soil over the roots. This protects the trees from drying out before they can be pruned and packed.

The pruning and packing will be more uniform if the work is done by one man rather than by the individual pullers. A light cleaver is an efficient root pruning tool. Roots of 1-year-old seedlings can be shortened to 4 inches without ill effects. Red pine and white pine 1-0 trees pruned to this length produce well-balanced 1-2 stock. Two-year-old seedlings ordinarily are not pruned so severely for transplanting; the roots of 2-0 red and white pines and 2-0 black and white spruces ordinarily are shortened to 4½ or 5 inches.

PREPARATION OF THE TRANSPLANT BED

Soil for transplanting is prepared in the same general manner as that prescribed for seedbeds (p. 59). The work of tilling and leveling should be completed far enough in advance of transplanting to permit the soil to settle. Moderately compact soil is particularly important where mechanical equipment is used for opening the trench or the transplanting is done by machine, because there will be less sloughing of the walls of the trench. The amount and type of ground preparation for spring transplanting will vary from season to season, depending upon overwinter conditions. However, if the soil is placed in good tilth just before winter, little additional work will be required in the spring.

In laying out transplant beds, consideration should be given to the method of transplanting and the type of machinery to be used in the subsequent operations, particularly where overhead irrigation has been installed. Usually, a slightly wider path is required between outside beds and irrigation lines than is required between beds.

Since the pattern of the beds will be governed by the initial bed, it is important that special care be used in laying out that bed. A string should be stretched full length of the field, parallel to the overhead lines, to serve as a guide for the tractor operator. After the first trip has been made, the wheel marks will serve as a guide for adjacent beds.

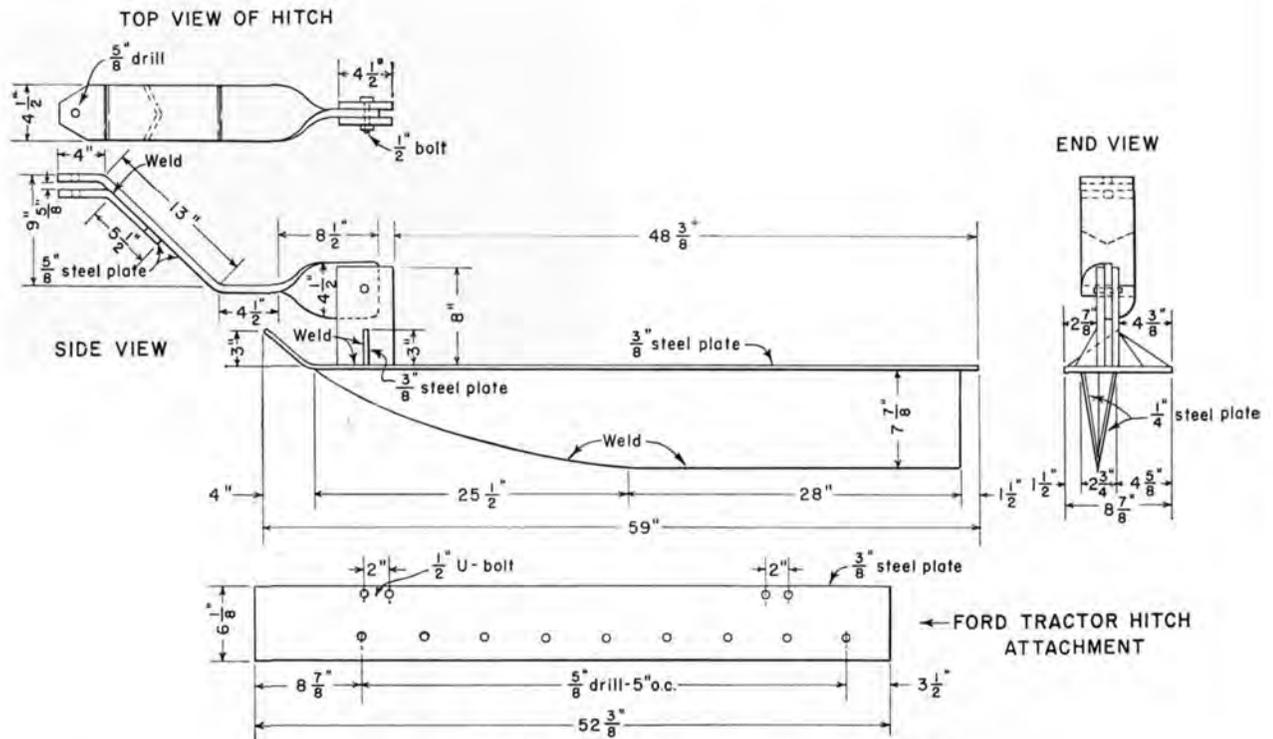


FIGURE 46.—Details of a specially designed transplant trencher.

Ordinarily, the small trenches in which the trees are set are made with some type of power-driven equipment. Trenching with a spade or hand trencher of special design is expensive and can be justified only where the transplanting operation involves very small amounts of stock. The type of hand-trenching device commonly used is made of 2 plates of steel 8 to 10 inches wide and 18 to 24 inches long, welded together to form a wedge-shaped tool. A T-handle 20 to 24 inches long is attached. The operator steps on the tool to force it into the ground, and moves the handle back and forth to produce a V-shaped trench 6 to 8 inches deep and 2 to 3 inches wide at the top. Trenchers of this type are not favored for heavy soils but can be used effectively in light sandy loam.

Mechanical trenching can be accomplished efficiently and economically with a small plow or a specially designed trenching tool (fig. 46). The trenching tool makes a V-shaped trench by compressing the soil as it is drawn through the bed. Since it makes a cleaner and more uniform trench in light sandy soils than can be obtained with a plow, it is favored by nurserymen in the Lake States.

Although a steady horse may be used to draw the trenching equipment, a tractor wide enough to straddle the bed ordinarily will do a better job. The tractor should be equipped with a special drawbar to which the demountable trencher can be attached and adjusted according to the spacing desired. In order to plant without interruption, a trench is made when the tractor makes one trip up a bed, and another trench is made in the adjacent bed on the return trip. The trencher is then moved to a new position on the drawbar for the next trip (fig. 47). Seven rows, spaced 7 inches apart, per bed are standard in U. S. Forest Service nurseries in the Lake States.

METHODS

The amount of transplanting to be done will dictate to some extent the method to use. In small nurseries where only a few hundred thousand trees are transplanted each season, the work can be done by hand about as easily and effectively as by machine. However, for large nurseries where several million trees require transplanting, some type of machine generally is used. Machine planting is a particularly desirable method where there is a shortage of dependable labor. Both methods require thorough planning and good organization to accomplish the job efficiently and economically.

Where the trenching is done by hand, a transplant crew is composed usually of a trencher, a planter, and a threader. The trencher makes the trench in which the trees are to be planted, the threader places the trees in the boards, and the planter sets the trees in the ground. An efficient 3-man crew will transplant 20 to 25 thousand trees per 8-hour day.



F-409150

FIGURE 47.—A tractor-drawn trencher in position. Operator rides this trencher to control depth and aid in steering.

The quantity of work, in terms of number of trees planted per day, and the quality, measured in terms of survival, depend to a large extent upon the proficiency obtained by each member of the crew in doing his particular job. It is essential that the various jobs be thoroughly analyzed and the personnel carefully selected and trained for the work to be performed. The planters and those making trenches should have good physiques and be able to stand the constant walking, bending, and tamping that the work of hand transplanting requires.

Spacing

The spacing to use in lining out stock varies with species, size of stock, and method of transplanting. It is therefore important that spacing be given full consideration, since the amount of stock that can be raised per unit of area depends on it. This is particularly true where the planting area is limited.

In hand transplanting, the spacing between seedlings commonly is 1 to 1½ inches for 1-0 stock, and 1½ to 2¼ inches for 2-0 stock. Where older stock is transplanted, or where the plants are to be left for 3 years or more, a spacing wider than 2¼ inches should be used.

In a spacing test, 2-0 white spruce transplanted and left for 2 years showed a 6-gram or 40-percent increase in average green weight per plant and a considerable increase in stem diameter when spacing was increased from 1½ to 3 inches. Even the stock grown at a 1½-inch spacing was entirely adequate in size for good field results. Therefore, there appears no reason for using spacing greater than 2 inches for 2-2 spruce. In the 4 spacings

tested, all of the trees were of excellent balance, with top-root ratios of 1.83 to 2.00:1.

Hand methods of transplanting facilitate slightly closer spacing between the rows than mechanical trenching or machine transplanting. The spacings that have proved effective in U. S. Forest Service nurseries in the Lake States are 6 inches for hand transplanting and $7\frac{1}{4}$ inches for machine transplanting, with plants $2\frac{1}{4}$ inches apart in the row.

Hardwood species usually are planted with a 9- to 14-inch space between rows or with 4 or 5 rows per 4-foot-wide bed. This spacing is adequate for the use of mechanical equipment for cultivating and for lifting the trees. Regardless of the spacing accepted as optimum, it should be uniform and regular enough to permit the use of standard methods and equipment for handling the weeding, cultivating, and digging of the stock.

Hand Transplanting

Hand transplanting (fig. 48) can be accomplished by setting the plants in the trench by hand or with a transplant board (fig. 49). The latter method is most commonly used because it is faster and more efficient. Various types of transplant boards have been designed by nurserymen based upon local requirement and personal preference (27, 95, 107, 140, 169).

The speed of hand transplanting has been improved gradually and costs of aftercare lowered by (1) using a longer board, (2) somewhat closer spacing of notches in the board, and (3) partial or complete mechanization for making the trench or furrow in which transplants are placed. A change in row direction, i. e., from short, cross-wise rows to long, continuous rows better adapted to mechanical cultivation, was also made.

In U. S. Forest Service nurseries, a transplant board $8\frac{1}{2}$ feet long and accommodating 50 to 75 plants has proved very effective. With such a board, production averages 11 thousand trees per man-day, using one foreman to five 2-man crews (1 stringer and 1 planter). The foreman opens the furrow with a horse-drawn 7-inch plow, and the crews set the plants in rows spaced 8 inches or slightly more apart.

Because seedlings must be protected from drying out, their threading into transplant boards should be done in a shelter. The shelter commonly used in Lake States nurseries is a skeleton frame made of light material and covered with canvas. Its front is left open or canvas flaps hang loosely to provide easy access for the planter when changing boards.

Two shelves are provided in the shelter, one for the transplant board that is being filled and the other for the empty board that is returned by the planter. These shelves, one about 15 inches above the other, should be placed at a convenient working height for the threader so that he can keep the boards filled at a steady pace. It is important that the shelter be long enough to accommodate the transplant boards, and that sufficient space be provided to keep a supply of seedlings at each end of the shelter.

To save time and walking, the threader starts at one end of a board, completes it, and closes the board. He then moves in the opposite direction as he fills the board that the planter has returned to him. Because the threader sees each seedling as he threads it, he should be trained to recognize inferior trees and instructed to discard them.

In setting the seedlings, the planter takes a filled board from the shelter and walks toward the open trench. As he approaches, he turns the board so that it can be easily opened after the planting is completed. He stands far enough back from the



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FIGURE 48.—Hand transplanting in nursery on Chippewa National Forest, Minn. The man at left is making a trench, and the man in center is tamping a board of 30 trees. The crew consists of 2 threaders (women) in transplant shelter in rear, 2 planters, and 1 trencher.

inches deep and wide enough to accommodate the shoe of the self-steering device on the machine. Guide furrows in adjacent beds can be made with a marker wheel attached to the machine. To insure straight, evenly spaced rows, the guide furrows should be kept free of loose soil and in good alinement. To prevent deviating from the prescribed course, the machine must be kept balanced, particularly as concerns the draft placed on the power unit by the two planting units. The operators selected to thread the seedlings into the pockets on the revolving disks, therefore, should be approximately the same weight.

Before starting a trip across the field, the transplanting machine is lined up on the beds with the center of the tractor in line with the guide furrow, and the steering shoe is placed in the V-trench. The unit is then driven into position for planting to begin. Next, the plant setters are attached to the drawbar in the proper position and the operators take their places on the seats. After each operator has taken a handful of seedlings, the machine is put into motion. The operator holds the seedlings in his left hand and with his right hand places a single seedling in each plant pocket on the revolving disk as it comes around in position. When one handful of seedlings has been planted, another is taken from a box that is within reach, and the threading of trees continues.

The plant pockets are spaced either $2\frac{1}{4}$ or $2\frac{1}{2}$ inches apart on the disk. The speed at which the disk turns varies with the gear ratio used on the disk and the packing wheels that furnish the power for turning the disk. Therefore, the spacing of plants can be increased or decreased by adjusting the speed at which the disk turns. Standard spacing in U. S. Forest Service nurseries is $2\frac{1}{4}$ inches, or approximately 5.4 seedlings per linear foot.

It is essential that the furrow-opening shoe be set deep enough to permit the roots of the seedlings to hang straight when they reach an upright position. If the seedlings are set at an angle, or the roots are planted in a horizontal position, the plant develops a crooked stem and is difficult to handle when field planted.

Where more than one machine is operated in the same general area, a foreman is usually assigned to supervise and direct the work. It is his duty to assist in turning the machines at the ends of the beds, to lay out new beds for planting, and to service the machines with seedlings. To avoid interruptions in the planting work, a supply of seedlings is kept at each end of the bed.

The production obtained by machine planting varies with the size and age class of seedlings planted, and the amount of ineffective time used in turning and servicing the machine. At the U. S. Forest Service nursery in the Lower Peninsula of Michigan, where the length of beds ranged

from 450 to 500 feet, a production of 30 thousand trees per 8-hour day was obtained with one machine.

The Soil Conservation Service nursery at Zanesville, Ohio, has devised a multiple-row planter that can plant as many as 6 rows simultaneously; 6 individual transplant units are mounted inside of a shelter on wheels. For traction power a wide-tread, caterpillar-type tractor is used. It was geared down to a speed of $\frac{1}{8}$ to $\frac{1}{4}$ mile per hour by adding a light truck transmission.¹⁵ This machine provides uniform row spacing, is easy to turn, shelters the trees, reduces supervision costs, increases production per man-day, and is easy to maintain.

A very compact 5-row transplanter with a short turning radius was built in 1953 at the Nekoosa-Edwards Paper Company industrial forest nursery, Port Edwards, Wis. An ordinary rubber-tired tractor was geared down to obtain a speed of about 10 feet per minute, and standard Holland transplant units were so mounted on it that 2 of them were between the forward and rear tractor wheels, 1 on each side of the tractor, and the remaining 3 units trailed behind. This provided uniform row spacing.

CARE OF THE TRANSPLANT BED

A lack of moisture immediately following planting frequently results in a high mortality of transplants. Where overhead irrigation is available, each bed should be sprinkled as soon as transplanting is completed. If it is not available, furrow irrigation can be used. The construction of the furrows for distributing the water should keep pace with the transplanting operation. Special attention should be given to irrigation needs when transplanting is done in the late summer or fall.

Shallow cultivation of transplant beds is beneficial because it eliminates weed growth and creates a light earth mulch that improves the moisture-absorbing capacity of the soil. Usually, power-drawn cultivators are used. Deep cultivation is not required ordinarily. Mulching to prevent frost heaving is not needed as a rule if the nursery is located on sandy soil and the transplanting is completed before the end of the growing season.

The conifers commonly produced in the Lake States do not require shading during the time they are in the transplant beds. Frequent irrigation to reduce ground surface temperatures and increase available moisture will bring through the more sensitive shade-loving species even when grown in full sunlight.

¹⁵ Information supplied by Tom O. Bradley, nursery manager, Soil Conservation Service nursery, Zanesville, Ohio.

HARDENING-OFF

Stock for fall planting must be properly hardened-off. Hence, irrigation should be curtailed during the late summer to hasten this process. (See *Improving Drought Resistance by Regulated Watering*, p. 69.) Dormancy can also be hastened by undercutting the beds in the fall several weeks ahead of digging. Severing the deeper roots, and slightly disturbing the soil, increases evaporation of soil moisture and retards intake of water. Schneider (139) noted a strong color change from green to purple within 4 days of undercutting 1-0 jack pine. Ponderosa pine may react similarly.

Seedlings, particularly conifers, are considered to be hardened-off when the terminal buds have formed and the stem and root tissues have ceased growth. Other characteristics that indicate dormancy are color and stiffness of the needles. This is particularly true of jack pine, the needles of which often take on a dark purplish cast and increase in stiffness as the plants enter the dormant stage. However, those of southern origin (44° to 45° latitude) tend to show much less color change than those of more northern origin (46° to 48°) under normal hardening-off procedures.

This is illustrated by a comparison of the degree of color change in 30 different lots of jack pine grown in the middle of the latitudinal range of the species in the Lake States at Hugo Sauer Nursery, Rhinelander, Wis. The seed was collected over practically the entire range of the species in the Lake States. A substantial increase in percent of total foliage with the bronze or purplish color (deemed to signify hardening) occurred in 2-0 jack pine between October 20 and November 4, 1953. But 1-0 stock showed a more complete color change than 2-0 stock, especially for the stock grown from seed collected between the 44th and 45th parallel of latitude (fig. 51). The following spring, April 19, 1954, the same lots of stock showed a color curve almost identical to that of November 4, 1953; this indicated that no change had occurred due to further subjection to cold in the 5-month period.

Color change in some of the stock carried to 3-0 age was less complete than at the 2-0 age, with a straight-line relation extending from 18 percent at latitude 45° to 73 percent at latitude 48° by November 8, 1954.¹⁶ Small lots of the same stock transplanted at about 8- by 2-inch

¹⁶ Latitude gave better correlations with color change of this jack pine than any of four other criteria. On this set of observations the correlation coefficient was 0.830, significant at 1-percent level. When related to degree days over 50° F., it was 0.682, significant at 1-percent level. When related to average January temperature, it was 0.511, significant at 5-percent level; and when related to number of days of frost-free period, it was 0.094, a nonsignificant correlation. The proximity of large lakes (Lake Superior, Lake Michigan, and Lake Huron), which have an extending effect on the number of frost-free days, apparently interfered with the prospect of positively correlating color change and length of frost-free period of the area of origin of the parent trees.

spacing in the spring of 1954 and observed at the 2-1 stage in the fall of 1954 showed no color change in any of 10 transplanted lots on October 18, and moderate color change on November 8, 1954, with a straight-line relation of 0 percent at latitude 44° and 20 percent at latitude 48°.

Apparently, latitude of parent trees, as well as class of stock and length of the hardening period when plants are subjected to cool temperatures, may have an effect on coloration and hardening-off of conifers.

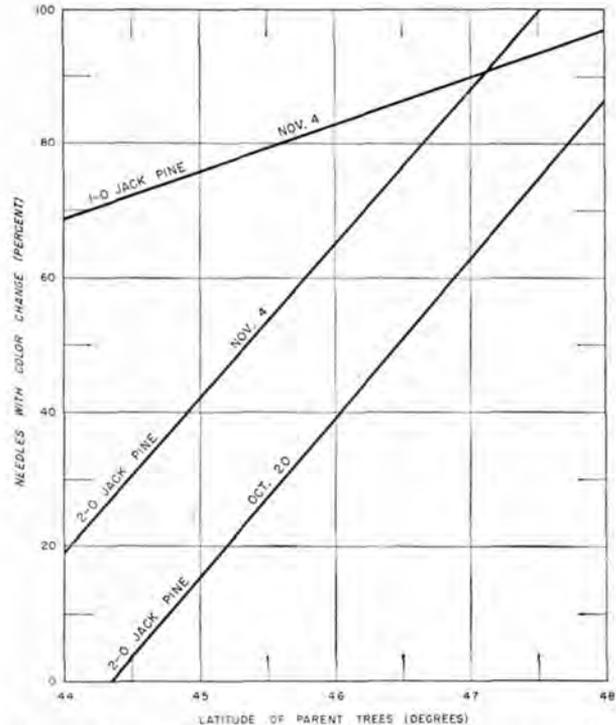


FIGURE 51.—Effect of latitude of parent trees on relative completeness of fall color change from green to bronze in needles of 1-0 and 2-0 jack pine grown in the Hugo Sauer Nursery, Rhinelander, Wis., which is at approximately 45.65° N. latitude. Thirty seed sources were involved. Correlation coefficients (*r*) for the 3 lots from top to bottom on graph are 0.684, 0.874, and 0.819, respectively. All are significant at odds of 99 out of 100.

Hardwoods enter the dormant stage with the occurrence of low temperatures and are dormant after the first few frosts, or after the stock has shed its leaves. Harvey (67), for example, noted that exposure of American elm seedlings for 5 days to a temperature of 32° F. hardened them sufficiently so that none were killed when later frozen at 21° for 24 hours. Since deciduous seedlings do not remain dormant very long after warm weather sets in in the spring, it is advisable to dig them in the fall and heel them in overwinter. This practice also helps to equalize the nursery workload between fall and spring.

SPECIAL PROPAGATION METHODS

Practically all stock for reforestation purposes in the Lake States is grown from seed. However, certain species used in windbreaks and shelterbelts, and in some research work, are propagated by cuttings or by grafting.

DORMANT STEM CUTTINGS

The species most likely to be propagated from dormant stem cuttings in Lake States nurseries are cottonwoods and willows. Such cuttings should come from relatively young plants, or from the sprouts of plants that have been cut back 2 to 4 years earlier. One- or two-year-old wood is preferred. In the fall, 3- to 5-foot switches, $\frac{3}{16}$ to $\frac{1}{2}$ inch in diameter, are cut out with sharp, long-handled, pruning shears, or a heavy, sharp knife. These switches are tied in bundles, covered with a canvas, sacking, or straw, and taken to a shelter where they are made into cuttings.

A fast method of preparing cuttings is for one man to assemble the switches in bunches of 5 to 8, with the butt ends matched. He then holds them one layer deep on a wooden block, and a second man chops them into lengths of 10 to 12 inches with a sharp cleaver or machete, or a weighted knife dropped in slotted guides. Cuttings of substantial size should be discarded, and the buds of the ones retained should all point in one direction. Those of acceptable grade are counted into bunches of 50, or any other convenient size, and tied twice with binder twine at a point 2 to 3 inches from the ends. They are then buried in moist sand in a pit or root cellar until spring.

In April or May the cuttings are set out in standard trenches about 9 inches deep. One or two buds, or 2 to 3 inches of cutting, should remain aboveground. The trench is then closed with a mechanical packer that is pulled by a rubber-tired tractor, or, in a small-scale operation, by walking along the trench and caving it in and firming the cuttings by heel action. Heavy watering is required to get good rooting.

The various species of cottonwoods as well as willows (especially white willow and one of its hybrids) are readily propagated in this manner and are ready to ship as 1-0 rooted cuttings by fall or the following spring. Rooted cuttings at 1 year of age will be sturdier and larger than 1-year-old cottonwoods or willows grown from seed; in fact, they will be about as large as 2-year-old trees of seed origin.

Cuttings are sometimes planted in the nursery in the fall (47). Survival of such plantings has been improved under prairie and plains conditions by setting a cutting so that only about 1 inch protrudes from the ground, and then completely covering it over with a ridge of soil a few inches deep. This covering prevents excessive drying out of the cuttings overwinter. The following spring, the shallow ridge of soil is removed to

uncover the end of the cutting. Cuttings can be set about $1\frac{1}{2}$ to 2 inches apart in the nursery.

Use of growth substances may increase percent of rooting. Soaking the bottom ends of cuttings in a 50- to 100-parts-per-million solution of indoleacetic acid for 18 to 24 hours before planting (167) will increase the percent of rooting of the more easily propagated poplars and willows.

Quaking and bigtooth aspen are very difficult to root without treatment but are reported to root well when taken in March and treated with 10 parts per million of indolebutyric acid for 27 hours (167). Several hundred other species and varieties of plants can be propagated more readily by such chemical treatment (99, 167, 185). Normally, however, few of them will be grown in forest nurseries.

ROOT CUTTINGS

Shipmast locust, a variety of black locust, can be propagated by root cuttings. Swingle (165) recommends taking 3- to 5-inch-long cuttings, $\frac{1}{4}$ to $1\frac{1}{4}$ inches in diameter, from roots of young trees and from younger parts of the root systems of old trees. The cuttings are taken while the trees are dormant, and they can be planted in the nursery any time before bud growth starts. Roots must be kept from freezing. A sandy soil, or a mixture of sand and peat in a greenhouse culture, makes the best rooting medium.

Root cuttings of aspen have also been tried but the percent of survival was very low. Wildings, or root cuttings with a small aboveground shoot of 1- to 2-foot length, have given better survival.

GRAFTS

Grafting is used in forest nurseries for very special purposes only. For example, grafts have been used in propagating strains of white pine resistant to blister rust (120). As forest products increase in value and as certain prized species become more scarce, it is quite likely that certain species, strains, selections, or hybrids will be propagated vegetatively for mass production.

In grafting, a 3- to 4-inch-long scion of the desired species is joined onto a potted tree of the same genus: A slit is made in the 2- or 3-year-old stock, the scion is placed in the slit and wrapped, and the two join and grow together. Grafting work is done in January, February, or March in the greenhouse and the potted grafts moved outside in late spring. Once completely healed over, usually at the end of 1 year, the top of the "stock" plant is cut off (56, 83).

Norway spruce often is used as a grafting stock for spruces, although white spruce is used occasionally. Scotch pine is used for two-needle pines, pitch pine for three-needle pines, and eastern white pine for the five-needle pines. For larches, European larch is satisfactory.

NURSERY PROTECTION

Constant vigilance is necessary if serious losses from nursery injuries are to be avoided. The early discovery of injury is quite as important as prompt treatment. Often it is desirable to have spray equipment and necessary chemicals and supplies on hand before trouble starts. The major sources of injury and some of the minor ones are described in this section. Formulas for preparing large quantities of insecticides and baits are given in the appendix, p. 120, and the safety rules and precautions for handling, mixing, and applying chemicals, p. 118, should be carefully observed.

UNFAVORABLE WEATHER CONDITIONS

Trees in nurseries require protection against wind, excessive heat, drought, freezing, frost heaving, drowning, and water erosion. Prevention of losses from these causes are discussed in detail in the sections on Seedbed Preparation and Sowing, p. 59; Soil Moisture and Irrigation, p. 67; Seedbed Care During Germination and the Seedling Stage, p. 71; and Transplanting Operations, p. 79.

MAMMALS AND BIRDS

Practically all nurseries are so situated that a fence is necessary to exclude either domestic livestock or larger wild animals such as deer. If deer are a problem, a fence at least 10 feet high is necessary.

Snowshoe hares and cottontail rabbits may cause damage in Lake States nurseries, especially to oak, elm, and certain pines, and in western and southwestern Minnesota, jackrabbits are a problem. A 4- or 5-foot-high wire fence of 1- to 2-inch mesh will exclude rabbits except where there is deep snowfall or heavy snowdrifting. In such areas, the fence should be 6 feet high. The fence generally needs to be buried at least 6 inches in the ground where the cottontail rabbit is the offender. Occasional winter checking is necessary to determine whether rabbits have gained entrance and are doing damage. If they have, they can be eliminated by snaring, trapping, or shooting.

Pocket gophers occasionally cut off tree roots below the surface. Regular pocket gopher traps or a poisoned bait, such as diced, fresh carrots dusted with powdered strychnine alkaloid at the rate of $\frac{1}{4}$ ounce of powder to 4 quarts of carrots, are effective controls. When poisoned bait is used, several placements should be made in each burrow system, and care should be taken in re-

plugging the placement holes to avoid covering the bait.

Moles, chipmunks, and squirrels occasionally dig up or eat seed in some nurseries. The hardware cloth screens used at time of seeding to prevent bird damage give some protection against these rodents. However, they often dig under the bedboards or somehow slip past the barrier. They can best be eliminated by shooting or trapping, or by carefully placed poison baits put out some weeks in advance of the seeding.

Many species of white-footed mice (*Peromyscus* spp.) may eat seed of conifers as well as of hardwoods. The meadow mouse (*Microtus*) also eats seeds; and the pine mouse (*Pitymys*) may do damage by girdling bark or cutting off small seedlings. Mice can be trapped easily with ordinary snap traps that are baited with apple, a vegetable, or oatmeal and placed in runways and near entrances of burrows. However, poisoned baits are probably the cheapest and most effective way of eliminating mice and some of the other seed-eating rodents. The principal poisons used are strychnine alkaloid and zinc phosphide.

Inside the nursery, bait stations should be located at intervals of about 100 feet and staggered somewhat where bedboards tend to confine and channelize rodent movement. Outside, bait should be placed along the fence and in a bordering zone about 200 feet beyond the fence. In this zone, especially if it is grassy, bait should be spaced as close as 30 feet apart, in 4 lines paralleling the fence, at intervals of about 50 feet. Bait remains effective somewhat longer if placed in small tin cans laid on their sides with the opening on a slight downslope to exclude rain. *Do not place bait where livestock will have access to it.*

Nurserymen with rodent problems may wish to write to the Fish and Wildlife Service, U. S. Department of the Interior, Washington, D. C., for the address of the poison-bait distribution center nearest to them. Prepared baits are available at such centers, and prices vary. County Agents also may be able to furnish information about distribution centers. An alternative to the purchase of prepared baits is to use one of several formulas recommended by the Fish and Wildlife Service (52) and make them up at the nursery. Two poison-bait formulas for mice are given in the appendix on p. 120.

Seed-eating birds can be excluded by hardware cloth screens or by patrolling the nursery in daylight hours during the critical germination period. Recent costs of using bird watchers who patrolled on foot with a shotgun have come to 8 cents per thousand trees. In a large nursery, a bicycle patrol may be necessary to give rapid enough coverage of all areas.

NURSERY DISEASES

Disease control, according to Hartley (64) is largely a matter of prevention by proper selection of nursery sites and species, and attention to soil condition, stand density, and sanitation. However, in spite of all reasonable precautions, some diseases are almost certain to be a problem in every nursery at one time or another.

Damping-Off

Probably the most serious disease in most Lake States nurseries is damping-off caused by fungi that attack the small, newly germinating seedlings just before or just after they emerge from the ground. The stems or roots of the seedlings decay. This disease is especially associated with conifers, and only the genera *Thuja*, *Cupressus*, *Juniperus*, and *Chamaecyparis* are somewhat resistant to it (10).

Hartley (63) identified various species of the genera *Pythium*, *Rhizoctonia*, and *Fusarium* as causal organisms of damping-off and suggested various acidification treatments of soil as a control measure. In Wisconsin nurseries, *Pythium* and *Rhizoctonia* are the two fungi that have caused appreciable economic loss, especially of red pine stock. Species of the genera *Cylindrocladium*, *Phytophthora*, *Botrytis* (62), and possibly *Alternaria*, also cause losses.

Damping-off is favored by the use of poorly rotted manures, dried blood, or materials that increase the carbon-nitrogen ratio of the soil (65). The disease is also favored by materials that decrease acidity, such as lime, limy sand, wood ashes, or nitrates, or by the use of irrigation water that has a hardness of over 100 parts per million as CaCO_3 or 125 parts per million as a bicarbonate (39). Damping-off fungi may be introduced by shipping in infected nursery stock from distant nurseries.

The usual method of controlling or reducing the incidence of damping-off is to treat the soil with $\frac{1}{16}$ to $\frac{1}{8}$ fluid ounce of concentrated acid per half pint or pint of water. However, the amount of acidifying material to apply depends largely on soil texture and its pH before treatment, as discussed in the section on Soil Management, p. 41. Dilute sulfuric acid is applied immediately after the seed is sown, and the beds are then watered. The treatment is most effective against *Pythium*, which thrives in neutral to slightly acid soils and in cool-temperature and high-moisture conditions. If *Rhizoctonia* is still a problem after such treatment, formaldehyde or mercuric and other dusts should be used. Roth and Riker (129) observed that *Rhizoctonia* is not inhibited by relatively acid conditions. Soils with a pH of 5.2 or less generally need no treatment for damping-off.

A study by Wilde (189) indicated best nursery survival of red pine seedlings when sulfuric acid was used at or near a 2.0 to 2.5 percent concen-

tration by volume. He suggests application at the rate of 7 gallons per 100 square feet of bed area in fall treatment and cutting the concentration to 1.5 percent in spring treatment.

In 1937 Barton¹⁷ observed that spring acid treatment of fall-sown white spruce was very deleterious. Density per square foot was reduced from 57.5 trees in fall-treated and fall-sown beds to 29.0 trees in spring-treated fall-sown beds. In this case there was no doubt of acid injury in spring treatment of fall-sown beds because of the softening of the seedcoat which had occurred in the period between sowing and treatment.

Rindt (122) used one-sixteenth avoirdupois ounce of aluminum sulfate per square foot as a control. The sulfate was mixed in a tank and then applied through the overhead lines for 20 minutes by using a sump pump. Other authors have recommended that where there has been no previous experience with aluminum or ferrous sulfate preliminary tests be made by actually trying treatment on a few square feet of soil (39). The pH value of the soil should then be determined 3 days later. The amounts to be used in such a test are given in table 32.

Hydrochloric acid has been used in some nurseries but is more expensive than sulfuric acid and the amount required is roughly 3 times as great. For phosphoric acid, about $2\frac{1}{2}$ times as much volume is needed as for sulfuric acid, or about two-thirds of the recommended number of avoirdupois ounces of sulfate.

Acetic acids have been used with success at one-half fluid ounce per square foot of seedbed, applied 5 or 6 days before seeding (43).

TABLE 32.—Amount (avoirdupois) of aluminum sulfate or ferrous sulfate to test on soils of varying pH where there has been no previous treatment¹

Initial pH	Amount of sulfate for—			
	Sandy soil		Heavy soil	
	Per square foot	Per 1,000 square feet	Per square foot	Per 1,000 square feet
5.0	Ounces 0	Pounds 0	Ounces $\frac{1}{4}$	Pounds 15.6
5.5	$\frac{1}{4}$	15.6	$\frac{3}{8}$	23.4
6.0	$\frac{3}{8}$	23.4	$\frac{1}{2}$	31.2
6.5	$\frac{1}{2}$	31.2	$\frac{3}{4}$	46.9
7.0	$\frac{3}{4}$	46.9	1.0	62.5
7.5	1.0	62.5	$1\frac{1}{4}$	78.1
8.0	$1\frac{1}{4}$	78.1	$1\frac{1}{2}$	93.7

Source: Fed. Security Agency, Civ. Conserv. Corps Forestry Pub. 9 (39).

¹ 3 days after test treatment of a few square feet of soil: if top $\frac{1}{2}$ inch of soil has a pH value below 4.0, treatment is too heavy; if above 5.0, it is not heavy enough.

¹⁷ Unpublished annual report, Hugo Sauer Nursery, 1937.

Deep treatment with sulfur to a depth of 6 or 8 inches, using $\frac{1}{4}$ to $\frac{1}{2}$ avoirdupois ounce per square foot, has value as a damping-off control in alkaline prairie soils. To avoid acid injury, it should be applied several warm months or a full year before seeding.

The repeated acidification of a nursery seedbed, particularly with aluminum sulfate, has the disadvantage of sometimes causing the caking or crusting of the soil surface, and it may kill or stunt the root tip of the seedlings. Hence, other treatments may be preferable. One of these is $\frac{1}{4}$ fluid ounce of commercial 40-percent formaldehyde per pint of water per square foot of seedbed. This solution is applied 4 to 10 days before seeding and then heavily watered (39). The shorter period is sufficient in warm weather or on soils with abundant humus, while the longer period is necessary in cold, damp weather, or on heavier soils.

One hour's sterilization with steam at 6 to 8 pounds pressure has controlled damping-off successfully in seedbeds (137). The seedlings were better in the treated areas, and weeding costs were reduced 82 percent. The disadvantages of steam sterilization are its lack of adaptability to large nurseries, its costliness, and its adverse effect on soil structure.

Other methods for controlling damping-off include applications of chemicals containing copper and zinc and of mercuric compounds to the seed or as soil dusts before or after seeding. It is expected that soil acidification soon will be supplanted by these recently developed fungicides in nurseries in the forested parts of the Lake States where the soils are naturally acid. Soil acidification will, however, continue to be of use in prairie soils or in certain nurseries where alkaline waters tend to build up soil alkalinity and create a problem in seedling nutrition.

Seed dusts of Orthocide 406 (N-trichloromethylthio tetrahydrothalamide) and copper carbonate reduced damping-off and increased emergence of pine and spruce seedlings (163). Other chemicals were nearly as effective. These dusts were applied dry just before seeding in sufficient amounts to coat the seed.

Soil dusts applied before seeding show promise of more prolonged protection than that obtained from seed dusts. Tests of several soil dusts indicated that the following were the most promising (163): Tersan (wetttable tetramethylthiuram disulfide),¹⁸ experimental fungicide 5400, 31 parts of Ceresan M (ethyl mercury p-toluene sulfonamide) plus 1 part of potassium iodide, and Manzate (manganese ethylene bisdithiocarbamate).

These fungicides were mixed with soil and applied to the seedbeds as dust—150 pounds per acre—at the same time the commercial fertilizers were applied. The seedbeds were then tilled to a

¹⁸ In earlier tests (121) Tersan was effective as a soil dust when used at the rate of 1.2 to 4.8 grams per square foot. The heavier treatments were best.

depth of 5 inches with a rototiller. Treatments of 300 pounds per acre were even more effective, but it is questionable whether the slightly improved stands warranted the increased cost. Treatment with these dusts should be made 3 days before seeding; if rain occurs, seeding should be postponed for 6 days.

Effective post-seeding treatments were Tersan, Crag fungicide 5400, Orthocide 406, Agrox (phenyl mercury urea), Manzate, and Semesan (hydroxymercurichlorophenol) applied at 150 pounds per acre in 3 separate 50-pound treatments at 1-week intervals, beginning 1 week after sowing (163).

The pelleting of seed, using Arasan (50 percent tetramethylthiuram disulfide) with 4 percent methyl cellulose as a binder, is reported to be more effective than treating the soil (12). For every pound of seed used in fall sowing, there were used 8 ounces of fungicide and 3 ounces of methyl cellulose, mixed in a pharmaceutical pill coater. In spring seedings, the fungicide was reduced to 2 ounces and binder to 1 ounce per pound of seed treated.

In southern nurseries, the spread of damping-off has been arrested by treating the affected patches and a border 1 to 1½ feet beyond them with Semesan at one-tenth ounce per pint of water per square foot. Treatments were made on cloudy days or in the late afternoon to avoid seedling injury. Top damping-off by *Rhizoctonia*, occasionally affecting white pine, can be controlled by applying Semesan and 4-4-50 bordeaux at the rate of 1 gallon per 100 square feet of seedbed (39).

Other indirect controls of damping-off include use of new soil; favoring fall instead of spring seeding; sowing for lower seedbed densities; using clean, nonalkaline sand as seedbed cover; and removing half-shade in periods of prolonged damp weather.

Acids and sulfates are best applied in solution from an acid cart by going over beds twice, that is, reversing direction of application on the return trip. This equalizes applications per square foot over the entire bed. Safety measures for handling acids and sulfates are given in the appendix, p. 118.

Acid carts often are made of wooden barrels that are equipped with lead pipe tapped at intervals of 2 to 3 inches and extending across the bed (fig. 52). The carts can be hand-drawn or pulled by a light, rubber-tired tractor. Larger nurseries in recent years have adopted a rubber-tired acid cart (fig. 53).

Cedar Blight

Junipers, especially eastern redcedar and its varieties, sometimes are attacked by cedar blight (*Phomopsis juniperovora*), particularly in nurseries in the southern part of the Lake States. Good results have been obtained by applying standard bordeaux mixture as soon as growth starts in the spring and every week thereafter.



F-243220

FIGURE 52.—Acid barrel used immediately after seeding for applying dilute sulfuric acid as a damping-off control. (Beal Nursery, Mich.)

In trees affected by cedar blight, the tops, particularly new needle growth, turn gray and, unless arrested, the infection may spread until the trees die. Heavy fertilization, high seedbed density, and humid weather tend to accelerate the spread of the disease.

Infected seedlings or transplants should be destroyed by burning. Once cedar blight is brought into a nursery on diseased stock from another nursery, it is virtually impossible to eradicate the disease completely. Hence, it is a good policy for nurserymen to grow their own juniper stock.

Leaf Diseases

Among the trees frequently affected by leaf spot diseases are the ashes, cherries, poplars, and willows (39).

In ashes, *Marssonia fraxini* first appears on the upper leaf surface as small, gray dots. These enlarge gradually to make larger patches. On the lower sides of the leaf, small round pustules appear that develop light gray masses of spores. The disease causes premature defoliation and retards normal growth.

On cherry leaves, *Coccomyces lutescens* causes light yellow to reddish-brown circular spots that

die. The spots may drop out, giving the appearance of a "shot hole."

Poplars and willows often are infected by an orange-colored rust (*Melampsora* spp.). Poplars are sometimes affected by *Septotinia* spp. that cause gray or brown blotches with concentric circles on the upper leaf and white spore masses of the imperfect stage on either surface.

Leaf diseases generally can be controlled with a 4-6-50 bordeaux spray. The first spraying of the season on cherries should be cut in strength to 2-3-50 because of early-season sensitivity of the species. Lime sulfur spray at 2-percent solution has been effective in controlling leaf rusts on ash. Many of the rusts have alternate host plants which if eliminated will solve the problem. The advice of a plant pathologist should be sought to determine the feasibility of this practice.

Occasionally, certain rusts (*Coleosporium* spp.) cause orange to whitish pustules on the needles of pines in Lake States nurseries. Another rust (*Chrysomyxa* spp.) sometimes attacks spruces, especially black spruce and blue spruce. Ordinarily, these rusts do little or no permanent damage in the Lake States area. If the marketability of the stock in commercial nurseries is im-

Control work should start in early July or as soon as the first telia are formed on the oak host plant. In central Wisconsin, as much as 25 percent of the jack pine in a large nursery has been affected by gall rust.

Sweetfern Blister Rust of Pitch Pines

Sweetfern blister rust (*Cronartium comptoniae*) is limited to two- and three-needled pines. It appears especially on jack, Scotch, ponderosa, and lodgepole pine, but it will also attack others such as Mugho, Austrian, and red pines. Alternate hosts of the disease are sweetfern and sweetgale.

The disease may attack seedlings and trees up to 2 inches in diameter (148). It causes a swelling near the soil surface, and the girdling action often is sufficient to kill the tree. On occasion, the rust has caused heavy losses in Lake States nurseries, particularly of ponderosa and lodgepole pine, neither of which is native to the region. In each instance, there was considerable sweetfern on areas surrounding the nursery.

In late May and early June infected trees develop white blisters filled with orange or yellowish spores. On older cankers, however, blisters are scarce or even absent. There is considerable resin flow from the infected parts that are sometimes twisted or flattened (61).

Nurseries in which the more susceptible species are to be grown should be located at least one-fourth mile from scattered sweetfern and sweetgale. Susceptible species, particularly those not native to the region, should not be planted in or near areas where the alternate host is present. Infected nursery trees should be destroyed. Eradication of the alternate host may be feasible in the vicinity of established nurseries.

Nursery seedlings or ornamentals can be protected by spraying them with bordeaux mixture (8 pounds copper sulfate, 10 pounds hydrated lime, and 2 pounds calcium caseinate in 100 gallons water) from about August 1 until the onset of frost. A lime sulfur spray, consisting of 2.5 gallons liquid or 6 to 8 pounds dry material in 100 gallons of water, is also effective (61).

Snow Mold

On occasion, an especially deep or long-persisting snow mantle pressing down on the trees may cause damage to spruce, balsam fir, and occasionally pines by promoting growth of a snow-mold fungus (*Phacidium infestans*) (39).

Dormant-strength lime sulfur sprayed as soon as the trees are dormant in the early fall is recommended as a precautionary treatment in nurseries where such damage has been noted (39). A Fermate spray also has given good control. Treatment will prevent transfer of the fungus to the field. In beds affected by snow-mold fungi, the needles are glaucous brown and, by fall, dark disk-

like bodies containing spore sacs appear on the underside of the needles. Complete mortality of trees may occur in patches up to 2 feet or more in diameter. As the trees are exposed by snow melting, there is a covering of white mycelia on the brown foliage (17).

Molds or Rots in Storage or Transit

Nursery stock may be damaged by heating and molding in storage or in transit if kept too long in tight bundles. Proper control involves reducing the period of time between lifting and cold storage, keeping storage temperatures low, using properly prechilled packing materials, and trucking the stock in overnight shipments.

In discarding damaged stock, care should be taken to distinguish between actual rots as shown by a sloughing of roots, and superficial or harmless molds on the stems and mycorrhiza on roots.

Rots of Seed in Beds

Seed may rot in waterlogged or flooded beds in localized low or poorly drained spots. The best measure is prevention through selection of soils with good surface and subsurface drainage or raising the seedbeds above the general level of the paths. Proper seed pretreatment is helpful because prompt germination reduces the chances of the seed rotting. Removing shade frames is necessary where the seedbed surfaces are too moist.

Root Rots

Trees with rather thick, fleshy roots, such as black walnut, black locust, and the oaks, are subject to root rots (*Phytophthora* spp.), especially on heavy, wet soils or on areas used repeatedly for production of the same species. Siberian elm also has been damaged in indoor winter storage or when heeled-in outdoors in unfrozen ground.

The root rot problem is accentuated by growing fleshy-rooted species to large-size or old-age classes. In digging, the long taproots are severely mangled and may rot in the heel-in bed. Root rot in Lake States broadleaf species is controlled best by proper rotation, and by using well-drained soils, changing heel-in beds, and producing 1-year instead of 2-year stock.

Since root rot has not been a serious problem in Lake States nurseries, controls have been tested on only a small scale. It may be necessary, however, to try them on an expanded scale if losses become severe. In southern nurseries, ethylene dibromide has given good results in control of root rot of pines, probably associated with nematodes. It is applied at the rate of 25 gallons per acre 2 to 3 weeks before sowing. It may be diluted in 100 gallons of water per acre for greater ease of application. A hand appli-

cator, such as a Mack Weed Gun or a Fumi-Gat, is satisfactory for small-scale treatment. For large-scale treatment, a commercially available soil-injection kit is desirable (69). This consists of a lift on the rear of a rubber-tired tractor equipped with adjustable shanks for lateral spacing. On the back of each shank, tubes leading down to near the tip convey the chemical under pressure from a 50-gallon drum attached to the rear of the tractor. Methyl bromide and chloropicrin were also successful in combating root rot (69). In trials at Chittenden Nursery, Mich., the former has given the best results, but sufficient tests have not been conducted to justify definite recommendations.

Cedar-Apple Rust

Large transplants or large ornamental stock of eastern redcedar and other junipers are susceptible to cedar-apple rust (*Gymnosporangium juniperi-virginianae*). The disease causes unsightly, brown galls that develop long, orange-colored spore horns in the spring. The disease passes to apples and hawthorn and back to juniper. In some States where apple growing is an important industry, regulatory laws require eradication of redcedar. Where it is necessary to grow eastern redcedar or other susceptible junipers, it is recommended that they be kept at least one-half mile away from the alternate host.

Cedar-apple rust also can be controlled by spraying junipers with bordeaux 180 (12 pounds copper sulfate, 12 pounds hydrated lime, 2 pounds mono-calcium arsenate, and 8 pounds zinc arsenate in 100 gallons of water with spreader) in the spring when the telial horns are no longer than one-fourth inch. This arrests their further development (60).

Elgetol applied as a spray at 1 gallon per 100 of water also has given satisfactory control, especially when applied during the spring when the telial horns are small.

Ferbam-sulfur applied in 3 sprays at 3- to 4-week intervals starting in early June will control the rust. It is made up of $\frac{1}{2}$ pound ferbam and 3 pounds of microfine, wettable sulfur in 100 gallons of water. Ferbam-sulfur also can be applied to the apple and hawthorn hosts 4 or 5 times at 7- to 10-day intervals, beginning in the spring when the telial horns first appear on the junipers.

Actidione (cyclo-heximide) at a concentration of 100 parts per million has shown some possibilities as a spray to prevent teliospore formation, in tests conducted by Forrest Strong of Michigan State University.

Needle Cast

Needle cast may attack balsam fir, Norway spruce, Douglas-fir, tamarack, jack pine, red pine, Scotch pine, eastern white pine, ponderosa pine,

and several conifers not grown in the Lake States. There are a number of species of fungi that cause the disease, including *Lophodermium pinastri*, *Hypodermella ampla*, *Elytroderma deformans*, and *Bifusella linearis*.

Needle cast, as the name implies, involves more or less heavy loss of foliage. Needles 2 years of age or older are discolored, become yellowish or brown in late spring or summer and, in severe cases, may drop off leaving only the first-year needles on the tree. Tiny, black, shiny, elongated, fruiting bodies may occur at early stages on the needles.

The disease has been controlled by spraying nursery beds with 2 percent lime sulfur with sticker, or 4-4-25 bordeaux mixture. Spraying is started when new needles are about half grown and may have to be repeated a number of times, particularly after rains, until growth ceases (17).

Cytospora Canker of Poplar and Willow

This fungus is very prevalent on the bark of poplars, willows, and mountain-ash. It may become serious when plants are injured or bruised, as by hailstones or by ice damage. It may occur on wildings growing on sandbars along streams. The disease may also affect cuttings lined out in the nursery or heeled-in with part of the bundle exposed. Damage in plantings is accentuated when the trees are planted on poor or dry sites, or in weedy situations where tree vigor is adversely affected. High vigor appears to be important in creating resistance to the disease.

On young, smooth-barked shoots the young infection causes brownish, shrunken patches. The cambium is gradually discolored and killed and the diseased portions may encircle the plant (17). Cuttings should be kept in cold storage at about 35° F., and any bundles heeled-in should be buried completely to avoid infection in cut ends.

When lining-out cuttings in the nursery, nurserymen can reduce infection by completely burying the cutting or putting a ridge of soil over the cutting until rooted. Abundant watering will maintain high vigor and thus reduce losses, especially early in the season. Nursery stock or cuttings from an infected nursery should not be moved to new nurseries. Some nurserymen dip freshly prepared cuttings in a 1-percent solution of Semesan or a 2-percent solution of Ceresan M before lining them out.

NURSERY INSECTS

Insects may cause serious damage in nurseries, and frequent checks are necessary to catch damage in the early stages so that prompt remedial measures can be taken. Fortunately, great strides have been made in recent years not only in the general knowledge of insects and their life histories but also in the development of new insecticides.

Various types of insecticides are available for control of insects. The stomach insecticides are

used for killing leaf feeders, especially larvae of moths, beetles, and sawflies. The chief inorganic stomach poison is arsenic in various forms, particularly as lead arsenate. There are also good organic forms of insecticides, such as derris, pyrethrum, and tobacco products. The newer organic chemicals such as DDT, chlordane, and benzene hexachloride act as stomach poisons and also as contact insecticides.

Contact insecticides, as the name implies, kill insects by contact and are chiefly used to control sucking insects. Among contact insecticides are nicotine sulfate, pyrethrum, lime sulfur, sulfur dust, oils and oil emulsions, DDT, chlordane, and benzene hexachloride.

White Grubs

White grubs are the larvae of the May beetle (*Phyllophaga* spp.) and related genera. They have killed over a million trees in a single season in individual nurseries. Damage caused by the grubs feeding on tree roots is especially serious in 1-0 and 2-1 trees. Virtually all of the conifers commonly grown in Lake States nurseries, and broadleaf species such as birches, ashes, and elms, are attacked.

In the Lake States, white grubs or larvae require several years to mature. Young grubs may be $\frac{1}{4}$ inch or less in length, and older grubs may be a full inch. Adults are thick, brownish beetles ranging from $\frac{3}{8}$ to 1 inch in length.

By far the most effective method of white grub control in forest nurseries is the application of 10 pounds of chlordane per acre in the form of 100 pounds of 10 percent dust. It should be applied with a potato or other power duster before seeding and then worked into the top 6 to 8 inches of soil by a rototiller or disk (145). Such treatment will prevent grub damage for about 4 or 5 years. In New York State nurseries, control of white grubs is obtained by use of paradichlorobenzene at 500 pounds per acre.¹⁹

Areas already occupied by seedlings or new transplants which are to remain in the ground for one or more growing seasons can be given an emergency treatment with 5 to 10 pounds of chlordane per acre. The chlordane is applied in emulsion form with a soil-injection kit with a sprayer, or through the overhead irrigation system, at dilutions of 1 to 1,000 or 1 to 1,500. Although such an emergency treatment is not completely effective, it will kill practically all of the smaller grubs and some of the larger ones. As soon as the trees are dug, the infested areas should be treated with a dust.

White grubs often are very abundant in sod areas or abandoned fields. If such areas are developed for nursery sites, the chlordane dust treatment should be used before seeding the first crop,

¹⁹ Personal communication from E. J. Eliason, Supervising Forester, New York State Conservation Department.

especially if counts show the grubs to be fairly numerous.

Aldrin and benzene hexachloride have been used effectively against white grubs. County Agents and State Agricultural Experiment Stations can provide the most recent recommendations on these chemicals.

Where vegetation such as oaks or aspens require protection from the leaf-feeding adult beetles, control can be attained by spraying such vegetation with 6 percent DDT or with lead arsenate at 4 pounds per 100 gallons of water.

In early control attempts, lead arsenate was used as a soil dust but often the poison caused heavy damage to trees, especially on sandy soils of low organic-matter content. Destruction of white grubs by rototilling once in June or July has given a 75-percent kill.

Ants

Ants may damage seedlings by injecting formic acid into them, burying them, harboring harmful aphids, cutting the leaves, or cutting them off.

Mound-building ants can be eliminated by applying 2 ounces of 50 percent wetttable chlordane powder for every 2 feet of mound diameter. The chlordane is best applied by first mixing each 2 ounces with 1 pound of sawdust or $\frac{1}{2}$ pound of dry sand as a carrier (141). An alternative is to punch holes in the mound with a broomstick and pour in carbon disulphide at the rate of 1 pound (or 1 pint) per 2 feet of mound diameter and plug the holes. The best time for treatment is late fall or early spring.

Ants can also be eliminated by using a poison bran bait made up with 2 pounds of sugar and 8 ounces of honey dissolved in 1 quart of boiling water, with 125 grams of sodium arsenate or 60 grams of thallium sulfate mixed into the syrup while hot. This is poured over and mixed with the bran, then scattered near the ant workings.

Strawberry Root Weevil

The strawberry root weevil (*Brachyrhinus ovatus*), sometimes called the conifer root weevil, is a pest not only on strawberry plants but also on numerous conifers, such as Norway spruce, ponderosa pine, white pine, red pine, jack pine, tamarack, Japanese larch, white-cedar, and white spruce (93). The adults are small, black beetles about a quarter inch or less in length. In the larval stage, they feed on the seedling roots, denuding them of their outer layers.

The heaviest damage often occurs in spring of the third year in the seedbeds. Turner (175) noted serious damage on 2-0 red pine by a girdle of the stem just below the ground line. Damage was worst on poor, dry, sandy areas. It is very probable that the preseedling chlordane-dust treatment of soil used for control of white grubs will also

check or largely eliminate damage from the root weevil.

For control in situations where the beetles have emerged, spray the foliage of infested trees with 1 pound of aldrin per 100 gallons of water (103). Dieldrin, heptachlor, or chlordane may be substituted for the aldrin.

The wingless adults have been controlled by spreading poison baits in the late afternoon as soon as the beetles begin to emerge in large numbers, making three applications a week apart. The bait may consist of 5 pounds of calcium arsenate dusted over 95 pounds of ground apple waste; or 20 pounds of bran, $\frac{1}{2}$ gallon molasses, 1 pound white arsenic, 3 ounces of oil of apples, and enough water to moisten the mixture (93).

Wireworms

Wireworms are the long, brown, so-called hard-shelled worms, usually with well-developed legs, that feed in the soil on small roots and other plant material. They are the larvae of the click beetles (Elateridae) which, when placed on their backs, flip into the air. Wireworm infestation can be reduced by keeping land free of weeds. Land not currently in tree production can be treated by pouring 1 ounce of carbon disulphide into holes 6 inches deep and 2 feet apart (172).

Grasshoppers

Grasshoppers have been troublesome pests since time immemorial. During drought years especially, they may strip the foliage from both broad-leaf and conifer nursery stock. Grasshoppers can be controlled with sprays, dusts, or baits.

Sprays may be made up of one of the following active ingredients per acre: $1\frac{1}{2}$ to 2 ounces aldrin, $\frac{1}{2}$ to 1 pound chlordane, or 1 to $1\frac{1}{2}$ pounds of toxaphene (110). If dusts are used, the above quantities should be increased by 50 percent. The lower dosages are used for young grasshoppers or where vegetation is short or sparse; otherwise, the heavier dosages are used. If the nursery stock is being damaged, it and a buffer strip 100 yards wide outside the nursery should be treated.

Other chemicals used in grasshopper control are methoxychlor, dieldrin, parathion, and dilan, but these should not be used unless specifically recommended by County Agents or the State Entomologist.

Emulsions and oil solutions are preferable to wettable powder sprays. Not more than 1 gallon of diluted oil solution is required per acre, using ground-spray equipment. Treatment is started when the young grasshoppers begin to move from their places of hatching.

Baits are made of bran or a bran-sawdust mixture, and for every 100 pounds of this material, one of the following active ingredients is used: 2 ounces aldrin, 8 ounces chlordane, or 1 pound

toxaphene. The wettable powder or emulsifiable concentrate is mixed in 10 to 12 gallons of water and then sprinkled slowly over the previously mixed batch of 25 pounds of bran and $3\frac{1}{2}$ bushels of sawdust (roughly 3 times the volume of bran). This bait is used at the rate of 20 pounds per acre, spread by hand or by a broadcasting machine. *Livestock should be kept away from baits and insecticides.*

Bark Aphids

White pine seedlings and transplants may be attacked by pine bark aphids (*Pineus* spp.), insects native to Europe. Usually, they are first noticed on the central stem and branches in the form of white to grayish-white masses of waxen wool that cover the larvae and adults. Bark lice, or woolly aphids as they are sometimes called, have been noted on balsam fir in the Northeast (88) and on red pine, Austrian pine, Scotch pine, and spruces (37). In the early spring, just before growth starts, these insects can be controlled by spraying with lime sulfur at 1 to 20 parts of water, miscible oils at 1 to 25 parts of water, or nicotine sulfate at 1 to 400 parts of water (88). This treatment will probably be effective on other bark aphids.

Spruce Gall Aphids

The spruce gall aphid (*Chermes abietis*) is a small, brownish insect from $\frac{1}{16}$ to $\frac{1}{8}$ inch long. It forms unsightly, reddish-brown galls $\frac{1}{2}$ to 1 inch long on Norway spruce or, sometimes, white spruce. The conelike galls are formed on twigs at the base of the current year's growth and are caused by activity of the female and of the nymphs.

Gall aphids generally are no problem in nurseries growing only seedlings or transplants, but they may attack larger ornamental stock or windbreak trees around the nursery. Spraying may be necessary to prevent disfigurement or even death of such trees.

Dormant sprays of 1 gallon of miscible oil to 20 gallons of water, or $16\frac{1}{2}$ pounds of powdered lime sulfur to 50 gallons of water, give good control. A summer spray of nicotine sulfate at 1 to 800 by volume in water with soap at 1 pound per 25 gallons of water also is effective (115).

Cutworms

Cutworms are larvae of night-flying moths (*Agrotis*, *Lycophotia*, *Euxoa*, *Septis* spp.). The larvae feed on roots of plants and at night may work above ground on the foliage or may cut off seedlings at the ground line.

In the late afternoon or evening, poison bran baits similar to those recommended for grasshoppers should be scattered thinly on the area where cutworm damage is starting. Dusts of DDT or chlordane also give effective control.

Red Spiders

There are a number of tiny spider mites (*Tetranychus* and *Paratetranychus* spp.), commonly called red spiders, which damage nursery stock as well as older trees by sucking the sap from leaves and tender stems. The insects are spread by wind currents, by infested nursery stock, and by crawling from plant to plant. Damage is especially heavy in dry, hot weather, and on trees of poor vigor. Frequent sprinkling with water will reduce damage. Injured leaves are very finely mottled and turn lighter green and finally brown. From a distance there is a bronze or brownish cast to the leaves or needles. Often there may be premature leaf drop in July. The adult mites usually are reddish in color except for the spruce mite which is dark green. Some species of the red spiders spin a web in summer for protection of young and eggs. Basswood, oaks, spruces, and hemlock commonly are attacked.

Red spiders can be controlled by spraying the nursery stock twice about a week apart with aramite or dimite (53), rotenone, tetraethyl pyrophosphate, or parathion. A good treatment consists of a spray made of 1 pound of cabinetmakers' or bill posters' glue in 10 gallons of water.

Scale Insects

Many genera of sucking insects known as scales (*Diaspis*, *Lecanium*, *Toumeyella*, *Pulvinaria*, *Chionaspis*, *Aspidiotus*, and *Physokermes*) attack elms, maples, basswood, birches, ashes, black locust, oaks, white-cedar, pines, spruces, and junipers. The insects are small, flat, and oval in shape, usually ranging from 1/16 to 3/16 inch in diameter. They fasten themselves to the undersides of leaves or to small stems. Scale attacks may be observed as small, white or gray, woolly dots, or by presence of shiny, smooth, half-shell shapes covered with a waxy coating.

Scale insects are controlled with contact insecticides applied either when the plants are dormant in spring or during the growing season. The following sprays may be used in the spring before growth starts: (1) 2 pints malathion (50 percent emulsifiable concentrate) in 100 gallons of water. (2) Lime sulfur at 12 pounds per 100 gallons of water, or at 5 gallons (liquid form) per 95 gallons of water (93). (3) Miscible oils or emulsions applied at about 1 gallon of miscible oil to 20 or 25 gallons of water when the temperature is above 40° F. Pressure should be ample to get good coverage of the leaves with the sprays.

The recommended summer spray for soft scales is 1 pint of 40 percent nicotine sulfate in 100 gallons of water with 4 pounds of ordinary laundry soap dissolved in it (111). Such a spray should be applied just after the insects hatch and before they have developed their protective, waxy cover. Re-

cently, good control has also been obtained with both DDT and malathion.

A spray used effectively on juniper scale is 3 pounds of 15 percent parathion per 100 gallons of water, or nursery Volck solution at 1 to 24 parts of water (102).

Tip-Boring Insects

Several insects that bore in the tips of pine and spruce trees may become a problem largely on windbreaks or natural trees in or near the nursery. Among these are the European pine shoot moth (*Rhyacionia buoliana*) and the native white pine weevil (*Pissodes strobi*). However, these insects seldom affect nursery stock.

Sawflies

Sawflies are heavy-bodied, wasplike insects, the females of which have a sawlike ovipositor on the abdomen. The larvae, or false caterpillars, usually are 1/2 to 1 inch long and defoliate pines and tamarack, and occasionally spruces, balsam fir, and northern white-cedar. The most important species in the Lake States belong to the genera *Diprion*, *Neodiprion*, and *Pristiphora*. The sawflies are most likely to be a pest in nursery windbreaks and hedges but may, on occasion, defoliate larger transplants or ornamentals.

The larvae are controlled readily by DDT, benzene hexachloride, or malathion. If infestation is very scattered, only the infected trees or spots need be sprayed. This can be done most effectively with a knapsack sprayer and an emulsion prepared from commercial emulsifiable concentrate containing 25 percent of DDT by weight; applications of 1 pint of the concentrate to 7 pints of water should be made at the rate of 20 to 25 gallons per acre (136). Larger areas may be treated by hydraulic sprayer, with 2 quarts of the concentrate in 99.5 gallons of water; the dosage should be 300 to 400 gallons per acre. When applied from aircraft, 1 pound of DDT (technical grade) in 1 gallon of oil solution per acre is also very effective.

A new development on control of the European pine sawfly (*Neodiprion sertifer*) is the use of a spray made up of a suspension of polyhedral virus in water. Bird (13) reports over 94-percent mortality of sawflies in a 50-acre Scotch pine plantation in southern Ontario within 21 days after spraying by aircraft, using 22 gallons of virus suspension containing 5 million polyhedra per milliliter. Skim-milk powder had been added to the suspension as a sticker. Essentially, the same results were obtained in smaller scale trials with 3-gallon, hand-pressure sprayers. Infestations of the European pine sawfly in the United States have also been controlled by airplane application of a spray containing this virus.

Pales Weevil

The pales weevil (*Hylobius pales*) is a reddish-brown to black snout beetle from $\frac{1}{4}$ to $\frac{3}{8}$ inch long. It emerges from the soil or from beneath stones in May and begins to feed. Its eggs are laid around July 1 in freshly cut pine logs or in large roots of freshly cut or burned stumps. The eggs hatch after several weeks and the grubs feed beneath the bark in July and August. They also feed in spring. The new generation of adults emerges in September and feeds until mid-October. It is during this period that damage may be done in adjoining nursery areas by their gnawing away the bark of seedlings at the ground line during the night. White and red pines and Norway spruce have been attacked by this insect. Hardwoods are injured only occasionally. As a control measure, Peirson (112) recommends that no pine land be used for nursery purposes until 3 years after it is cleared. On infested nursery stock, a spray of 0.25 percent benzene hexachloride is effective.

Blister Beetle

Adult blister beetles (*Macrobasis* spp., *Epicauta* spp., *Pomphopoea* spp.) sometimes defoliate nursery stock of black locust, Siberian peashrub, and other broadleaf trees and shrubs.

The beetles are of medium to large size, rather slender, and soft-bodied. They may vary in color from green, gray, and brown to black (37).

Control can be attained by dusting with 30 to 35 pounds of 10 percent chlordane powder per acre, or by spraying with $1\frac{1}{2}$ pounds of lead arsenate to 50 gallons of water.

Cottonwood and Willow Leaf Beetles

Cottonwoods and willows sometimes are defoliated in nurseries by leaf-eating beetles of such genera as *Chrysomela* and *Plagioderia*. The eggs of these beetles are laid in May or June and in about a week hatch out larvae that feed on foliage.

These insects can be controlled by spraying the nursery stock with 2 quarts of emulsifiable concentrate containing 25 percent DDT by weight in 99.5 gallons of water, or 4 pounds of lead arsenate per 100 gallons of water. Spraying should be done as soon as defoliation starts.

Red-Humped Caterpillar

The red-humped caterpillar (*Schizura concinna*) has defoliated butternut and black walnut in Wisconsin forest nurseries. Control of these and many other caterpillars, as well as the larvae of

the elm leaf beetle, may be attained by sprays containing 1 pound of DDT wettable powder or 4 pounds of lead arsenate per 100 gallons of water.

Nut Weevils

Larvae of certain snout beetles (*Curculio* spp.) often eat out the interior of acorns and destroy their viability. If freshly collected oak seeds are dumped in water, some of the poor ones float and can be discarded. The rest may be placed in a tight container for 24 to 48 hours with a cup holding carbon disulphide. Four fluid ounces of carbon disulphide will treat a 100-pound can of seed.

NEMATODES

Nematodes are tiny, threadlike, soil-inhabiting worms that injure roots of trees and weaken the plants. The soil may be treated with either methyl bromide at the rate of 1 pound per 100 square feet, ethylene dibromide at 25 gallons per acre, carbon disulphide, or chloropicrin, following the manufacturer's directions as to the method of treatment.

MECHANICAL INJURY

Mechanical injury, especially in cultivation, can cause considerable loss of young seedlings. Such damage can be reduced by (1) avoiding too early cultivation, (2) cutting down the number of drills from 10 to 6 or 7, (3) using shields to prevent excessive throwing and burial of soil from cultivation tools, and (4) obtaining uniform spacing in the rows while transplanting.

Considerable damage may also be done in hand weeding by pulling up trees along with the weeds. Such damage can be held to a minimum by removing the weeds when they are small, by the presowing application of chemicals to kill weed seeds, and by using mineral or white spirit sprays that largely eliminate hand weeding.

CHLOROSIS

Chlorosis (pale-colored foliage) reflects a number of unfavorable conditions such as alkaline soils or deficiencies of specific elements such as manganese or nitrogen. (See Soil Management section, p. 49.) By correcting these conditions, the chlorosis usually can be eliminated. For example, in several instances iron deficiency has been corrected within a week to 10 days by using a 1-percent foliage spray of ferrous sulfate and then avoiding washing it off the foliage (39).

INVENTORY

For proper management each nurseryman must know the number of trees in his nursery by kinds and classes. As it is normally impractical to make complete counts, some adequate sampling method must be employed.

Preliminary estimates, often needed for planning distribution of stocks, are generally made in late June or early July on first-year seedlings. A more intensive and more accurate inventory is made in late summer or fall, generally to obtain an estimate within 3 to 5 percent of the actual number of seedlings in the various lots.

The intensity of sample taken will be determined by the accuracy of count needed, the purpose of the inventory, the experience gained in past years through comparison of sample inventories with actual counts of trees shipped or lifted, and the amount of time and money the nursery has to devote to the inventory.

In many Lake States nurseries the sampling unit of inventory in seedbeds is a 4.0 by 0.5-foot narrow strip across the full width of the bed. The area is defined by a frame of wood, wire, or heavy tin with exact inside dimensions. The frame may have four steel pin legs which rest in the path or inside the bed, and which are pressed down, if necessary, to bring the frame's bottom well down into the seedlings.

The number of 4.0- by 0.5-foot sample counts that can be taken per 8-hour man-day, where seedlings average around 45 to 50 per square foot, is as follows:

Class of stock	Sample counts (number)
1-0	120-160
2-0	90-120
3-0	80-100

In transplant beds the sampling unit for machine-planted trees is generally a 6-foot-long section of an individual row. When transplanting is done across the bed with 4- to 6-foot-long transplant boards, the sampling unit is the individual row corresponding to the bed width. In counting transplants a 6-foot wooden pole (or one corresponding to bed width) with a long, thin nail or heavy 4-inch-long wire bent at right angles to the pole at each end will serve as a sampler.

In transplant inventory, the usual rate of counting where there are about 30 trees per 6 feet of row is 160 to 200 samples per 8-hour man-day. Transplants, because of their greater uniformity of spacing and per-unit-of-area stocking, require less intensive sampling for the same degree of accuracy than do seedbeds.

The cost of inventory then amounts to a few cents per thousand seedlings if the percent of sample is properly gaged to the overall totals in each specific lot of stock, class of stock, seed lot, or season of planting.

Nursery inventory tends to become a tedious task, and the nurseryman will want to select personnel who can count accurately and record the data carefully. He or a foreman may, on occasion, run an unexpected sample recount on one of the sampling units just after an entry is made and while the counting frame is still in place.

Seedbed counts can be made most advantageously by a 2-man crew, 1 man working each half (or approximately half) of the bed. This does away with having to jump across the bed. The surface of broadcast-sown beds inside of the 4.0- by 0.5-foot counting frame may have to be marked into smaller units to facilitate counts and avoid duplication or misses. A shallow mark scratched lengthwise down the approximate center of the counting strip, and 4 to 6 cross scratches made with a nail, increase accuracy of counts. Drill-sown beds are somewhat easier to inventory than broadcast-sown beds since the former are counted a drill at a time as the counter moves progressively across the bed.

Transplant inventory can be accomplished nicely by 1 man doing his own counting and tallying on sample transplant rows of 6-foot length or 4- or 5-foot bed width.

Most nurseries use a mimeographed form for recording inventories. One convenient form lists individual seedbeds and groups of 10 beds between pipelines according to their permanent numbers. It includes block or compartment, section (generally a 10-bed unit between pipelines), and bed (generally numbered from 1 to 10 going from west to east or from north to south). It also includes date of inventory, length of bed, and information on species, class of stock, seed source and lot, and percent of sample taken. Each sample is shown separately, and a calculation is made of total trees in each lot. Many nurserymen also find it convenient to record an estimate of percent of field-plantable trees or of those suitable for transplanting in the nursery, so that the total inventory may be realistically reduced by the estimated percent of cull.

Tables 33 and 34 are presented as a guide for inventory of nursery seedlings and transplants. These tables are so designed that the nurseryman has a choice of the sampling intensity he wishes to adopt, but the bold figures are suggested as

practical. It should be noted that the intensities of sample needed for nonuniform beds are considerably higher than for uniform beds to be within comparable limits of error. "Error," commonly referred to by statisticians as "standard error," implies that the correct value will lie within the range of the specified error, plus or minus, in 2 out of 3 trials. When these tables are used, the total linear footage of each lot should be the controlling factor. The total number of seedlings expected is merely a supplemental guide that assumes a certain average stand per square foot of normal bed.

Many nurserymen use 10 sample counts per 500-foot bed. This has considerable merit and, as seen in table 33, would in uniform seedbeds give estimates within 5 percent of error for any lot of stock of a total bed length of 1,000 feet or com-

prising about 180 thousand trees. However, for an individual bed of 500-foot length, 17 sample units would be needed to be within 5 percent accuracy.

As a matter of simplicity, most nurserymen adopt samples of 1, 2, 5, 10, 15, or 20 per bed. If only 1 or 2 samples are taken per bed, then the 10 or 20 samples per section (of 10 beds between pipelines) should be rather carefully distributed over the entire sampling area of 500 by 50 feet. This can be accomplished by selecting the 1 or 2 samples at random within each bed.

For a sampling intensity involving 5, 10, 15, or 20 units per bed, the location of the sampling plots could be determined by pacing. The interval between sample plots in each 500-foot bed would be 100, 50, 30, and 25 feet, respectively, for these sampling intensities. The pacing scheme is a

TABLE 33.—Number of counting plots required in inventory of nursery seedlings which will be within specified limits of error ¹

Number of beds	Total length of bed	Total number of trees expected ²	Samples required per bed when specified percent of error												
			In uniform bed is—						In nonuniform bed is—						
			0.5	1	2	3	5	10	1	2	3	5	10	15	20
	<i>Fl.</i>	<i>Thousands</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>
1	500	90				46	17	4				58	18	7	4
2	1,000	180			50	23	8	2				82	29	8	3
5	2,500	450			20	9	3					35	12	3	1
10	5,000	900			10	5	2				36	16	6	1	
20	10,000	1,800		20	5	2	1				18	8	3	1	
50	25,000	4,500		8	2	1					8	3	1		
100	50,000	9,000	17	4	1				14	4	1				
200	100,000	18,000	8	2	1				8	2	1				

¹ Samples are 4.0 by 0.5 feet taken across the bed. Bold figures represent total numbers of samples suggested as being feasible to take per bed of 500-foot length and still retain fairly good accuracy.

² Approximate only, with plants averaging about 90 per 4.0- by 0.5-foot counting plot, or 45 per square foot.

TABLE 34.—Number of counting plots required in inventory of nursery transplants which will be within specified limits of error ¹

Number of beds	Total length of bed	Total number of trees expected ²	Samples required per bed when specified percent of error												
			In uniform bed is—						In nonuniform bed is—						
			0.25	0.5	1	2	3	5	0.25	0.5	1	2	3	5	10
	<i>Fl.</i>	<i>Thousands</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>
1	500	18			18	4	2	1				47	21	8	2
2	1,000	36			9	2	1					24	10	4	1
5	2,500	90		14	4	1						36	9	4	1
10	5,000	180		7	1							19	5	2	1
20	10,000	360	14	4	1							9	2	1	
50	25,000	900	6	1						15	4	1			
100	50,000	1,800	3	1						8	2	1			
200	100,000	3,600	2	1						15	4	1			

¹ Samples are 6-foot-long sections of individual rows. Bold figures represent total numbers of samples suggested as being feasible to take per bed of 500-foot length and still retain fairly good accuracy.

² Approximate only, with trees averaging about 31 per 6-foot counting plot, or about 9 per square foot of bed.

departure from strictly random sampling, but since pace length is likely to vary somewhat the net pattern of sample distribution would be as good as a random scatter.

Some nurserymen rely solely on bed inventory estimates for the larger orders of stock, totaling around 100 thousand trees or more. Should an estimate, accurate within 3 percent, be desired on such an order, some 46 sampling units would be required, provided the seedbeds are uniform. For small shipments of only a few thousand trees, a 100-percent count of the trees must be made after digging.

It will be noted that table 33 assumes that at least 1 sample is taken in *each* 500-foot-long bed. The table will probably serve nurserymen most usefully by giving them an idea of how small a sample is required for larger lots of stock, that is, those involving 1.8 million trees or more. For such lots as few as 1 or 2 samples per bed will usually give an accuracy of within 3 percent in uniform beds; about 3 sampling units are needed to be within 5 percent accuracy in nonuniform beds.

In the above examples, the uniform beds were 1-0 red pine sown to get about 50 trees per square foot and which actually averaged 45.0 per square foot. The nonuniform beds were 2-0 red pine which were sown to get about 50 trees per square foot but, due to unusual losses from wind and heavy rain which flooded the beds, they averaged only 16.5 trees per square foot.

Table 34 is based on 6-foot-long sampling units from individual rows. The trees were planted mechanically with a Holland transplanter in 7 rows per 4-foot-wide bed, with the rows running lengthwise of the bed. The uniform beds averaged 30.6 surviving plants per 6-foot counting plot; the less uniform beds averaged 28.7 surviving trees.

Table 34 shows the number of such sampling units to take at random in the nursery inventory of transplants. If a nurseryman had 50 beds, each 500 feet long, all of them containing about 900 thousand trees, the average stand computed on the basis of 1 sample 6-foot-row count taken at random in each of the 50 beds would, on the basis of the sample study made here, give an overall estimate of within 0.5 percent. In the nonuni-

form beds, it would require 15 samples per bed to obtain the same accuracy, or 4 samples per bed to obtain a 1.0 percent standard error for the entire lot of 50 beds.

It should be kept in mind that each individual seeding must be sampled, such as a seed source, age of stock, species, year of collection of seed, and season of sowing or transplanting if these are causes of variation in the average stand per square foot, as is likely to be the case.

For instance, if a nurseryman had 50 beds of nonuniform 1-0 white spruce and 20 beds of uniform 2-0 red pine and wanted an estimate on each lot within 2 percent, he would need to make 8 counts in each bed of the white spruce or a total of 400, and 5 counts in each bed of red pine or a total of 100 counts (table 33). The total in any one lot of trees is then calculated by multiplying the total square footage of seedlings by the average stand per square foot as derived from the average of all frames.

For transplants, the total linear footage of individual rows is sometimes used as the basis for calculation. If square feet of net bed area is used for transplants, figuring a bed as 4 by 500 feet, or 2,000 square feet, each individual 6-foot-long counting row accounts for 3.43 square feet of bed. The net plantable number of trees is calculated by reducing the total by the cull percent, which is usually made by the nurseryman himself from experience as tempered by actual dug samples. Usually, 10 to 20 samples are the maximum that would be taken in any one lot of stock for estimate of cull percent. In larger transplants, such as 2-2, the cull percent should be so low that no dug samples are necessary for cull estimate.

For inventory of large or uniform lots where less accurate estimates are needed than those obtained by taking one sampling unit per bed, the percent of error when taking the single sample in every other bed can be estimated by doubling the percent of error given in tables 33 and 34. If every third bed is sampled with one counting plot, the percent of error in the tables should be multiplied by about 2.5. If only every fourth bed is sampled by one counting plot, the percent of error will then be about three times that shown in the tables.

LIFTING, GRADING, AND PACKING OF NURSERY STOCK

When nursery stock is ready to be outplanted or sold, it represents all of the costs, direct and indirect, that have accrued over a period of years in producing it. It is important, therefore, that the digging, pulling, and packing of the trees be supervised closely so that the investment can be liquidated fully.²⁰

Nurseries making shipments of many small lots of 1,000 to 5,000 trees involving a number of species have a complex tree-distribution problem compared to those that distribute larger lots and handle only a few species and classes of stock. In U. S. Forest Service nurseries of the Lake States, stock is produced exclusively for planting on national-forest lands. Consequently, there is no need for making an accurate count of the trees or to put the stock up in small bundles. Usually, the inventory by individual seedbeds is a good basis for estimating how many linear feet of bed must be dug for specific orders of trees.

State or private nurseries, which must provide an accurate count of the trees for the many small orders filled, invariably put trees in tied bunches of 20, 25, 50, or 100 at the time of packing.

DIGGING

For a small nursery, stock can be dug for shipment fairly cheaply with a spade or a fork. For large nurseries, however, mechanical devices for digging stock are indispensable. Besides greatly reducing the digging costs, a better job of loosening the soil to facilitate pulling the stock can be accomplished with a tree digger than by hand methods (see page 37 for description of tree lifters and page 79 for details of lifting stock).

An agitator-type mechanical lifter was devised in 1952 by R. O. Sowash while superintendent of the Eveleth Nursery in Minnesota. It differs from the standard lifter in that a crankshaft with eccentrics is mounted below the tines or shakers. The crankshaft is run at about 900 rotations per minute from a 2-hp. gasoline engine mounted forward on the tree lifter. The agitating effect of the eccentrics on the shakers has a loosening effect on the soil, leaves the roots standing upright in the loose soil with none of them exposed, and permits more rapid pulling of the trees without root injury.

²⁰ Stock of some species grown in the southern part of the Lake States region may suffer injury or death if the roots are exposed to freezing during handling, shipment, or storage. The species most susceptible to such injury probably is black locust.

The lifter itself was pulled by a 40-hp. caterpillar-type tractor.

In New York and Pennsylvania State nurseries, 2-row potato diggers are used to lift and shake soil from small trees, according to E. J. Eliason of the New York State Department of Conservation. These diggers are wide enough to lift a 4-foot bed, or an equivalent width of transplant rows.

PULLING

It is important that the pulling crew be thoroughly trained so as to insure a minimum of injury to the seedlings. A description of their work is given in the section Lifting Stock for Transplanting, p. 79.

The practices used in caring for the stock as it is removed from the beds vary with the class of stock, the amount of culling required, and how and where the stock is packed for shipment. In larger Lake States nurseries, the plants are gathered in small boxes and taken to a central point where they are packed in crates or bundles for shipment. Each puller fills his own box. (Boxes are 26 inches long, 17½ inches wide, and 8½ inches deep.) As the trees are pulled and sorted they are placed in the box in layers between pieces of moist burlap to protect them from drying out.

If the percentage of cull trees is negligible, the culling can usually be done in the field at the time the trees are pulled. The trees are spread out loosely in the shade of the puller's body and rapidly examined for undersized, mechanically injured, and diseased plants. These are discarded and the acceptable plants placed in pickup boxes (fig. 54).

Where the percentage of cull plants is relatively high, or the trees must be counted and tied in small bunches, it ordinarily is more satisfactory to do the culling and tying in a building equipped for this purpose. Culling tables of various types have been tried in U. S. Forest Service nurseries with varying degrees of success.

Some nurserymen have found culling tables equipped with endless belts very effective (fig. 55), especially where an accurate count of the plants is necessary (172). When used as a device for counting trees, the belt is divided into a given number of units or spaces—usually 50—and the spaces numbered from 1 to 5, depending upon the number of workers assigned to placing trees on the belt. As the belt travels along, a certain number of plants—usually 2—are placed in each



FIGURE 54.—Pulling red pine seedling stock for transplanting. Each puller culls and packs his own box of trees. (Chittenden Nursery, Wellston, Mich.)



F-473837

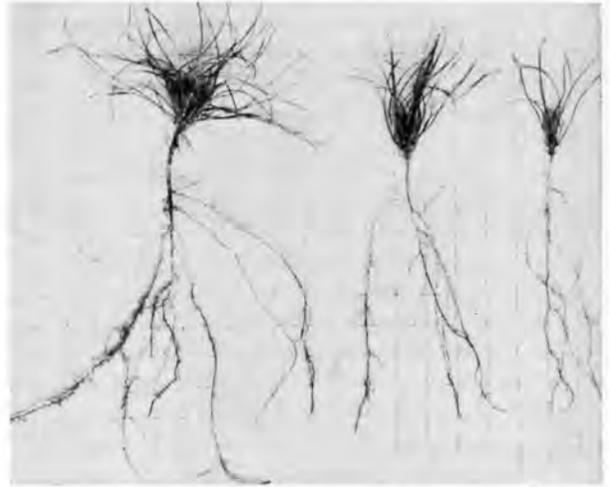
FIGURE 55.—Culling or grading table with endless belt.

space. Thus, an accurate count of 100 trees is obtained.

Where culling and counting is done under shelter, the trees should be kept moist with wet burlap or other media during sorting. Undue exposure of the roots impairs the vitality of the plant and reduces its chances of surviving when planted in the field.

GRADING

In any lot of nursery stock there usually are some trees not suitable for field planting or nursery transplanting because they have been damaged or are too small (149). Such stock is sorted out and discarded. In seedling stock, the bulk of the discards is likely to be very small plants of low vigor (fig. 56). The percent discarded may range from 5 to 20 percent, and occasionally more. In



F-345916

FIGURE 56.—Samples of 3 grades of 2-0 red pine stock designated as large, medium, and small, used in field survival test of graded stock. At end of 2 drought years in the field, the average field survivals of the 3 classes of stock were 44.1, 36.5, and 29.1, respectively. Least significant mean differences between these 3 values are 7.6 at 5-percent level, and 11.0 at 1-percent level, indicating definite advantage for larger stock. (Background is 1-inch squares.)

transplants, the percent of discards or culls should seldom be more than 1 to 3 percent. In fact, no culling need be done with transplants except for an occasional tree that is root-stripped or split.

Tables 35 and 36, which are based on general experience in the Lake States and supplemented by a number of nursery and field experiments, provide a guide for grading nursery stock. Caliper is the chief criterion because it reflects relative size and, usually, sturdiness. The goal should be production of premium grades of stock. Premium grades are those that are well balanced and exceed the indicated seedling or first-year transplant caliper specifications by $\frac{3}{64}$ inch or more and the second-year transplant specifications by $\frac{3}{64}$ inch or more.

Culling out of undersized trees is done by ocular estimate of minimum specification. Barton (5) devised a simple training aid for workers for grading trees. It consists of a welding rod 13 inches long and $\frac{1}{8}$ inch thick, with two 2-inch-long pieces welded at right angles across the top at 4 inches (or minimum top length) from the top end. The intervening $\frac{1}{8}$ -inch space between the cross rods acts as a caliper gage. Acceptability of top length is judged by whether the seedling has a 4-inch-long top. Another 2-inch-long crosspiece is welded 1 inch above the bottom of the long rod to give an 8-inch interval between the 2 sets of horizontal 2-inch-long crosspieces. The 8-inch length is for checking acceptable root length of field planting stock.

Balance is based on the ratio of weight of top to weight of root (146). For Lake States conifers, top-root ratios, on a green weight basis, of less than 3:1 are considered very good; those around

TABLE 35.—Minimum specifications for stock for nursery transplanting¹

Species and age class (years)	Period to be left in nursery as transplants	Minimum caliper at ground level	Minimum top length to tip of terminal bud	Estimated usual cull of seedling stock
	<i>Years</i>	<i>1/64 inch</i>	<i>Inches</i>	<i>Percent</i>
Jack pine:				
1-0	1	4	1.5	15
Red pine:				
2-0	1	4	2.0	15
2-0	2	3	1.5	10
1-0	2	2	1.0	15
White pine:				
2-0	1	4	2.0	10
2-0	2	3	1.5	5
1-0	1	3	1.5	5
1-0	2	2	1.0	2
White spruce:				
2-0	1	4	2.0	20
2-0	2	3	1.5	15
3-0	1	4	2.5	10
3-0	2	4	2.5	10

¹ Minimum root length permissible is 3 inches if well branched, or 4 inches for the usual run of stock.

4:1 are fairly good; at 5:1 the trees are considered rather topheavy, and at 6:1 very topheavy (160). The last two groups are likely to suffer severe losses from drought, heat, and competition with other plants, or from overwinter losses in fall plantings. Good balance is largely attained in Lake States nurseries by use of transplant stock, by avoiding leaving the seedlings too long in the seedbed, and by using low densities in the seedbeds.

Not much information is available as a guide for grading hardwoods. Generally, broadleaf species should have a minimum stem caliper of 1/64 inch at the ground line to give good field survival for 2-0 stock and 1/64 inch for 3-0 stock (table 37). At reasonable densities of about 10 plants per square foot of bed, or per linear foot of drill (spaced at least 9 inches apart), the cull percent in discarded stock should not be over 15 or 20 percent, and often may not be over 10 percent.

TABLE 37.—Field survival and growth of planted hardwood species as affected by nursery grades based on size

Species and nursery grade	Top length	Root length	Fresh weight per tree	Stem diameter at ground line	First-year field survival			First-year height in field
					Good vigor	Poor vigor	Total	
	<i>Inches</i>	<i>Inches</i>	<i>Grams</i>	<i>1/64 inch</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Feet</i>
3-0 yellow birch:								
Large	34.3	11.2	47.8	26	92	6	98	2.0
Medium	19.9	9.7	9.5	15	94	6	100	1.1
Small	12.5	6.7	2.4	8	70	18	88	.5
3-0 paper birch:								
Large	43.9		59.9	26	98	1	99	2.8
Medium	30.6		19.3	19	94	6	100	2.2
Small	15.7		2.6	9	70	18	88	1.3

TABLE 36.—Minimum specifications for stock for field planting¹

Species and age class (years)	Minimum caliper at ground level	Minimum top length to tip of terminal bud	Estimated usual cull
	<i>1/64 inch</i>	<i>Inches</i>	<i>Percent</i>
Jack pine:			
1-0	5	2.50	30
1 1/2-0	5	2.75	20
1-1	6	2.50	3
2-0	5	3.00	15
Red pine:			
2-0	5	2.50	20
3-0	6	3.00	15
2-1	5	2.25	5
1-2	6	2.75	2
2-2	8	4.00	2
White pine:			
2-0	5	2.25	20
3-0	6	4.00	10
1-1	5	2.25	10
2-1	6	2.50	5
1-2	6	2.50	2
2-2	6	3.00	2
White spruce:			
3-0	6	3.00	30
2-1	6	3.00	15
3-1	6	3.00	10
2-2	6	3.50	2
Black spruce:			
2-0	5	2.75	20
3-0	6	3.50	10
2-1	6	3.00	10
2-2	6	3.50	2

¹ Minimum root length is 5 inches for well-branched, fibrous root system; for the usual run of stock, 6 inches or more of root length is satisfactory.

PRUNING

The mechanical devices customarily used for digging trees can be adjusted to sever the taproot at the proper point, but they do not cut the shallower lateral roots. Since many of the lateral roots exceed the length required for field planting stock, it usually is necessary to do a small amount of root pruning. This operation ordinarily is performed at the time the trees are being packed for shipment.

For pruning roots of excessive length, a number of tools and devices have been tried, including large paper trimmers, shears, and rotary pruners run by electric motor. A cleaver, used with a hardwood block, has proved to be an effective tool for root pruning conifers (101). The device has a straight blade made of $\frac{3}{8}$ -inch-thick sheet steel with dimensions of 12 by 6 inches. Its cutting edge is straight. The sheet is fitted into a handle 18 inches long and fastened with 3 machine bolts $\frac{1}{4}$ by $1\frac{1}{4}$ inches with a $\frac{5}{8}$ -inch head.

The plants are assembled in small bunches, placed on the wooden block, and the roots cut with a downward stroke of the cleaver. To insure a uniform job, experienced workers should be assigned to this work. Seedlings with roots pruned too short are apt to succumb to drought conditions when planted, and if the roots are too long the seedlings are difficult to plant properly. Under most conditions in the Lake States, a root length of 8 inches is satisfactory.

PACKING

Since the manner in which the plants are packed for shipment influences the length of time they can safely be kept in storage and the condition of the trees when received at the planting site, the packing should be done by experienced and thoroughly reliable workers.

Packing can be done more economically in the nursery. Therefore, it is standard practice at U. S. Forest Service nurseries in the Lake States to pack in the field. One or more portable packing shelters, convenient to water and transportation facilities, are placed on the area from which the stock is to be dug. Each shelter is provided with at least one large barrel for soaking the packing

medium. The shelter is large enough to accommodate two tree balers or an equal number of crates, and a supply of pickup boxes as they are brought in from the field filled with trees. An 8- by 10-foot unit, with a 7-foot back wall and a 9-foot front wall, constructed of 2- by 4-inch material, well braced, makes a satisfactory shelter (fig. 57). Canvas is used to cover the top and enclose two sides to protect the trees from drying out during packing.

State nurseries that pack relatively large numbers of small orders usually find it advantageous to do their packing indoors, using a well-spaced layout of tables on which the trees can be packed and tagged for shipment in orderly fashion. A 1- or 2-days' supply of recently dug trees of various species and age classes, or a reserve in cold storage enables them to fill orders during inclement weather.

The type of container in which the trees are packed depends to some extent upon the species of stock, size of the shipment, method of transportation, and distance the trees are to be transported. Conifers are packed in either bundles or crates, but hardwoods usually are packed in bundles. For shipment to nearby areas on the national forests, crates often are used (fig. 58). For long-distance shipping either by truck or rail, where excess weight or the extra cost of returning crates to the nursery is a factor, the stock is packed in bundles or bales. The weight of bundles is negligible compared to the 30-pound weight of crates. Either method requires about the same amount of sphagnum moss or shingle tow (shavings from shingle manufacture) for packing.

The State nurseries in the region prefer to bundle the trees in asphalt-impregnated paper or burlap-backed paper and tie them with stout cord.

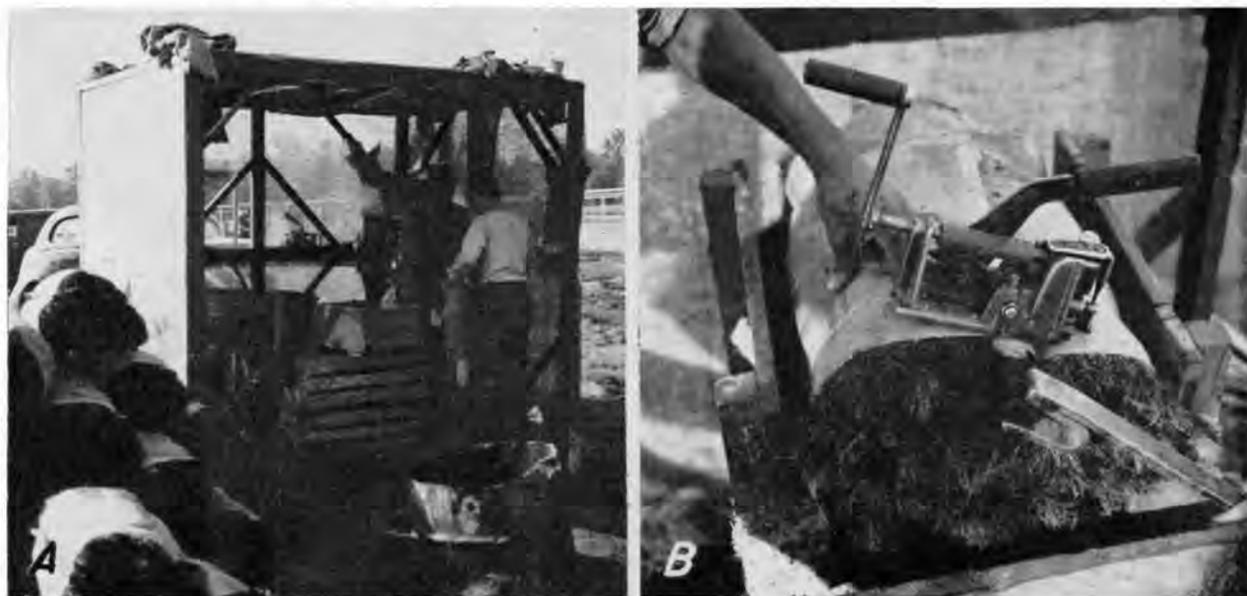


FIGURE 57.—A, Packing shelter. Two men pack and bale the seedlings. Bales of packed seedlings are ready to be hauled to the cold storage plant until needed in the field. B, Closeup of baler and tying machine. Notice iron bar used to twist slat and to draw burlap tight around bundle. (Chittenden Nursery, Wellston, Mich.)

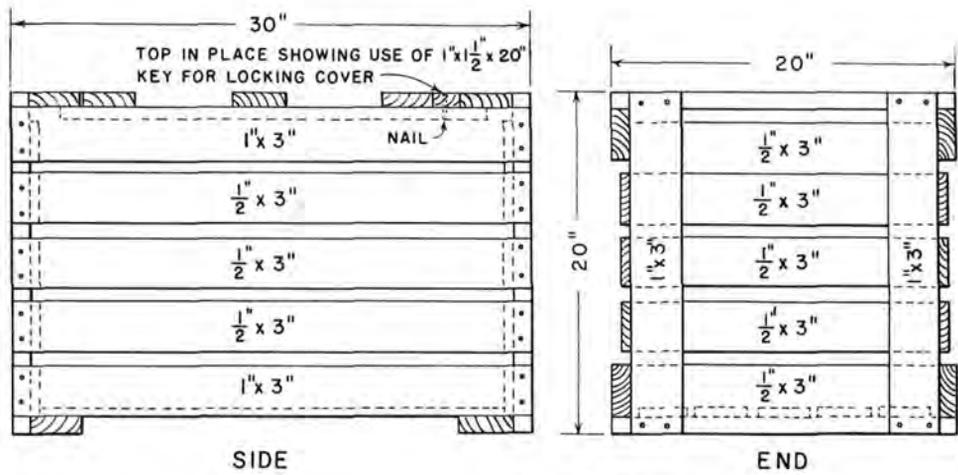
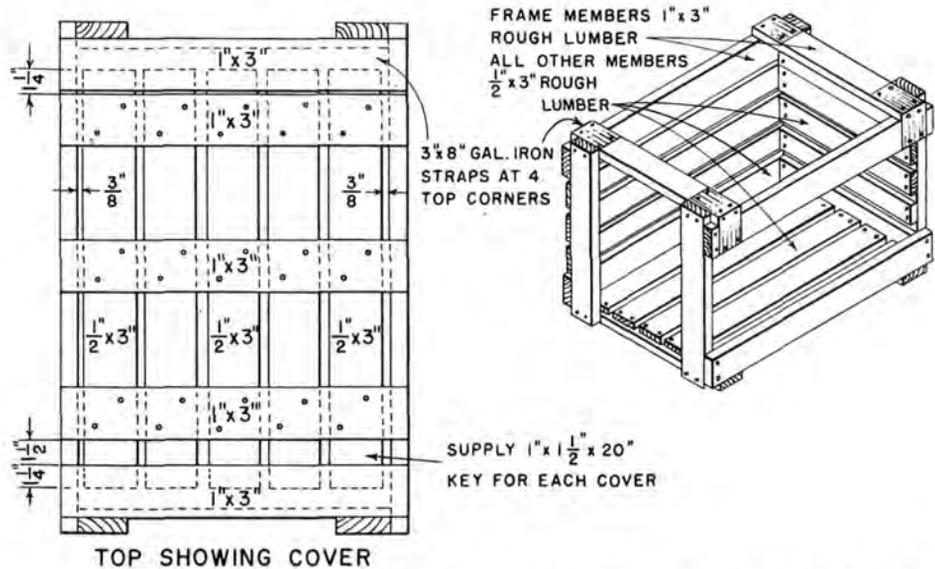


FIGURE 58.—Details of shipping crate construction.



Data from one Lake States nursery show that about 100 bales, each of 60 pounds, or a total of 600,000 pine trees, can be loaded on a truck (97).

When crates are used, they are usually lined with burlap. (Some nurseries prefer a lettuce crate with a paper liner, said to be somewhat less subject to molding.) The burlap prevents the loss of packing material while the stock is in transit. It should be of a size to cover the bottom of the crate, the two sides, and lap over the top. A layer of moist packing material is placed on the burlap in the bottom of the crate, then a layer of trees, with the roots to the center and slightly overlapping. Alternate layers of trees and packing material are built up until the crate is full.

While the crate is being filled, packing material is wedged between the roots and the sides of the crate. A mosser will facilitate this work (fig. 59). Two mossers are inserted, one on each side of the crate, and moss is pushed down into each in a layer. After the crate has been filled with alternate layers of trees and moss, the mossers are pulled out, leaving a uniform layer of moss on two sides of the

crate. The trees should be packed tightly with the top layer extending above the top of the crate. When the crate is full, the loose ends of the burlap are brought together over the top layer of moss or shingle tow and the lid of the crate forced into place.

Four layers of moss, including the bottom and top and two equally spaced intermediate layers of packing material, have proved adequate for the average size crate. Each layer should be 2 to 3 inches thick and thoroughly moist when placed in the crate. Moist material about the needles reduces aeration and transpiration and impairs the keeping quality of the trees while in the container.

In preparing a bundle or bale of trees, 2 pieces of 13-gauge, galvanized tie wire 66 inches long are first placed in proper position in the tree baler (fig. 60) with the ends of the wires bent down over the front and back. Two 1-by-2-by-24-inch wooden strips are then placed in position on top of the wires. A 20-by-60-inch piece of burlap is placed over the wires and wooden strips with the ends drooped

over the front and back. A layer of wet packing material is then spread out on the burlap followed by a layer of trees in a double tier, with roots to the center and slightly overlapping. Alternate layers of packing material and trees are added until the baler is full. Special care is necessary to work packing material between the roots of the trees and the burlap to insure a complete and unbroken layer about the trees when the packing is finished and the bale is bound together.

When the baler is full, the 2 ends of the burlap are brought together and wrapped around a third 1- by 2- by 24-inch wooden strip. A special tool or wrench is placed on one end of the strip and the strip is twisted and the burlap drawn up tightly. After the burlap is tight, the operator holds the tension on the wrench by throwing his leg over the handle or secures it by holding it with a lock attached to the frame of the baler. The loose ends of one wire are then brought together and inserted into the proper notches of the tying machine and drawn tight by turning the handle on the machine. The second wire is handled in the same manner, and the bale is completed.

Wales (184) states that the cost per M for packing trees was 18 cents when using the Olson baler along with the Girard wire-tying machine as compared to 27.7 cents when using regulation crates. In some nurseries, $\frac{3}{8}$ -inch steel strapping has supplanted wire ties.

Crates or bales of trees should not be stacked closely or left unprotected in the field for prolonged periods. Stock that is to be held several days at the nursery should be placed in cold storage at 34° to 40° F.

In the Lake States, several kinds of material are used for packing. Sphagnum moss and shingle tow have been used extensively with equally good results. Although sphagnum moss has greater moisture-holding capacity than shingle tow, it tends to cause heating in the bales or crates more readily than shingle tow unless it is precured. The green moss also compacts tightly and reduces aeration within the container. Where moss is gathered locally, it should be collected early enough so that it can cure 3 or 4 months.

The moisture-holding capacity of shingle tow is greatly increased after the wood fibers are broken down. Consequently, old material is better than new or freshly cut material. Storing it out of doors will hasten deterioration. Because shingle tow absorbs moisture slowly, it should be soaked in water for a considerable time prior to its use.

A mixture of sphagnum moss and shingle tow of equal proportions has good moisture-holding capacity and provides adequate aeration for stock packed either in crates or bales. Some nursery-

men have also used partially decomposed peat very effectively as a packing material. Peat usually is lumpy when dug from the bog and its physical condition can be greatly improved if it is put through a shredder.

SHIPPING WEIGHT OF TREES

The shipping weight of nursery stock varies according to species, age classes, and methods of packing (table 38). Younger classes of stock also occupy less space per thousand trees. For example, when packed in bales, 6,000 2-0 red pines have about the same volume as 3,000 3-0 trees or 2,000 2-2 trees. Stock packed in bales usually weighs about 13 to 30 pounds less per thousand trees than that packed in crates:

	Jack pine (2-0)	Red pine (2-1)	White pine (2-2)
Bale:			
Trees.....number	2,325	1,551	734
Weight per bale...pounds	83	87	113
Weight per M trees...pounds	36	56	154
Crates:			
Trees.....number	2,816	1,781	991
Weight per crate...pounds	156	153	166
Weight per M trees...pounds	55	86	167

TABLE 38.—Approximate shipping weight per thousand trees of nursery-grown forest planting stock packed in shingle tow and sphagnum moss and wrapped in heavy paper¹

Species	Age	Packaged weight per thousand trees	
		Years	Pounds
Fir, balsam.....	3		50
Do.....	4		70
Pine, jack.....	2		50
Pine, red (Norway).....	2		50
Do.....	3		75
Do.....	4		100
Pine, white.....	2		40
Do.....	3		60
Do.....	4		90
Redcedar, eastern.....	3		65
Do.....	4		90
Spruce, Norway.....	3		60
Do.....	4		80
Spruce, white.....	3		50
Do.....	4		70
Ash, white.....	1		50
Do.....	2		70
Locust, black.....	1		50
Oak, red.....	1		50
Walnut, black.....	1		60

¹ Information supplied by Wisconsin Conservation Department.

STORAGE AND SHIPMENT OF NURSERY STOCK

Scheduling of operations at the nursery to make the best use of available labor often is difficult. The problem is likely to be most acute at the time stock is being lifted and new beds sown. Unexpected delays also may be encountered after stock has been delivered to a planting area. Therefore, means of storing stock without deterioration are necessary.

Broadleaf species can be dug in the fall, counted, and heeled-in in trenches until spring without suffering ill effects. Conifers, however, cannot be heeled-in over winter without severe loss. Hence, the lifting of conifers must be delayed until spring, and if stock is to be held for some time before transplanting or shipment it must be placed in cold storage. For limited storage of several days to a week in the spring, conifer stock can be heeled-in in a cool shaded area. The soil must be moist and thin layers of stock must be used. Cold storage or a cool cellar are preferred even for this limited period. Cold storage is

also a means of providing a reserve supply of stock for keeping nursery labor busy at such tasks as grading or packing during periods of inclement weather.

Preferred storage temperatures in the range of 34° to 40° F. can be maintained with mechanical refrigeration or the use of ice. When a refrigeration unit is used, it must be so planned that it will operate well when several hundred thousand or more trees are in storage. If ice is used, the stock is placed in layers on shelves or racks with the tops of the seedlings to the outside and the roots slightly overlapped to the inside where they are packed in iced moss or shingle tow. Chunks of ice are then placed on top of the packing medium.

Since the temperature inside tightly packed bundles or crates of trees may be 10 to 20 degrees warmer than that of the chamber at the beginning of storage, molding and rotting of roots or tops may occur unless certain precautions are

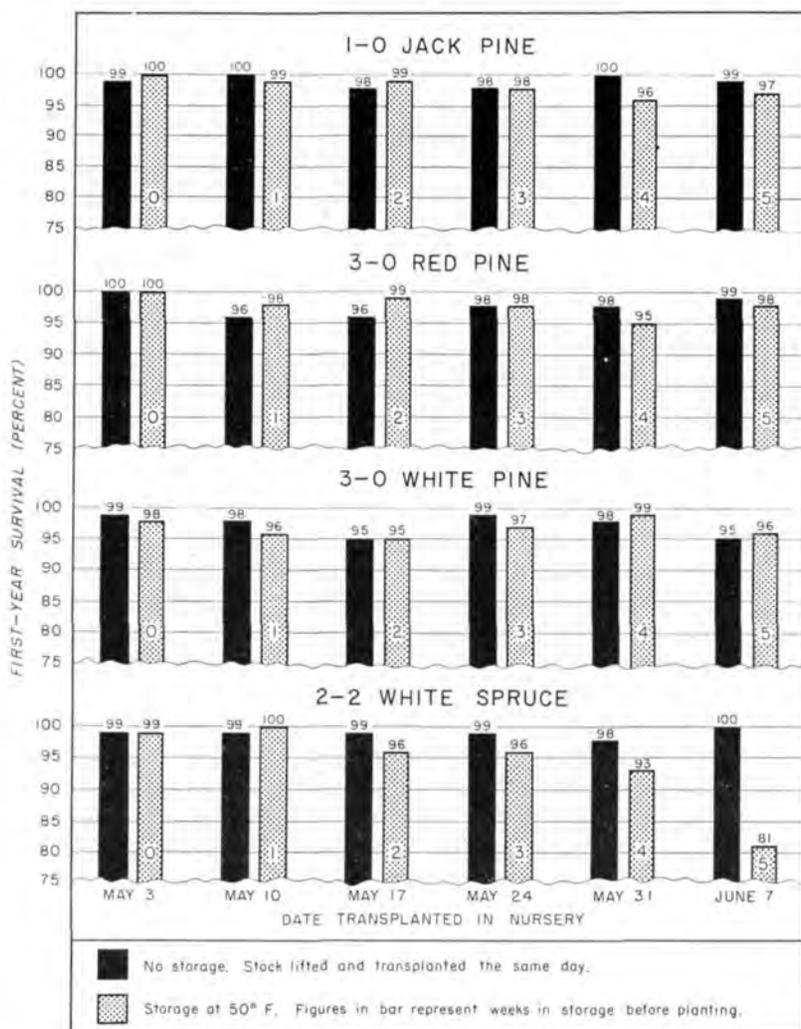


FIGURE 61.—Comparison of first-year nursery survival of four species of conifer stock in a cold storage experiment. (Hugo Sauer Nursery, Rhineland, Wis.)

taken in packing. The stock should be packed in the shade, and cold packing materials and cold water used. Cakes of ice dropped into the barrels containing sphagnum moss and water will lower the temperature satisfactorily. Stock in storage is watered once a week. Watering is facilitated by a small metal tube, attached to a hose, which is thrust halfway into the bales or crates to get water to the moss and roots.

An experiment on effect of storage on survival and growth of coniferous nursery stock was run in 1938 at Hugo Sauer Nursery at Rhinelander, Wis. Representative lots of 1-0 jack pine, 3-0 red pine, 3-0 white pine, and 2-2 white spruce were lifted on May 3 and stored in accordance with usual practice at that time. The stock was packed in crates and placed in a refrigerated room. Air temperatures before May 15 were generally at or below 50° F., with an absolute minimum of 38°. After May 15 they occasionally reached 60° to 65° for periods of several hours because of more frequent use of the cold storage facilities and larger amount of stock in refrigeration, which therefore threw a heavier load on the refrigeration unit. Temperatures in the root zone, of course, fluctuated much less than the air temperature.

Trees were taken from the stored lots and transplanted at weekly intervals beginning May 10 and ending June 7. Similar lots were lifted from the nursery beds and transplanted at the same dates for comparison.

First-year survivals indicated very little difference between stored or unstored stock of 3 pine species in a 5-week period (fig. 61). White spruce, however, showed a considerable drop in survival for stock held in storage for 5 weeks. The lot lifted in the nursery and planted on the same day (June 7) gave 100-percent survival. The results for 5 weeks' storage were significantly poorer in an analysis of variance than for shorter storage periods. The results of this test provide some guide as to the safe maximum period of storage under conditions of limited temperature control.

Nursery survival alone is not a complete criterion of the effect of prolonged storage; one of the most serious effects is the loss of growth of the trees. Nursery stock stored for 5 weeks was distinctly smaller at the end of the first season after transplanting than the stock stored for shorter periods. Comparing the size of stock at the end of the first season in the nursery, the reduction in weight of stored versus unstored trees was 42 percent for the jack pine, 28 percent for white spruce, and 20 percent each for red and white pines (fig. 62). The difference is attributed mostly to the fact that the unstored stock had a 5-week longer growing period, largely in May, which is one of the most favorable months.

Stock lifted directly from the seedbeds and transplanted the same day survived very well for all plantings made from May 3 to June 7, but

the early season transplantings produced somewhat larger stock of better color than the later transplantings. For example, the stock lifted and transplanted on June 7 was lower in weight than that transplanted on May 3 by 35, 18, 8, and 3 percent respectively for jack pine, red pine, white pine, and white spruce. Color difference in foliage was especially striking in case of white spruce; here the percent of stock with light yellow-green foliage (perhaps indicating a nitrogen deficiency) in September 1938 was 12.3, 16.0, 33.0, 44.3, 52.3, and 71.7 percent, respectively, for unstored stock transplanted May 3, 10, 17, 24, 31, and June 7, respectively. Such yellowing can, of course, be offset to some extent with liquid fertilizers.

In a second series of the experiment started 2 weeks earlier, representative lots of jack pine,



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FIGURE 62.—A, Decrease in size of 3-1 red pine from late transplanting. From left to right, trees were lifted and transplanted on the same date at weekly intervals on May 3, 10, 17, 24, 31, and June 7. B, Decrease in size from prolonged storage and progressively late transplanting of 1-1 jack pine. From left to right, trees were transplanted on May 3, 10, 17, 24, 31, and June 7, and had respectively 0, 1, 2, 3, 4, and 5 weeks in storage prior to transplanting. All trees were lifted on May 3. (Hugo Sauer Nursery, Rhinelander, Wis. Background is 1-inch squares.)

red pine, white pine, and white spruce were dug at 1-week intervals beginning April 19 and ending May 24, thus giving a range of storage intervals of 0, 1, 2, 3, 4, and 5 weeks. All trees were field planted on May 25. Survival counts made at the end of the first year indicated that survivals were generally quite satisfactory even with 5 weeks of storage (fig. 63). However, 1 lot stored for a 4-week period showed a significant 10-percent reduction in survival for jack pine, red pine, and white spruce. The only explanation for the poorer survival is that the trees were just breaking dormancy on the date of lifting (April 26) and may have been particularly sensitive at that stage.

Based on these tests and experience in regular nursery operations, storage can be recommended for conifer nursery stock for periods as long as 5 weeks. The loss in size of stock caused by prolonged storage is most serious for 2-0 red and white

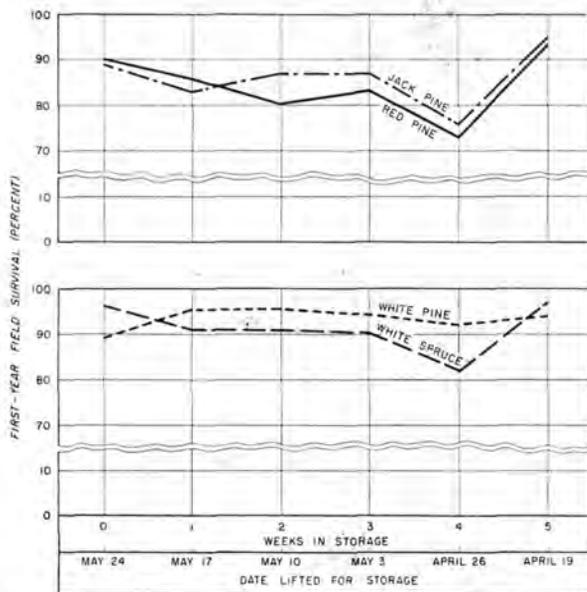


FIGURE 63.—Effect of storage on first-year field survival of stock of 4 species.

pinus scheduled for field planting as 2-1 stock. Such stock, stored for as long as 4 to 6 weeks before transplanting, is really only 2½ years old as far as growth or development is concerned when it is lifted for field planting. To get full development, it should be transplanted early. Long storage of seedlings is less harmful if the stock is scheduled for two seasons in the transplant bed, because second-year transplants usually make good growth and are invariably large enough to give excellent survival in the field.

When shipped, nursery stock should be in transit as short a time as possible to avoid heating, molding, or drying out of the trees. On public and industrial forests, larger quantities of planting stock usually are transported in 1½-ton trucks or larger units such as truck trailers. A 1½-ton truck can haul about 60 thousand 2-2, 90 thousand 3-0, or 180 thousand 2-0 trees if crated, and about 50 percent more of each class of stock if packed in bales. On occasion, about 500 thousand of rather small 2-0 red pine or 1-0 jack pine have been successfully hauled in 1 trip on a 1½-ton truck. Pickup trucks or jeeps are frequently used in short hauls of smaller quantities of stock, especially where these may be going directly from the nursery to nearby planting crews.

State nurseries usually rely on railway express shipments or motor freight for serving customers.

For the usual nonrefrigerated shipment by truck, the chief precaution is to check the line of travel for existing temporary load limits that may have been imposed during or following spring breakup. The cargo should be well protected against the sun and wind with tarpaulins. In warm weather, it may be possible to do most of the trucking in the cool of the night. Watering enroute should not be necessary with loads of trees properly packed and protected against wind and sun. On arrival at the destination, the stock should be unloaded immediately in a building, under shade of trees, or in a field ice-house constructed for stock storage. Ideally, not more than 3 to 7 days should elapse from the time trees leave the nursery or cold storage plant until they are field planted.

COST OF TREE PRODUCTION

The cost of growing stock will vary between nurseries depending upon their size, the methods and practices used, the number of species and age classes produced, seed costs, wages paid to laborers, and specifications set for acceptable planting stock. Losses resulting from insect attacks, diseases, unfavorable climatic conditions, or other causes, raise the cost of producing stock by reducing the output of plantable trees.

Cost keeping, besides being a means of determining the actual cost of production, frequently reveals which costs are out of line. Thus, by analyzing the cost of each operation, the nurseryman can initiate changes to improve the efficiency of the work and effect savings in production costs. This is particularly important in operations that involve handling large amounts of stock, such as transplanting and distribution. Although the cost of stock is important, quality of the trees should not be sacrificed. The objective should be to raise adequate planting stock at minimum cost.

U. S. Forest Service nurseries classify all nursery expenditures into 11 projects. The costs are kept currently, by major and minor projects, and at the close of each fiscal year are brought together into five major projects. Cost per thousand trees in each project is then determined.

Nursery expenditures are currently charged to one of the following projects: *Major Projects*. (1) First-year seedlings; (2) second-year seedlings; (3) first-year transplants; (4) second-year transplants; (5) tree distribution. *Minor Projects*. (6) Maintenance of soil fertility; (7) mess; (8) work animals and motor vehicles; (9) administration; (10) general maintenance; (11) investments other than planting stock (permanent improvements and equipment).

In practice, the cost for labor, materials and supplies, and equipment used is charged direct to the project on which the labor is performed and the materials and supplies used. For example, rotary tilling the soil in preparing seedbeds, sowing seed, mulching seedbeds, removing mulch, watering, weeding, and all other items of cost during the first year, except the value of the seed, are chargeable to Project 1, first-year seedlings. The cost of seed is brought into the cost of tree production as a separate entry on the cumulative record for the lot of stock to which it is chargeable.

Expenditures directly chargeable to other projects are similarly charged to the projects involved, including the nurseryman's time.

When the cost-keeping records for the major projects are closed, the charges for the various minor projects are added. This is done by prorating the minor charges among the major projects on the basis of time in hours spent on each major project, or on the basis of hours of use or miles operated in the case of work animals, tractors, and motor vehicles.

Ordinarily, costs of fertilizing are charged currently to the major projects affected. However, extraordinary expense, such as stockpiling a quantity of peat or preparing compost for future use, is deferred and charged off as the material is used. Where maintenance-of-soil-fertility charges do not vary materially from one year to another, it is taken into account currently in determining tree production costs; otherwise it is charged off once in every 2- or 3-year period.

The cumulative or final cost of the stock, as determined by U. S. Forest Service methods of cost accounting, includes the average cost per thousand for each major project during the period the stock is in the nursery. For example, a block of red pine produced and shipped as 2-1 transplants includes first the cost of the seed, to which is added the average cost per thousand for first-year seedlings. Then, at the end of the second year, the cost for second-year seedlings and the average cost per thousand for transplanting (if transplanting is done in the fall) is added. The third year the stock is charged with project costs for care of first-year transplants and, finally, with stock distribution project costs and depreciation set up for 3-year stock.

It has been found that a further breakdown in costs by species shows relatively little difference in the unit cost per thousand. A slight difference of a few cents per thousand normally may be expected if some species are grown more densely than others or require shading during the first year. However, the efforts and expense involved in keeping labor and material and supply costs for each species or block of stock to determine the difference can hardly be justified.

Typical costs of growing nursery stock in a large Federal nursery in each of 4 one-year periods, from first-year seedlings to four-year transplants, are relatively high for the first year in the seedbed and the first year as transplants, and less for the other 2 years. The cost in 1948, including depreciation and distribution, is shown in the following tabulation:

	Production cost per thousand	Cumulated depreciation per thousand ¹
First-year seedlings.....	\$1. 85	\$0. 17
Second-year seedlings.....	. 45	. 33
First-year transplants.....	5. 48	. 50
Second-year transplants.....	1. 81	. 67
Distribution (lifting and packing).....	1. 27

¹ Based on 20 million production and \$10,000 total annual depreciation.

The cost per thousand trees packed for shipment would be as follows: 2-0 stock, \$3.90; 2-1, \$9.55; and 2-2, \$11.53. As an example, the total cost for first-year transplants includes the first 3 figures and the last figure in the production cost column plus its cumulated depreciation of 50 cents per thousand.

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APPENDIX

COMMON AND SCIENTIFIC NAMES OF TREES AND SHRUBS MENTIONED

CONIFERS

Douglas-fir.....	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Fir, balsam.....	<i>Abies balsamea</i> (L.) Mill.
Hemlock, eastern.....	<i>Tsuga canadensis</i> (L.) Carr.
Juniper, Rocky Mountain.....	<i>Juniperus scopulorum</i> Sarg.
Larch, European.....	<i>Larix decidua</i> Mill.
Larch, Japanese.....	<i>L. leptolepis</i> (Sieb. & Zucc.) Gord.
Pine, Austrian.....	<i>Pinus nigra</i> Arnold
Pine, eastern white.....	<i>P. strobus</i> L.
Pine, jack.....	<i>P. banksiana</i> Lamb.
Pine, ponderosa.....	<i>P. ponderosa</i> Laws.
Pine, red (Norway).....	<i>P. resinosa</i> Ait.
Pine, Scotch.....	<i>P. sylvestris</i> L.
Pine, Swiss mountain (syn. Mugho).....	<i>P. mugo</i> Turra
Pine, western white.....	<i>P. monticola</i> Dougl.
Redcedar, eastern.....	<i>Juniperus virginiana</i> L.
Spruce, black.....	<i>Picea mariana</i> (Mill.) B. S. P.
Spruce, blue.....	<i>P. pungens</i> Engelm.
Spruce, Norway.....	<i>P. abies</i> (L.) Karst.
Spruce, western white.....	<i>P. glauca</i> var. <i>albertiana</i> (S. Brown) Sarg.
Spruce, white.....	<i>P. glauca</i> (Moench) Voss
Tamarack.....	<i>Larix laricina</i> (Du Roi) K. Koch
White-cedar, northern.....	<i>Thuja occidentalis</i> L.

BROADLEAVES

Ash, black.....	<i>Fraxinus nigra</i> Marsh.
Ash, green.....	<i>F. pennsylvanica</i> Marsh.
Ash, white.....	<i>F. americana</i> L.
Aspen, bigtooth.....	<i>Populus grandidentata</i> Michx.
Aspen, quaking.....	<i>P. tremuloides</i> Michx.
Basswood, American.....	<i>Tilia americana</i> L.
Beech, American.....	<i>Fagus grandifolia</i> Ehrh.
Birch, paper.....	<i>Betula papyrifera</i> Marsh.
Birch, yellow.....	<i>B. alleghaniensis</i> Britton
Butternut.....	<i>Juglans cinerea</i> L.
Cherry, black.....	<i>Prunus serotina</i> Ehrh.
Cottonwood, eastern.....	<i>Populus deltoides</i> Bartr.
Elm, American.....	<i>Ulmus americana</i> L.
Elm, rock.....	<i>U. thomasi</i> Sarg.
Elm, Siberian.....	<i>U. pumila</i> L.
Hickory, shagbark.....	<i>Carya ovata</i> (Mill.) K. Koch
Locust, black.....	<i>Robinia pseudoacacia</i> L.
Locust, shipmast.....	<i>R. pseudoacacia</i> var. <i>rectissima</i> Raber
Maple, red.....	<i>Acer rubrum</i> L.
Maple, silver.....	<i>A. saccharinum</i> L.
Maple, sugar.....	<i>A. saccharum</i> Marsh.
Mountain-ash, American.....	<i>Sorbus americana</i> Marsh.
Oak, northern red.....	<i>Quercus rubra</i> L.
Oak, white.....	<i>Q. alba</i> L.
Peashrub, Siberian.....	<i>Caragana arborescens</i> Lam.
Poplars.....	<i>Populus</i> spp.
Walnut, black.....	<i>Juglans nigra</i> L.
Willow, white.....	<i>Salix alba</i> L.

SAFETY RULES AND PRECAUTIONS FOR HANDLING, MIXING, AND APPLYING CHEMICALS

Most insecticides and fungicides as well as some other sprays and baits contain poisons injurious, if not deadly, to humans and livestock. Many act through the skin or lungs as well as through the digestive tract. In addition, some are flammable or explosive, or involve other hazards. Enforcing the following general rules should minimize accidents with poisons and other hazardous materials (183).

1. Plainly mark both temporary and permanent containers to show nature of contents (poisonous, flammable, or the like) and date of purchase (some chemicals change or deteriorate with age). Keep dangerous materials tightly closed (unless their nature requires venting); out of reach of children, irresponsible persons, livestock and pets; and in an adequately ventilated storeroom, preferably locked.

2. When mixing or applying poisonous materials, take extreme care to keep them out of mouth, eyes, nose, and lungs and away from tender parts of the body. Ordinarily, wear leather or paraffined-cloth gloves (rubber or plastic gloves must be used with certain chemicals), and

always wear goggles, respirator, or a combination of the two if the substance requires. If manufacturer specifies, mix substance only in open shed or outdoors.

3. Prohibit smoking during the mixing or application of flammable or explosive substances.

4. Burn or bury empty packages and bags that have contained poisons. Bury unused or discarded materials. When mixing vessels, sprayers, and the like are washed after use of the more poisonous substances, empty wash water into hole in ground, and fill in the hole. Do not burn empty arsenical containers except in open air.

5. Always wash hands and face thoroughly after mixing or applying poisonous substances. After long exposure, bathe and change clothes. Wash the clothes after each day's spraying operation.

6. Make sure that no poisonous spray material can in any way get into domestic or livestock water supplies.

7. If sulfuric acid must be diluted (as for acidifying soil to control damping-off), always pour the acid, which is the heavier liquid, into the water. Water poured into sulfuric acid splatters badly, with serious danger, especially to the eyes.

Only the most responsible and trustworthy personnel should be allowed to handle chemicals that are toxic to humans, explosive, or flammable. It is extremely important that the labels on insecticides, fungicides, or weed killers be read carefully and then followed. Containers for chemicals, once emptied, should be stored in a safe place or destroyed. Surplus mixtures should be buried and covered with soil. They should not be poured into streams or ponds where they may endanger human life, fish, or livestock (37).

Workers handling concentrated acid should be equipped with goggles, rubber gloves, and acid-proof aprons. Acids can be handled safely by using a 3-gallon crock, carried in a frame by 2 men (fig. 64). Once diluted to a 2-percent solution, it is not particularly hazardous to handle.

Workers should not breathe the fumes of chemicals such as methyl bromide, allyl alcohol (144), and chlorobromopropene. They should use special injectors for methyl bromide as supplied or recommended by the manufacturer of the chemical, and they should wear masks when handling allyl alcohol or chlorobromopropene.

The insecticides aldrin, chlordane, and toxaphene are somewhat toxic to man and other warm-blooded animals but are not dangerous when diluted and carefully handled. Concentrated materials should not be inhaled, swallowed, or allowed to touch the skin.

Certain insecticides, such as DDT, are harmful to bees which are helpful in pollinating many plants. Insecticides generally should not be

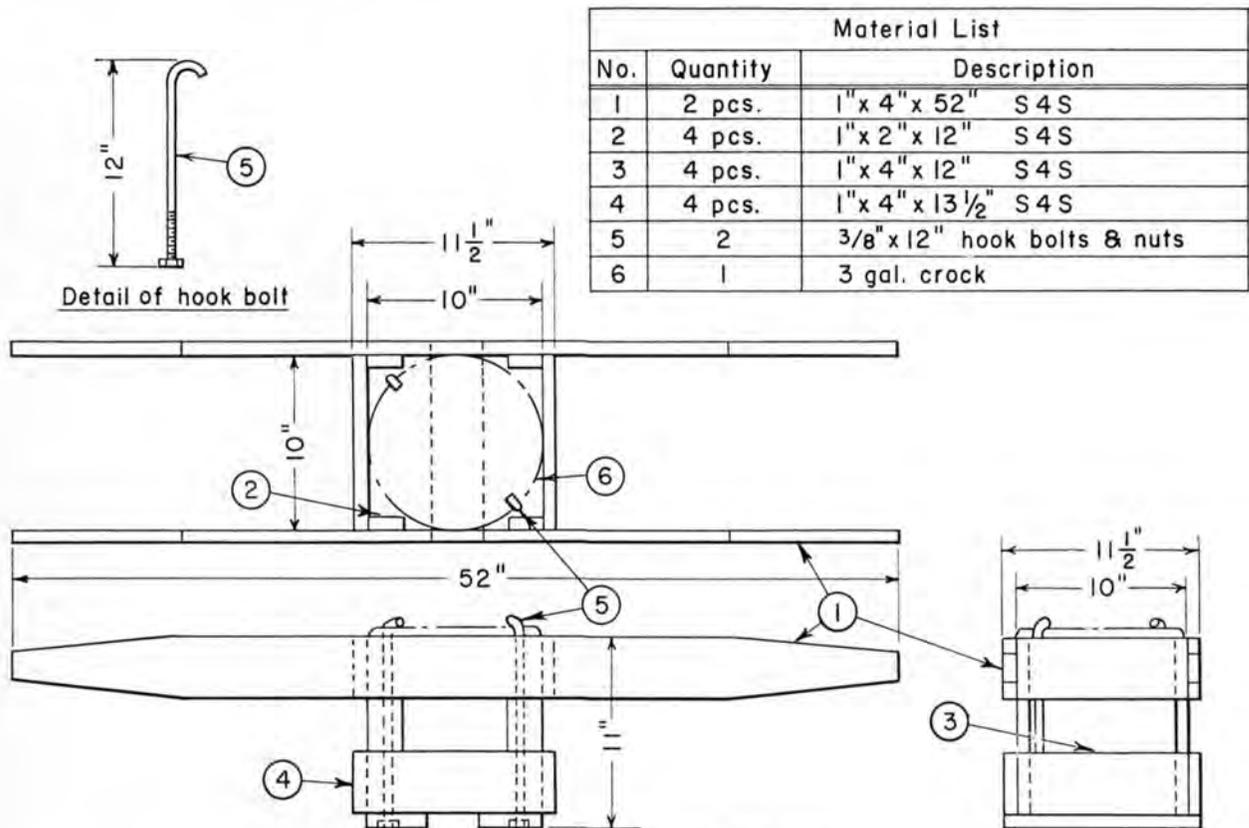


FIGURE 64.—Device for handling acids.

applied to plants in bloom. If spraying is necessary with DDT, it should be done when the flowers are in the bud stage. To avoid injury to bees, however, toxaphene can be sprayed in the early morning or late evening.

Glass carboys of acids should never be removed from their crates or shipping packages. The glass containers may break from moderately hard contact with concrete floors or a small piece of gravel or rock between the carboy and floor. If carboys must be removed from their containers, they should be handled on a cleanly swept wooden platform free from gravel or protruding nails or screws and preferably with a layer of heavy cardboard under the glass jar.

Some chemicals, such as carbon disulphide, are explosive. Others, such as chlorates and mineral spirits, are quite flammable. They must, therefore, be stored in separate buildings or containers well separated from warehouses and other buildings. At the Griffith State Nursery in Wisconsin mineral spirits are stored in 50-gallon steel drums placed on horses along drives at ends of seedbeds that are to be sprayed that year. Drums are spotted about 100 feet apart. This method reduces risk of fire to an absolute minimum and also the time required to fill the sprayers. Some nurseries have special 500- to 1,000-gallon tanks and pumps for storage purposes.

Lime sulfur should not be used where the spray may drift onto paint, stonework, or ornamental stone walks. In such instances oil is preferred as a dormant spray.

Oil sprays are not recommended for summer use because the oil may injure the foliage or new growth of small nursery trees. In dormant sprays, thorough mixing or emulsification is necessary before application. Oil emulsions over 4 percent in strength may cause damage to trees. If oils or oil emulsions are used, tanks must, in most cases, be quite free of any lime sulfur residues since these may break down the oil emulsion.

Copper sulfate, used in preparation of bordeaux mixture, goes into solution best if used in powdered form. Quick lime or hydrated lime is used in the preparation of bordeaux. These materials go into suspension more readily if rainwater or a water of low mineral content is used. A common bordeaux mixture used in nursery work is 4-6-50, containing 4 pounds of copper sulfate, 6 pounds of quick lime (or 8 pounds of hydrated lime), and 50 gallons of water. The copper sulfate must be completely dissolved and the lime thoroughly in suspension to prevent clogging of the sprayer and to get a uniform mixture. Sprayers should be thoroughly cleaned out after use.

Sprayers used for weed or brush killers such as 2,4-D or 2,4,5-T should not be used for spraying insecticides or fungicides in the nursery because residues of these particular chemicals may damage or kill the trees. If it is necessary to use these sprayers, they should be thoroughly scrubbed out with soap and water and rinsed repeatedly.

SPRAY FORMULAS FOR INSECTICIDES AND FUNGICIDES

A number of well-tested formulas have been developed for preparing insecticides and fungicides (tables 39 and 40). They will prove helpful to nurserymen in protecting nursery beds as well as larger trees in windbreaks or natural stands near the nursery.

MOUSE BAITS

Zinc Phosphide Formula (52)

Steamed rolled oats.....	98 pounds
Amber petroleum jelly.....	10 ounces
Mineral oil.....	10 ounces
Zinc phosphide.....	1 pound

The mineral oil and petroleum jelly are warmed together until they are fluid, but not hot. Zinc phosphide is added to the mixture and stirred vigorously. This material is then poured over the oats and mixed thoroughly. Zinc phosphide baits are generally effective for about 3 weeks after preparation.

Strychnine Alkaloid Formula

The bitter taste of strychnine alkaloid sometimes results in less ready acceptance by certain mice. The formula is as follows:

Steamed rolled oats.....	12 pounds
Powdered strychnine alkaloid.....	1 ounce
Baking soda.....	1 ounce
Gloss starch.....	¾ ounce
Water.....	1 pint
Heavy corn sirup.....	¼ pint
Glycerine or petrolatum.....	1 tablespoonful

The starch is mixed with ¼ teacup of cold water, stirred into ¾ pint of boiling water, and cooled until it forms a thin paste. Strychnine is mixed with the baking soda, then added to the starch paste and stirred until free of lumps. The corn sirup and glycerine or petrolatum then are added. The mixture is poured over the oats and allowed to dry before sacking.

CONVERSION FACTORS

This list is useful in experimental work and empirical test plots, and for conversion of the United States system of weights and measures to the metric system:

Length

1 inch	= 2.54 cm.
1 foot	= 0.3048 meter
1 yard	= 0.9144 meter
1 mile	= 1609.3 meters

Area

1 square inch	= 6.4516 square cm.
1 square foot	= 0.093 square meter
1 square yard	= 0.836 square meter
1 acre	= 0.4047 hectare
1 acre	= 43,560 square feet

TABLE 39.—*Formulas for insecticides and fungicides* ¹

INSECTICIDES

Formula No.	Ingredients	Water	Sticker or spreading agent
		<i>Gallons</i>	
1	Lead arsenate 2 to 5 (av. 4) lb.....	100	1 pt. of fish oil.
2	Derris or cube powder (4% rotenone) 2-8 lb.....	100	½ gal. fish oil.
3	Nicotine sulfate (40% nicotine) 1 pint.....	100	3 lb. solid soap or 6 lb. liquid soap.
4	Pyrethrum powder (0.8 to 1% pyrethrins) 1 lb.....	100	Do.
5	Emulsifiable pyrethrum extract (1% pyrethrins) 1 pint.....	100	None.
6	Derris or cube powder (4% rotenone) 1.5 lb.....	100	3 lb. solid soap or 6 lb. liquid soap.
7	Oil emulsion (75% oil) 4 gal.....	96	None.
8	Miscible oil (90% oil) 5 gal.....	95	Do.
9	Miscible white oils 1 gal.....	100	Do.
10	Lime sulfur (10 gal. liquid or 40 lb. dry).....	90	Do.
11	Parathion 1 lb.....	100	Do.
11a	Tetraethyl pyrophosphate (40% emulsifiable) ½ pt.....	100	Do.
12	Aramite 15W, Neotran, or Dimite, 2 lb.....	100	Do.
13	DDT (emulsifiable, 25% DDT) 1 qt.....	100	Do.
13a	DDT (50% DDT wettable powder) 1 lb.....	100	Do.

FUNGICIDES

14	Lime sulfur (2.5 gal. liquid or 6-8 lb. dry).....	100	None.
15	Bordeaux-copper sulfate 8 lb., hydrated lime 10 lb.....	100	Calcium caseinate 2 lb.
16	Bordeaux mixture powder 16 lb.....	100	Do.
17	Wettable sulfurs.....	(²)	According to directions on container.
18	Sulfur dust ³	0	None.
19	Puritized agricultural spray 1 to 1.5 pt.....	100	Do.
20	Ferbam 1.5-2 lb.....	100	Do.
21	Ferbam ½ lb., wettable sulfur 3 lb.....	100	Do.
22	Elgetol 1 gal.....	100	Do.

¹ Taken from revised Tree Pest Leaflet 31, Spraying and Dusting to Control Insects and Diseases, by S. F. Potts and A. M. Waterman (117).

² According to directions on container.

³ For control of chewing insects, 2 pounds of lead arsenate or 1 pound of 50% DDT powder can be added per 10 pounds of sulfur.

Volume and Capacity

1 cubic inch	= 0.554 fluid ounce
1 cubic inch	= 16.387 cubic cm.
1 cubic inch	= 0.01639 liter
1 cubic foot	= 0.02832 cubic meter
1 cubic yard	= 0.765 cubic meter
1 pint	= 0.5 quart
1 quart (liquid)	= 0.9463 liter
1 gallon	= 3.7853 liters
1 gallon	= 231.0 cubic inches
1 quart (dry)	= 1.101 liters
1 fluid ounce	= 29.5737 cubic cm.
1 bushel	= 0.35238 hectoliter
1 U. S. gallon	= 0.83268 imperial gallon
1 bushel	= 2150.42 cubic inches
1 bushel	= 1.24446 cubic feet
1 bushel	= 32 quarts (dry)

Weight

1 grain	= 0.002286 avoirdupois ounce
1 avoirdupois ounce	= 28.35 grams
1 pound	= 453.6 grams
1 short ton	= 907.18 kilograms
1 gram	= 0.0353 avoirdupois ounce
1 gram	= 15.43 grains

Velocity

1 foot per minute	= 0.3048 meter per minute
1 mile per hour	= 1.609 kilometers per hour

Power

1 horsepower	= 745.7 watts
1 horsepower	= 0.7457 kilowatt

Weight as Pressure Applied to Area

1 pound per square inch	= 70.3067 grams per square centimeter
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Weight as Applied to Volume

1 pound per cubic yard	= 0.5933 kilogram per cubic meter
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Weight of Various Units of Volume of Water

1 cubic foot	= 62.424 pounds (at 40° F.)
1 cubic foot	= 28.317 kilograms
1 cubic yard	= 764.56 kilograms

Discharge as Flow of Water

1 gallon per minute	= 3.7853 liters per minute
1 cubic foot per minute	= 0.4719 liter per second

TABLE 40.—Concentrated-spray formulations for use in mist blowers, aircraft, and hand atomizers ¹

Formula No.	Ingredients	Quantity to make		Gallons to apply		Percent of toxicant
		1 gallon	100 gallons	Per acre	Per 60-foot tree	
1	DDT	3/8 lb	40 lb	2 1/4	1/2	5
	Kerosene	1 gal	99 gal			
2	DDT, technical	1/2 lb	50 lb	2	1/2	6
	Xylene	1 1/4 pt	15 1/2 gal			
	Kerosene	6 3/4 pt	81 3/8 gal			
3	DDT, technical	1/2 lb	50 lb	2	1/2	6
	Xylene	1 1/4 pt	15 1/2 gal			
	Triton X-100	3/4 oz	5/8 gal			
	Water	6 1/2 pt	82 gal			
4	DDT, 50% wettable powder	1 lb	100 gal	2	1/2	6
	Water	1 gal	97 gal			
5	Benzene hexachloride, emulsifiable, 20% gamma isomer.	4 oz	3 1/8 gal	4	1	.67
	Water	7 3/4 pt	97 gal			
6	Chlordane, 50% emulsifiable	1 pt	12 1/2 gal	2	1/2	6
	Kerosene or water	7 pt	87 1/2 gal			
7	Chlordane, 50% wettable powder	1 lb	100 lb	2	1/2	6
	Water	1 gal	97 gal			
8	Nicotine sulfate	8 oz	6 1/4 gal	4	1	2.5
	Water	7 1/2 pt	93 3/4 gal			
9	Rotenone, 5% emulsifiable extract	1 pt	12 1/2 gal	5	1 1/2	.6
	Water	7 pt	87 1/2 gal			
10	Rotenone, 5% powder	1 lb	100 lb			
	Water	7 1/2 pt	94 gal	5	1 1/4	.6
	Mineral oil (50 to 90 sec. Saybolt)	3 oz	2 1/2 gal			
11	Pyrethrum extract, 1% emulsifiable	1 pt	12 1/2 gal	4	1	.125
	Water or kerosene	7 pt	87 1/2 gal			
12	Lead arsenate	2 lb	200 lb			
	Water	7 1/2 pt	90 gal	6	1 1/2	21
	Mineral oil (50 to 90 sec. Saybolt)	0.4 pt	5 gal			
13	Refined white mineral oil (45 to 75 sec. Saybolt).	1 gal	100 gal	6	1 1/2	100
14	Refined white miscible mineral oil (50 to 100 sec. Saybolt).	1 qt	26 gal	15	3 3/4	25
	Water	3 qt	74 gal			
15	DN-111	8 oz	50 lb	6	1 1/2	6
	Water	1 gal	98 1/2 gal			
16	Aramite 15W	1 lb	100 lb			
	Water	7 3/8 pt	95 gal	6	1 1/2	2
	Soybean oil or linseed oil	1/8 pt	2 1/2 gal			
17	Liquid lime sulfur	1 gal	100 gal	15	3 3/4	100

¹ Taken from revised Tree Pest Leaflet 54, Control of Forest and Shadertree Insects with Concentrated Sprays Applied by Mist Blowers, by S. F. Potts (116).

Number of Plants Per Unit of Area

10 per square foot = 107.63 trees per square meter

Temperatures

- 20° F. = -28.9° C.
- 10° F. = -23.3° C.
- 0° F. = -17.8° C.
- 25° F. = -3.9° C.
- 30° F. = -1.1° C.
- 32° F. = 0° C.
- 40° F. = 4.4° C.
- 50° F. = 10.0° C.
- 70° F. = 21.1° C.
- 100° F. = 37.8° C.
- 130° F. = 54.4° C.
- 140° F. = 60.0° C.
- 150° F. = 65.6° C.

Formulas:

Degrees Fahrenheit = ° C. × 1.8 + 32
 Degrees Centigrade = (° F. - 32) / 1.8

Volume Per Acre or Per Unit of Area

- 1 cubic foot per acre = 0.06997 cubic meter per hectare
- 1 cubic yard per acre = 1.8892 cubic meters per hectare
- 100 gallons per acre = 8.68 cubic centimeters per square foot
- 100 gallons per acre = 0.2938 fluid ounces per square foot
- 1 gallon per acre = 9.353 liters per hectare
- 1 bushel per acre = 0.8708 hectoliter per hectare
- 1 bushel per 100 square feet = 379.32 hectoliters per hectare

Weight Per Acre or Per Unit of Area

1 pound per acre	= 1.1208 kilograms per hectare
100 pounds per acre	= 1.04 grams per square foot

Dollars Per Unit of Area

\$1.00 per acre	= \$2.47 per hectare
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SOURCES OF INFORMATION ON NURSERY PROBLEMS

Nurserymen who have problems with nursery insects or diseases can get advice on identification and control by writing to their State agricultural college or their State nursery inspector who is invariably a trained pathologist or entomologist. The inspector may also send out releases on new quarantine regulations affecting the nursery industry. Advice on nursery disease and insect problems can also be obtained from the Division of Forest Disease Research and the Division of Forest Insect Research, Forest Service, U. S. Department of Agriculture, Washington 25, D. C.

Advice on control of mammals and birds can be obtained from the Fish and Wildlife Service, U. S. Department of the Interior, Washington 25, D. C., or from the Conservation Departments of the respective States.

Nurserymen who plan interstate shipments of stock should become familiar with any Federal and State regulations which may affect their shipments. This information can be obtained from the Plant Quarantine Branch of the Regulatory Program Section, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

Problems in nursery soils can be referred to the respective soils departments of the several State colleges and universities.

SOURCES OF INFORMATION ON NURSERY MACHINERY, EQUIPMENT, AND CHEMICALS

The nursery industry, as much as possible, uses equipment and products of standard manufacture. A list of manufacturers of nursery machinery, equipment, and chemicals can be obtained from the Forest Service, U. S. Department of Agriculture, Washington 25, D. C. (Mention of specific firms does not constitute an endorsement by the Forest Service or the U. S. Department of Agriculture.)

Blueprints of specialized equipment, assembled from manufacturers' parts, or which must be built by the nurseryman, can be obtained from one of several regional offices of the U. S. Forest Service.

In the North Central Region of the U. S. Forest Service (comprising the States of Michigan, Minnesota, Wisconsin, North Dakota, Iowa, Indiana, Ohio, Missouri, and Illinois) nurserymen can obtain, at cost, blueprints of certain items

of special nursery equipment or buildings such as nursery lifters, hand trenchers, root pruners, tree balers, central warehouses, cold storage sheds, cone storage sheds, and seed extractories. These blueprints can be obtained by writing to the Regional Forester, U. S. Forest Service, Milwaukee, Wis.

REQUIREMENTS AND PROCEDURES FOR NURSERY STOCK INSPECTION IN THE LAKE STATES

Each State has its own laws requiring inspection of trees before they can be sold and removed from the nursery premises. In brief, these laws provide for an annual inspection of the nursery by the State nursery inspector or his representative, define the fees to be so charged, and provide for the issuance of a certificate of inspection. The law defines certain species on which there is a quarantine as regards shipment into the State. It defines power of the nursery inspector to recommend and enforce destruction of certain pest-infested stock or to enforce its treatment with appropriate insecticides or fungicides. The law also provides for tagging of State shipments of nursery stock and wildings and provides for penalties for violations of quarantine and other aspects of nursery regulations. It contains provisions affecting the growing, tagging, and transport of Christmas trees.

Individuals in any of the three Lake States contemplating growing or dealing in the merchandising of nursery stock can obtain detailed information on current laws affecting the business by writing to one of the following agencies:

1. State Entomologist, St. Paul Campus, University of Minnesota, St. Paul 1, Minn.
2. State Entomologist, Department of Agriculture, State Capitol, Madison, Wis.
3. Director, Bureau of Plant Industry, Department of Agriculture, Lansing, Mich.

Those residing in other States can obtain similar information for their respective States from their State nursery inspector who is usually located at the Agricultural Experiment Station or at the State Department of Agriculture.

Plant quarantine regulations which are in force on a national basis by the U. S. Department of Agriculture are available from the Agricultural Research Service, whose address is listed under Sources of Information on Nursery Problems.

WHERE TO PURCHASE SEED

A partial list of tree-seed dealers in the United States and a few foreign countries can be obtained by writing to the Forest Service, U. S. Department of Agriculture, Washington 25, D. C.

A list of tree-seed dealers in the Lake States area, or dealers who handle seed native to the Lake States, can be obtained from the Lake States Forest Experiment Station, St. Paul Campus, University of Minnesota, St. Paul 1, Minn.

WHERE TO PURCHASE NURSERY STOCK

Nursery stock for reforestation and windbreak planting can be purchased from State-owned nurseries in Michigan, Wisconsin, and Minnesota. It is necessary to make applications considerably in advance, make payments in advance, order a certain minimum number of trees (usually around 500), and agree not to resell the trees with roots attached as ornamental stock. Some States permit use of the trees for resale as Christmas trees; others do not.

Prices of stock, which is sold at approximately the cost of production, generally range from \$5 to \$25 per thousand trees. Price lists can be obtained, along with regulations governing the purchase, from one of the several addresses listed below:

1. Division of Forestry, Department of Conservation, Lansing, Mich.
2. Department of Forestry, Michigan State University, East Lansing, Mich.
3. Division of Forestry, Department of Conservation, St. Paul, Minn.
4. Wisconsin Conservation Department, Madison, Wis.

Nurserymen or others wishing to purchase nursery stock for ornamental, windbreak, and Christmas tree planting from private commercial nurseries can obtain such a list by writing to the State nursery inspection office in the specific States. For the three Lake States, write to the addresses listed under Requirements and Procedures for Nursery Stock Inspection, p. 123.

U. S. DEPARTMENT OF AGRICULTURE FOREST SEED POLICY (1939)

The U. S. Department of Agriculture has adopted a forest tree seed policy regarding seeds of trees and shrubs to be used in reforestation, shelterbelt, and erosion control planting which provides guidance for its various conservation agencies engaged in such work. The policy is given below:

Recognizing that trees and shrubs, in common with other food and fiber plants, vary in branch habit, rate of growth, strength and stiffness of wood, resistance to cold, drought, insect attack, and disease, and in other attributes which influence their usefulness and local adaptation for forest, shelterbelt, and erosion-control use, and that such differences are largely of a genetic nature, it shall be the policy of the United States Department of Agriculture insofar as practicable to require for all forest, shelterbelt, and erosion-control plantings, stocks propagated from segregated strains or individual clones of proven

superiority for the particular locality or objective concerned.

Furthermore, since the above attributes are associated in part with the climate and to some extent with other factors of environment of the locality of origin, it shall be the policy of the United States Department of Agriculture:

1. To use only seed of known locality of origin and nursery stock grown from such seed.

2. To require from the vendor adequate evidence verifying place and year of origin for all lots of seed or nursery stock purchased, such as bills of lading, receipts for payments to collectors or other evidence indicating that the seed or stock offered is of the source represented. When purchases are made from farmers or other collectors known to operate only locally, a statement capable of verification will be required as needed for proof of origin.

3. To require an accurate record of the origin of all lots of seed and nursery stock used in forest, shelterbelt, and erosion-control planting, such records to include the following minimum standard requirements to be furnished with each shipment:

- (1) Lot number.
- (2) Year of seed crop.
- (3) Species.
- (4) Seed origin: State—County—Locality—Range of elevation.
- (5) Proof of origin.

4. To use local seed from natural stands whenever available unless it has been demonstrated that seed from another specific source produces desirable plants for the locality and uses involved. Local seed means seed from an area subject to similar climatic influences and may usually be considered as that collected within 100 miles of the planting site and differing from it in elevation by less than 1,000 feet.

5. When local seed is not available, to use seed from a region having as nearly as possible the same length of growing season, the same mean temperature of the growing season, the same frequencies of summer droughts, with other similar environment so far as possible, and the same latitude.

6. To continue experimentation with indigenous and exotic species, races, and clones to determine their possible usefulness, and to delimit as early as practicable climatic zones within which seed or planting stock of species and their strains may be safely used for forest, shelterbelt, and erosion control.

7. To urge that States, counties, cities, corporations, other organizations, and individuals producing and planting trees for forest, shelterbelt, and erosion-control purposes, the expense of which is borne wholly or in part by the Federal Government adhere to the policy herein outlined.