

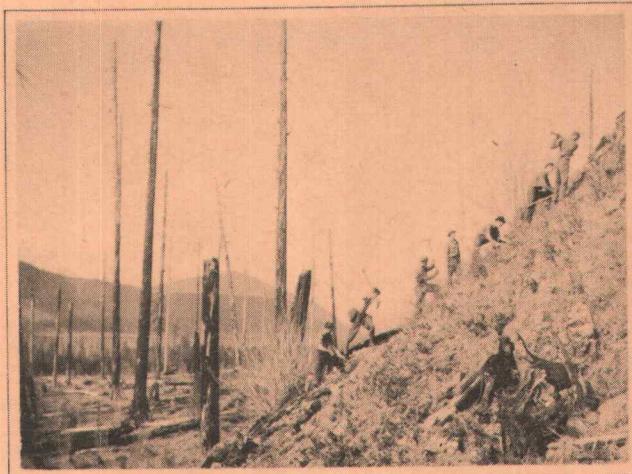
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FREE MATERIAL

**FOREST PLANTING
IN THE
DOUGLAS-FIR REGION**

BY

JULIUS F. KUMMEL, CHARLES A. RINDT, AND THORNTON T. MUNGER



U.S. DEPARTMENT OF AGRICULTURE

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FOREST PLANTING IN THE DOUGLAS-FIR REGION

By

Julius F. Kummel

Enlarged and revised by Charles A. Rindt and Thornton T. Munger^{1/}

CHAPTER 1. INTRODUCTION

Scope of This Bulletin

It is the purpose of this bulletin to describe the various techniques of artificial reforestation that have been found practicable in the Douglas-fir region of western Washington and Oregon. It is intended primarily for the use of seed collectors, nurserymen, planting foremen, and foresters who are engaged in the management of forest lands, either publicly or privately owned. It should also be useful to forestry students, teachers, and other individuals seeking technical information in this field. It is not designed as a complete treatise on all the arts of reforestation, for which there are already adequate texts (11)(43) (55) (57) (63), but is directed to consideration of the practices which the forester in the Douglas-fir region may need to employ.

This bulletin embodies the more important results of a long series of experiments and of extensive nursery and planting operations, of which the senior author had direction for a period of over 30 years. Though the research and experience was gained largely by the Forest Service on the national forests, the findings of other agencies and on other types of land have been drawn upon to the extent that they are available, so that this bulletin may be applicable to the various conditions and types of land that occur within the region. It deals primarily with Douglas-fir but makes some mention of the associated species of western Washington and Oregon.

Place of Artificial Reforestation in the Growing of a Timber Crop

Artificial reforestation is the term used to denote the process of forest establishment by man in sowing seed or planting young trees, in contrast to establishment by the natural process of seed dissemination from living trees. Its place in the practice of forestry in the Douglas-fir region arises more from the necessity to correct the devastation wrought by fire and improper cutting than as an essential first step in the process of timber growing.

1/ Julius F. Kummel was Chief of Planting in the North Pacific Region of the Forest Service from 1908 to 1941; he retired in 1942. Charles A. Rindt was Chief of Planting 1941-42 and is now with the Guayule Rubber Project, Los Angeles, California. Thornton T. Munger is Chief of the Division of Forest Management Research of the Pacific Northwest Forest and Range Experiment Station.

Conditions generally throughout the region are quite favorable for natural reforestation. The timberland owner who is trying to keep his land productive can usually depend upon natural seeding to start the new crop, if he makes provision in logging to leave trees to supply seed and if the area is protected from accidental fires. Even when depending primarily on natural seeding, however, he may find artificial reforestation a useful supplement when the former is slow or inadequate. Only under rather special conditions will he need to adopt it as an integral part of his technical program for continuous timber production.

Repeated fires, both in virgin timber and on cut-over land, are the chief cause for conditions that require planting. Single burns of small size in the forest usually restock promptly from seed produced by surrounding timber. In larger burns, islands of timber along streams and in protected canyons often escape destruction. These supply seed to restock interior portions of the burn. Thus natural restocking following a single burn is the rule unless the fire be very large or severe. Each subsequent fire, however, greatly decreases the opportunity for natural reforestation. The interior islands of living trees, which escaped the first fire, are likely to be killed by the second, the existing seedlings are killed, and conditions made much less favorable for the establishment of seedlings from any seed that may reach the area. Following a virgin forest conflagration the ground soon becomes littered with bark, dead limbs, and chunks of wood, which coupled with the rank growth of weeds and shrubs, make in a second fire an intense heat on the surface that is apt to render the ground unfavorable for natural reseeding.

The effect of repeated fires on logged areas is similar to that in uncut forests. Small cut-over areas can reseed from adjoining timber. As logging enlarges the area, seeding from the side is ineffective and either provision must be made for leaving single seed trees or patches of uncut timber or the area will have to be artificially reforested. Should the seed trees be killed by a subsequent fire, it will be necessary to plant to attain prompt restocking. Otherwise regeneration will take place only by the slow and uncertain process of migration and chance seeding from a distant seed source.

In addition to the employment of artificial reforestation as a reclamation measure following severe or repeated burns and as an emergency measure when natural seeding fails, it may be used advantageously sometimes as an alternative to natural regeneration. When the character of the timber or the exigencies of logging make the leaving of seed trees or seed blocks impracticable, it may be better and cheaper to clear cut completely and plant. In places it may be better to plant promptly after logging than to await natural reproduction, in order to prevent erosion, to forestall capture of the area by brush, or to avoid the loss of years of potential production. If a change in the proportion of certain species is desired, planting is often the easiest way to accomplish it. It is the only way by which new species can be introduced.

Description of the Douglas-fir Region

The region considered in this bulletin consists of that part of Washington and Oregon lying west of the summit of the Cascade Range, the so-called Douglas-fir region, which is bounded roughly by the California line on the south and extends into British Columbia on the north. The forested slopes on the east side of the Cascade Range in both states and the mountainous regions of eastern Oregon and north eastern Washington, although within the range of Douglas-fir, are not considered in the present discussion because they are distinctly different in climate and forest composition.

Except for intervening valleys and benchlands, the topography generally is hilly or mountainous; the altitudinal zone of forest growth is from sea level to timber line at 4,000 to 6,500 feet, depending on latitude. The distinctive physiographical features are: (1) The Cascade Range, which extends the entire length of the region along the eastern boundary with an average altitude of about 6,000 feet and several peaks over 10,000 feet, (2) the Olympic Mountains in northwestern Washington, (3) the Siskiyou Mountains in southwestern Oregon, (4) along the coast between the Olympics and Siskiyous an irregular series of hills and ridges, mostly under 2,000 feet in altitude, designated as the Coast Range, (5) the Columbia River which bisects the region east and west, (6) the Puget Sound-Cowlitz-Willamette depression, a series of lowlands and valleys between the Coast Range and the Cascade Range, and (7) the Umpqua and Rogue River Valleys and other minor valleys on east-west drainages.

The climate of the region is characterized by equable temperatures and moderate to heavy precipitation. Though the precipitation decreases somewhat from north to south, it varies greatly with altitude and with reference to the two north and south mountain ranges. These intercept the moist air in the prevailing westerly winds off the Pacific Ocean and accordingly are wetter on their western slopes than on their eastern, or in the valleys between. The coast region, sometimes spoken of as the "fog belt," which roughly embraces a belt 30 to 40 miles wide on the seaward side of the Olympic Mountains, Coast Range, and Siskiyou Mountains, is the most humid and most equable part of the region. Here the annual precipitation, nearly all in the form of rain, is from 70 to well over 100 inches per year. The dry season is shorter than elsewhere and summer fogs are not uncommon. The daily and seasonal fluctuations in temperature are less here than elsewhere in the region; freezing weather is infrequent and not of long duration.

The western slopes of the Cascade Range also have a high annual precipitation, from 45 to 100 inches, depending on altitude and latitude. At the upper elevations it is chiefly in the form of snow. The higher elevations also experience low winter temperatures and a long season under a snow cover.

In the depression between the Coast and Cascade Ranges the lowland valleys have an annual rainfall of 30 to 45 inches. In the interior valleys of southern Oregon it is as little as 20 inches and on a small area in northwestern Washington, within the rain shadow of the Olympic Mountains, it is only 17 inches. The seasonal range of temperature in the valley region is greater than in the coastal region but seldom falls below 15° F. or rises above 100°. In southern Oregon temperatures of over 100° are more common.

A feature of the climate which is of utmost importance in the conduct of artificial reforestation is the summer drought. There is normally a long period from late June to early September, and sometimes until later in the fall, when there is practically no rain. Even in the Cascade Mountains periods of 40 to 50 days without rain and with much bright, hot weather are not uncommon. This creates a problem in planting not encountered in regions of abundant summer rainfall.

Except for a few meadows, prairies, rocky barrens, and the country above timber line, the entire region was originally in forest; the greater part of that which is not now in agricultural use is, because of soil, altitude, or topography, best suited for forest purposes. The virgin forest, overwhelmingly coniferous, is characterized by trees of large diameter and height, great density, and heavy volume per acre. The presence of large areas of nonstocked or poorly stocked burns or cut-over areas is an anomaly in this region of favorable physical conditions and climate and luxuriant virgin forests.

Douglas-fir (Pseudotsuga taxifolia) is the predominating tree, running from sea level almost to timber line throughout the length of both states; it forms 60 percent or more of the stand on more than half the forest land. Associated with it in varying amounts are western hemlock (Tsuga heterophylla) and Sitka spruce (Picea sitchensis), especially in the cooler more humid locations, where, as in the "fog belt," they sometimes entirely replace the Douglas-fir; western redcedar (Thuja plicata) on the wetter ground; Pacific silver fir (Abies amabilis), noble fir (Abies procera), and mountain hemlock (Tsuga mertensiana) in the mountains and which replace it at the higher elevations; California incense-cedar (Libocedrus decurrens), sugar pine (Pinus lambertiana), and ponderosa pine (Pinus ponderosa) in the warmer sites of southern Oregon; grand fir (Abies grandis), western white pine (Pinus monticola), Port Orford white-cedar (Chamaecyparis lawsoniana), Pacific yew (Taxus brevifolia), and other species in certain localities.

The broadleaf species are usually incidental and confined to bottom lands except for red alder (Alnus rubra) which forms almost pure continuous stands in the coast region, and except for the oaks (Quercus spp.) and Pacific madrone (Arbutus menziesii) which are prevalent on the warmer sites of southern Oregon.

Area in Need of Reforestation

The area in need of reforestation in the Douglas-fir region and which is chiefly valuable for forest production runs into millions of acres. According to the survey of forest resources, made by the Pacific Northwest Forest Experiment Station during the period 1930 to 1933 (4), there were somewhat over 2 million acres of burns and old cut-overs (clear cut before 1920) which were then less than 10 percent restocked. In addition, of the 2,160,038 acres clear-cut between 1920 and 1933, about 42 percent was considered to be nonstocked, making a total at that time of 3,108,000 acres in a deforested condition.

Table 1 shows by states and ownerships these several classes of nonrestocking lands, as of 1933, expressed in thousands of acres. It will be seen that nearly two-thirds of the total is privately owned land. Most of the nonrestocked land within the national forests and other categories of public lands is on old burns which were not cut before the fire, while the majority of the privately owned nonrestocked lands are on clear-cut areas. The total is rather evenly divided between the two states--Oregon has more of the deforested burns and Washington of the deforested cut-over lands.

Recently there has been a resurvey and revision of the estimates in the 22 counties that have been most heavily cut and subjected to change since 1933. This shows that a certain amount of burns and cut-overs hitherto reported as nonstocked has restocked, that there are additional burns, and that there has been a great acreage recently cut-over, of which about 50 percent is so far nonstocked. Using the revised figures for the 22 counties and adjusting the 1933 figures for the remaining 16 counties to account for some restocking of the originally nonstocked area and for the recent burns and cutting, it appears that there are now in the region 3,426,000 acres in a deforested condition.

Though this figure is believed to be fairly close to the acreage less than 10 percent restocked, it is constantly changing and does not necessarily indicate the exact size of the planting program. It includes considerable land not in urgent need of planting, such as lands of low timber-producing capacity due to high altitude or poor soil, now serving well for stock grazing, or cut-over lands that will reproduce naturally if given time and security from fire, and land that will be withdrawn from the timber-producing category in favor of agricultural or grazing use.

On the other hand, many of the cut-over lands that are classed as stocked have a very inadequate number of young trees and will not be fully productive unless the blank places are filled in artificially. Some of these areas may warrant supplemental planting to bring them quickly into full production, to forestall their capture by brush or low-value trees, or for other special reasons.

To bring the potentially productive forest area promptly into a fairly well stocked and productive condition would require the artificial planting of some $2\frac{1}{2}$ or 3 million acres.

Table 1.--Area of Deforested Burns, not Restocked, of Nonrestocked Old Cut-overs and of 42 Percent of Recent Cut-overs Thought to be Nonrestocked, as of 1933,
by States and Ownership Classes (4)

State	Type	Pri- vate acres	State, county, munic- ipal acres	Na- tional forest acres	Other federal acres	Total acres
Oregon	Nonrestocked burns, not cut-over before burning	505	74	380	210	1,169
	Nonrestocked cut-overs, clear cut before 1920	119	10	4	7	140
	42% of cut-overs cut between 1920-33, now nonstocked	245	17	7	33	302
	Subtotal for Oregon	869	101	391	250	1,611
Washington	Nonrestocked burns, not cut-over before burning	121	53	167	25	366
	Nonrestocked cut-overs, clear cut before 1920	457	51	2	15	526
	42% of cut-overs cut between 1920-33, now nonstocked	521	57	16	12	605
	Subtotal for Washington	1,099	161	185	52	1,497
Region	Nonrestocked burns, not cut-over before burning	626	127	546	235	1,535
	Nonrestocked cut-overs, clear cut before 1920	576	61	6	22	666
	42% of cut-overs cut between 1920-33, now nonstocked	766	74	23	45	907
	Total for Region	1,968	262	575	302	3,108

1/ Includes Indian tribal and trust allotments.

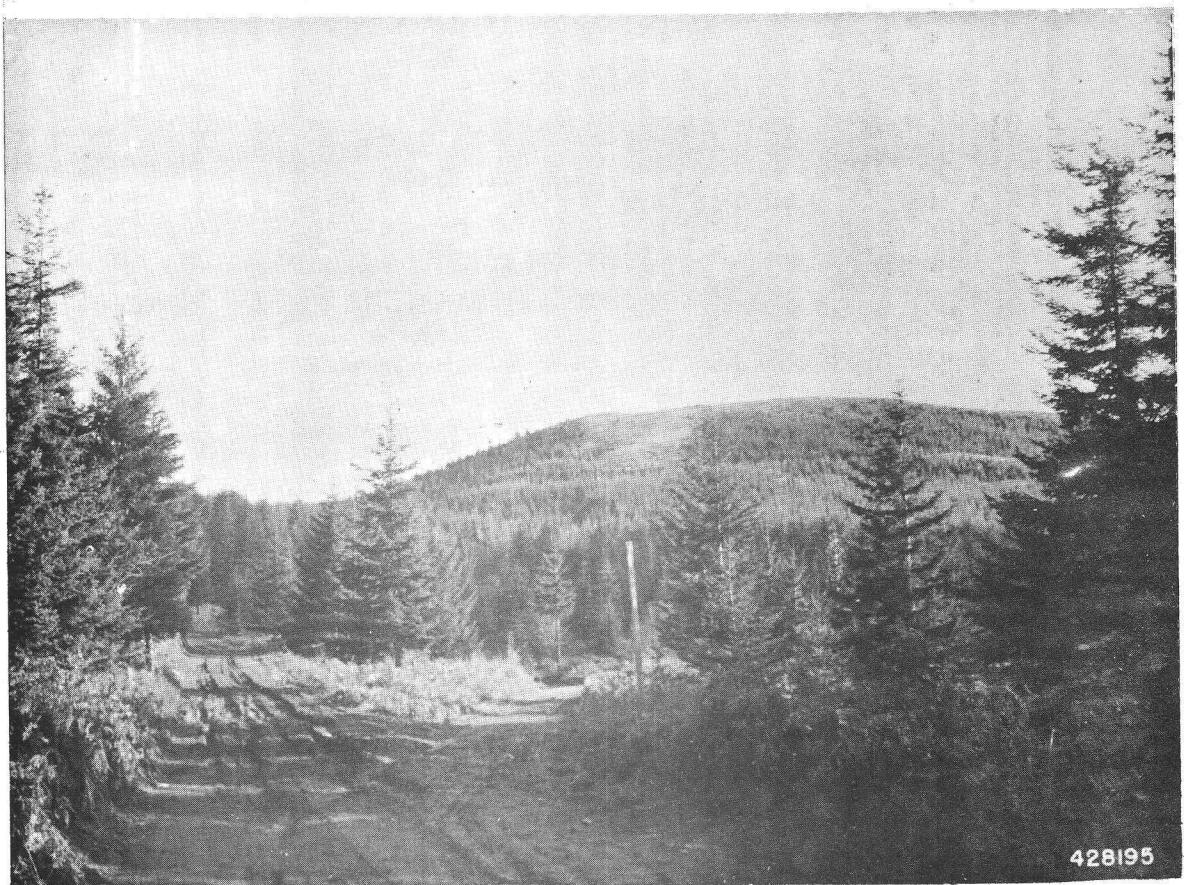
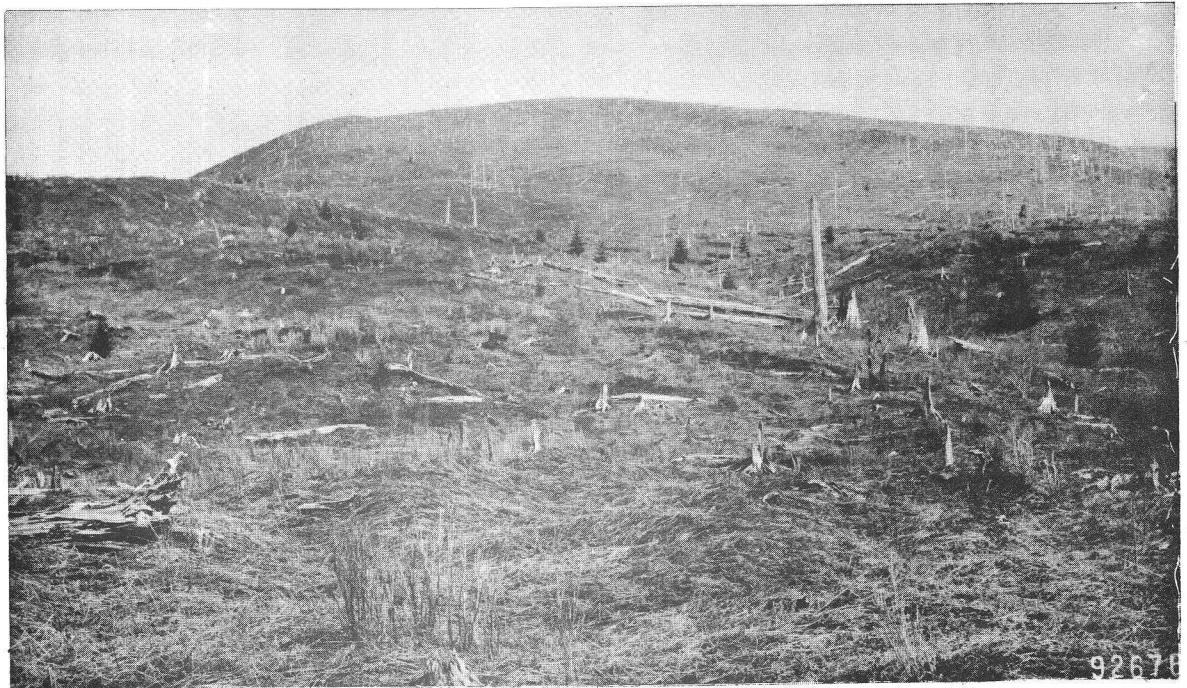


PLATE I. The western slopes of Mt. Hebo, Siuslaw National Forest.

- (A) In 1910 before planting, and after repeated forest fires.
(B) The identical area in 1943 as the result of planting in 1912-14.

History of Artificial Reforestation in the Region

Probably the first commercial planting of forest trees in the Pacific Northwest was the establishment in 1901 and succeeding years by the Willamette Pulp and Paper Company of several hundred acres of successful black cottonwood plantations on riparian land in Oregon. From then until the early 1920's nearly all of the artificial reforestation done in the region was on the national forests. Direct seeding was commenced by the Forest Service in 1908 and after several years' trial was discontinued, except for small experiments, in favor of planting nursery-grown trees. In 1910 the Wind River Nursery was established on the Columbia National Forest, and it has since then been continuously maintained as the major, and now only, nursery of the Forest Service, with a present output of 3,500,000 trees annually and a capacity of 5,000,000 trees.

In the decade following the first world war a few large lumber and paper companies engaged in a reforestation program (14). Four nurseries were operated by these companies, most of which were discontinued after a few years. With the output of these nurseries several thousand acres of plantations were established on privately owned cut-over lands in both Washington and Oregon. In 1942 the West Coast Lumbermen's Association built a large nursery at Nisqually, Washington with a rated annual output of 5 million trees, for the cooperative use of its members.

The City of Seattle built a nursery in 1925 to raise trees to reforest denuded lands in the Cedar River municipal watershed, a task that has now been about completed with the planting of between 4,000 and 5,000 acres.

Under the terms of the Clarke-McNary Act of 1924, and soon after the passage of this Act, both Oregon and Washington established federal-aid nurseries at Corvallis and Pullman, respectively, for raising trees primarily for the use of farmers for windbreaks and wood lots. The Oregon nursery now has an annual output of 1,600,000 trees and the Washington nursery at Pullman 80,000. In 1935 the State of Washington built a nursery on its Capitol State Forest near Olympia which now has a production of about 4,000,000 trees a year. On the Pack Demonstration Forest of the University of Washington is a small nursery for growing trees for forest planting and for experimentation.

Other federal agencies besides the Forest Service have within recent years established nurseries to reforest lands in their care--the Indian Service at Neah Bay, Washington, the Soil Conservation Service near Bellingham, Washington and Warrenton, Oregon, and the O. & C. Revested Lands Administration at McKinley, Oregon.

The forest tree nurseries of the region now operated by public agencies, together with that operated by the lumbermen's association, have an aggregate annual output of about 20 million trees, or enough to plant 30,000 acres a year. This could be increased easily by more intensive use of the land and facilities at these plants.

The neighboring province of British Columbia maintains two large forest tree nurseries and plants about 10 million trees a year.

For many years after the commencement of artificial reforestation in Washington and Oregon the area planted each year was only about 2,000 acres, nearly all on the national forests. Recently, as several other agencies have engaged in planting, the acreage has increased several-fold. The total area of successful plantations on the national forests is now 71,256 acres. The following table gives the reported (or estimated) acreages of successful plantations (and sowings) through 1942 by principal classes of owners:

Table 2.--Area Planted in Western Washington and Oregon

Planting agencies	Acres of successful plantations	
	Washington	Oregon
State and municipal ¹ /	25,531	1,500
Industrial companies ¹ /	13,800	4,650
Organization and schools (other than state)		265
Individuals ² /	1,668	4,090
Forest Service on national forest	41,833	29,423
Other federal agencies	5,000	5,000
Total by states	87,832	44,928
Total for western Washington & Oregon		132,760

¹/ Through 1941 only.

²/ Includes some farm planting east of Cascades.

If adjustments were made in this table for amounts planted in 1942 by certain agencies and for 1943 by all agencies and for the small area east of the Cascades included in these figures, the total of successful plantations would now be about 143,000 acres.



PLATE II-A. A steep sidehill on an old burn on Still Creek, Mt. Hood National Forest, planted 10 or 12 years previously, except for the area to the left.



PLATE II-B. A planted forest 30 years from seed on Wildcat Mt., Mt. Hood National Forest, in which the trees are from 30 to 40 feet tall and 8 to 10 inches in diameter.

CHAPTER 2. SEED

Importance of a Supply of Proper Seed

A supply of seed of good quality, proper parentage, and of reasonable cost is a basic requirement for the successful production of nursery stock or for direct seeding. When the reforestation project is to continue for a number of years, the supply should be adequate for several years' needs in order to tide over a possible seed crop failure.

There are several commercial tree seed collectors in the region and many dealers throughout the country who handle seed suitable for planting here.^{2/} If seed is to be purchased, it is advisable to place orders in advance of the collecting season to insure delivery. It is often possible and preferable for the landowner to collect his own seed; he may thus have greater assurance of obtaining seed suited to the area to be reforested.

Production

The seed of different trees varies greatly in character and in the manner in which it is produced. This has considerable bearing on the methods employed in collecting and processing. Flowers are produced in the spring, pollinization takes place, and the seed ripens later in the same year, or, in the case of a few species, such as the pines and Alaska yellow-cedar (*Chamaecyparis nootkatensis*), in the second year. In most species male and female flowers occur on the same tree. Because of this the individual seed may inherit the qualities of the single tree on which it is produced, or of two separate parent trees.

The majority of local species bear their seeds in multi-seeded fruits in the form of cones, capsules, or berries. As the seed within such fruits are too small to be collected individually after dissemination, except under rare conditions, it is the common practice to gather the fruits and extract the seed from them. Some species, like oaks, have single-seeded fruits. The type of fruits produced by various species and the time of ripening are indicated in table 3.

Extremes in size and shape of cones are represented by the large cylindrical cones of sugar pine, 12 to 20 inches long and $2\frac{1}{2}$ to $3\frac{1}{2}$ inches wide when unopened, and the small, almost spherical cones of Port Orford white-cedar, only $1/3$ -inch in diameter. The number of seeds per cone ranges from a few to several hundred. However, some of the seeds are hollow or otherwise undeveloped. Cones also differ in the manner in which the seed is released. For most species, the cone scales merely spread apart and the cone remains intact on the branch. In cones of the balsam firs (*Abies* spp.) the scales fall away entirely leaving only the central stalk. The capsules of cottonwood

^{2/} Names of dealers in seed and nursery-grown trees for forest planting are obtainable from the Regional Forester, Portland, Oregon.

Table 3.--Type of Fruit and Time of Ripening of Some Pacific Northwest
Trees

Species	Type of fruit	Time of ripening
Douglas-fir	Multi-seeded cone	Fall
Western hemlock	Small multi-seeded cone	"
Western redcedar	" " "	"
Port Orford white-cedar	Small spherical multi-seeded cone	"
Pines	Multi-seeded cone	"
Balsam firs (Abies)	Multi-seeded cone which falls apart	"
Spruces	Multi-seeded cone, papery scales	"
California incense-cedar	Small cone with two seed-bearing scales	"
Larches	Multi-seeded cone	"
Junipers	3- or 4-seeded bluish-black "berry"	"
Pacific yew	Single-seeded, fleshy red "berry"	"
Alders	Multi-seeded cone	Late fall
Ashes	Clusters of simple seeds	Fall
Birches	Multi-seeded cone which falls apart	Spring
Cascara buckthorn	Small clusters of 2-3 seeded berries	Late summer
Cottonwoods	Clusters of multi-seeded capsules	Spring
Pacific dogwood	Single seeds in headlike clusters	Late summer
Bigleaf maple	Seeds in pairs or in clusters	Fall
Pacific madrone	Clusters of small multi-seeded berries	Late fall
Oaks	Single acorns	Fall
Willows	Clusters of small multi-seeded capsules	Spring

(*Populus*) and willow (*Salix*) are quite small, are borne in tassel-like clusters, and contain a very large number of tiny seeds. The spherical berries of Pacific madrone are seldom over $\frac{1}{2}$ -inch in diameter, are borne in large clusters, and contain several seeds. The berries of cascara buckthorn (*Rhamnus purshiana*) are somewhat smaller, occur in small clusters, and contain only two to three seeds. The single seed of the yews (*Taxus*) has a bright red, berry-like, fleshy covering. Most species are provided with devices for wind dissemination, such as the membranous wings of nearly all the coniferous species and of several of the broadleaf trees, and the silky threads of willows and cottonwoods.

The age at which trees commence to produce seed varies between species and to some extent between individuals within the same species, depending upon the conditions under which the tree is growing. Trees located in the open, free of competition for light and nourishment, often produce seed several years earlier than those in a forest. It is not uncommon for Douglas-fir in the open to commence bearing at 15 years of age, and instances of earlier bearing have been reported. In fairly dense stands the time is more commonly 20 to 30 years.

Of very practical significance to the tree planter in maintaining an adequate seed supply is the fact that the abundance of the crop of most species varies greatly from year to year. A good crop will be interspersed with one or more light crops, and occasionally with an almost total failure. Exceptions to the prevailing condition may occur in restricted localities. Good crop years do not necessarily coincide for all species in a region, although frequently they may for many of them. In a light crop year, not only is production less but also the proportion eaten by birds and rodents or destroyed by insects is usually increased due to the limited supply, thus further reducing the amount available for collection.

A rating made annually by the Forest Service of the Douglas-fir cone crop in western Oregon and Washington indicates (25) that in the 33 years from 1909 to 1941 the crop was on the average a "failure" 7 times, "light" 13 times, "medium" 6 times, and "abundant" 7 times.

Collection of Seed of Coniferous Trees

Since the species most commonly used in artificial reforestation in the Douglas-fir region are cone-bearers, the following discussion of collecting will deal primarily with the methods used in gathering cones. Cones may be collected (1) by picking from standing trees, (2) by gathering from felled trees, or (3) by taking piles stored on the ground by squirrels.

Since most kinds of cones open soon after maturity, the collecting period is comparatively short. This necessitates advance scouting to determine the location of a good collecting area within the provenance decided upon and to complete organization of the operation before

the collecting period arrives. From the standpoint of economy a good collecting area should have an adequate number of heavily bearing trees, the cones should be of good quality, and the area should be accessible. Trees of a size suitable for climbing are an additional requirement when cones are to be obtained from standing trees.

Source of Seed for Planting and Direct Seeding

That the trees in the planted forest may possess desirable qualities of hardiness, rapidity of growth, good form, and resistance to disease, it is important to collect from proper parent trees. Two considerations should be kept in mind: (1) To collect from only thrifty, well-formed individuals not affected with any defects or weaknesses likely to be hereditary, and (2) to collect from a locality where climate and site are similar to those of the area to be planted.

Choosing the Right Individual Parent Trees. There is evidence to indicate that certain characteristics of a parent tree, like immunity from diseases and spiral grain, are transmitted, but not so acquired characteristics, like limbiness of an individual tree growing in the open. Of course with conifers, only the mother parent is known; furthermore, many of these individual characteristics of parent trees which should be favored or shunned are not easily recognized. It is a good rule, however, to obtain seed only from sound vigorous specimens, and to buy seed only from dealers who are known to practice this discrimination in collecting their cones and fruits.

Experiments reported by Munger and Morris^{3/} (41) showed that neither the age of the mother parent, its growing space, the soil, nor infection with conk rot had any effect on the early growth of the progeny.

Choosing the Right Regional Races. It is well known that there are various regional races of Douglas-fir and their characteristics are persistent wherever planted. The differences in the Douglas-fir of the Rocky Mountains, of the northern interior, and of western Washington and Oregon are conspicuous; some botanists separate them into two species and two varieties. There are also within the last region various locality strains whose progeny behave differently when planted together.

It has been repeatedly observed at the Wind River Nursery that the progenies of seed from higher altitudes or more northern latitudes start growth earlier in the spring and complete growth earlier in the fall than the native stock, thus suffering more from late spring frosts. Conversely, trees from warmer regions planted in cooler localities start growth later and continue later into the fall, thereby being subject to fall frosts.

^{3/} Munger, Thornton T. & Morris, William G. Further data on the growth of Douglas-fir trees of known seed source. Pacific Northwest Forest Expt. Sta. 1942. Mimeo.

The growth rate of high-altitude Douglas-fir is inherently slower than that of low-altitude strains; it may be stimulated somewhat by planting at low altitudes, but it does not equal that of low-altitude strains planted in their home habitat.

The environmental factors that create these regional races are not well known; of temperature, precipitation, and soil moisture the first is undoubtedly the most potent. It is related to changes in altitude and latitude, which are very pronounced in this region. Temperature is a factor both in determining the length of the growing season and the prevailing degree of warmth, i.e., both in extremes and averages that might affect a tree's development. The rate of growth of trees is also affected by the moisture supply, but it is not known to what extent dependence upon moisture or ability to maintain a good growth without much moisture is hereditary in certain strains. Obviously the safest course is to obtain seed from a locality whose growing season and precipitation do not depart greatly from that of the planting site.

Without scientific proof of the effect, if any, of soil on hereditary traits, it seems safe to follow a similar course with regard to soil. Since Douglas-fir is adapted to a wide range of soil types, minor differences in soil between locality of seed origin and the planting area can well be disregarded, yet it is wise to avoid use of seed produced on abnormally bad soils.

In addition to the desirability of using seed from a provenance that fairly well matches the planting site, there are apparently certain strains that wherever planted show superior growth to other strains. Munger and Morris, in the experiments already cited, found evidences of such superior strains, which seem to be associated with the optimum habitat of the tree--in this case, Douglas-fir. Seed collectors should, therefore, not only try to match the environmental factors of seed source and planting site but they should also seek out the strains of each species that are optimum in vigor and growth rate and use them wherever appropriate.

Classification of Seed Sources. In a pamphlet issued by the Forestry Department of the Long-Bell Lumber Company (31) six seed sources, based on elevation and frost-free period, were defined for convenience of seed buyers. Kummel, for Forest Service practice, has recommended two latitudinal zones of three altitudinal zones each. Munger⁴ has divided the region into nine provenances for purposes of correlating seed collecting with planting, as follows:

- Northern fog belt.
- Southern fog belt.
- Northern valleys.
- Willamette-Umpqua Valleys.

⁴/ Munger, T. T. A subdividing of the Douglas-fir region for purposes of correlating seed collecting with planting. 1942. Ms.

Rogue River basin.
Lower slopes in Washington.
Lower slopes in Oregon.
Upper slopes in Washington.
Upper slopes in Oregon.

These are shown diagrammatically on a map of Washington and Oregon (figure 1). Munger in explaining this classification says:

"Each of these 9 provenances is thought to be fairly homogeneous climatically, but there are very sharp local variations, like that between north and south exposures which the seed collector and planter must take account of. In setting up these provenances there is no implication that seed from one cannot be used successfully in planting on another. In fact there is some reason to believe that the seed from some regions will produce superior progeny wherever planted and likewise some seed will always produce inferior progeny even when planted in a more favored region. Hence, while for general practice it may be well in planting to use seed collected in the same provenance, yet on an experimental basis at least there should be some planting of progeny from the superior provenances in the next most similar zones.

"In seed collecting there are certain parts of some of these divisions which should be avoided, but which cannot be recognized as separate provenances in this very broad classification--such as wind-swept passes, the Columbia Gorge, the seaward frontage, ridge and mountain tops, and perhaps areas of particularly bad inferior timber.

"While altitudinal limits are a primary criterion in defining these provenances they must not be followed too arbitrarily. Sometimes the head of a mountain valley at 1,000 feet elevation will actually have the climate of the encircling 3,000-foot hills, and vice versa."

The U. S. Department of Agriculture in 1939 issued a seed policy for guidance in all tree planting by that Department; it prescribes, in part, as follows:

- "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.....
- "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.....

PACIFIC OCEAN

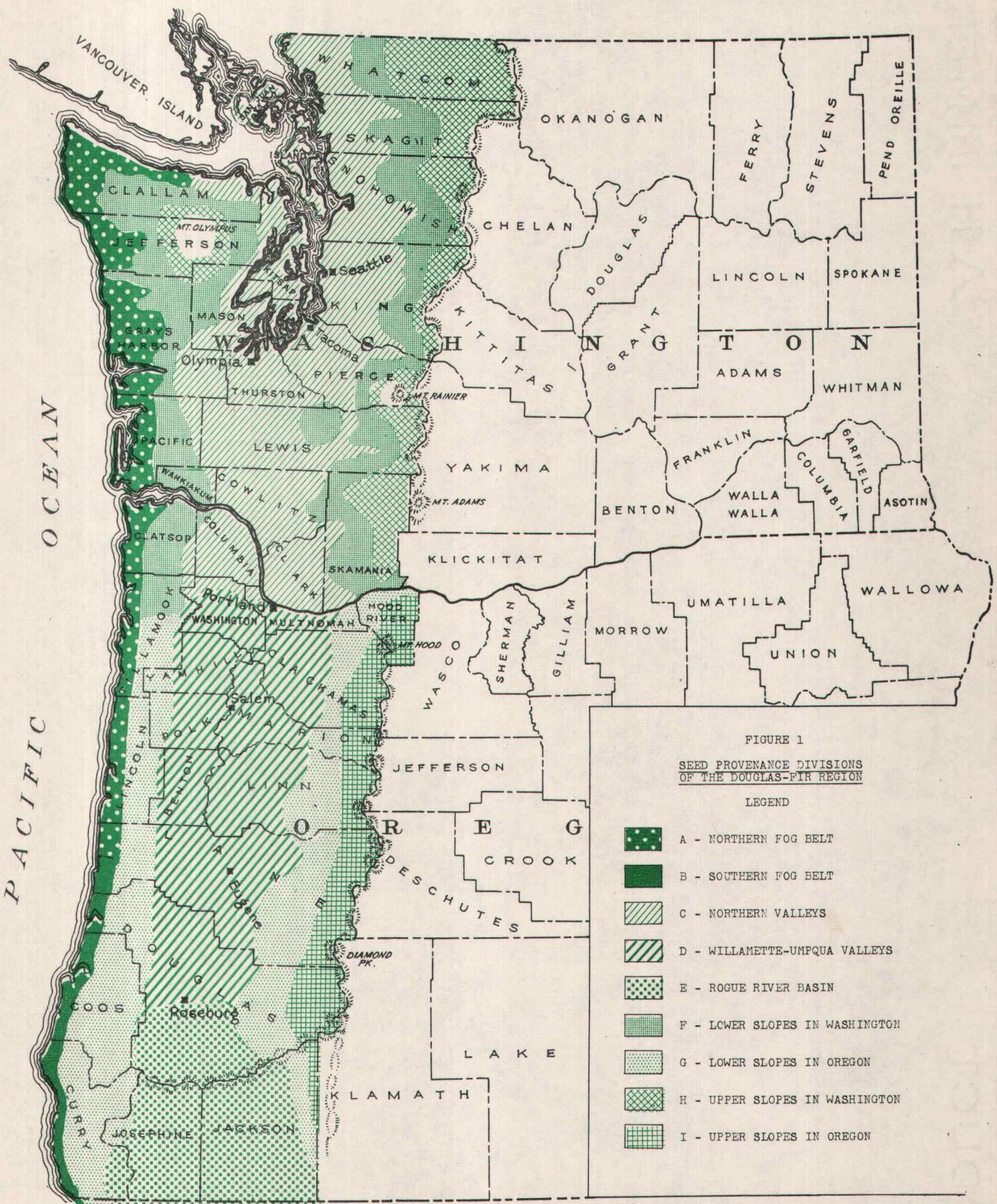


FIGURE 1

SEED PROVENANCE DIVISIONS
OF THE DOUGLAS-FIR REGION

LEGEND

- | | |
|--|--------------------------------|
| | A - NORTHERN FOG BELT |
| | B - SOUTHERN FOG BELT |
| | C - NORTHERN VALLEYS |
| | D - WILLAMETTE-UMPIQUA VALLEYS |
| | E - ROGUE RIVER BASIN |
| | F - LOWER SLOPES IN WASHINGTON |
| | G - LOWER SLOPES IN OREGON |
| | H - UPPER SLOPES IN WASHINGTON |
| | I - UPPER SLOPES IN OREGON |

- "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....."

Instances of Improper Seed Sources. The results of early planting now show in several instances the disadvantages of using stock whose hereditary strain was not suited to the site. On a 1912 plantation on the Mt. Hood National Forest, ranging from 2,600 feet to 3,200 feet in altitude, stock from low altitude seed made about a third better height growth on the lower edge of the plantation than on the upper edge in 5 and in 10 years. This may be due partly to inherently better growing conditions in the lower zone, but is thought to be due also to unsuitability of the low-altitude strain to the 3,000-foot elevation.

The Mt. Hebo plantations on the Siuslaw National Forest show a marked difference in their behavior on the high and low elevations. Assuming that the entire project had a sufficiently similar mild, moist coastal climate, low-altitude seed was used throughout the range of elevations from about 800 to 3,150 feet. Now 20 to 25 years after the main portions of the plantations were established a pronounced variation in the condition of the trees at different elevations is noticeable (plate III). The plantations on the higher slopes have been declining steadily in survival and thrift. Though survival the first year after planting was fair to good, a very large proportion of the upper slopes now has less than 100 trees per acre. Two experimental plots near the top of the mountain at 3,100 feet elevation had 78 and 86 percent survival the first year, 40 and 60 percent, respectively, in the third year, and none in the tenth year. The few trees which have persisted are stunted and unthrifty to a degree far beyond what could conceivably be due to the influence of altitude alone; the site is well within the natural habitat of high-grade Douglas-fir forests.

Other species than Douglas-fir likewise are undoubtedly represented in the region under discussion by various regional races or strains, and the same principles in selecting the source of seed should be used as research and experience has proven wise in the case of Douglas-fir, namely:

- (1) Collect seed from trees of good form and vigor.
- (2) Select a locality for obtaining seed where the environmental factors are similar to those of the planting site.
- (3) Select a seed source, if possible, that both complies with "(2)" above and coincides with the optimum development of the species.

Selecting an Area for Efficient Collecting

Characteristics to be looked for in judging cone quality are the proportion of sound seeds and the size of the cone. The proportion of viable seeds depends upon the number of seeds in which the kernel has developed normally and upon the amount of insect infestation. Old and over-mature trees are generally believed to have a larger percentage of unfilled seeds than thrifty trees of younger age. Some insect infestation is usual but in some years and localities it reaches epidemic proportions, with the result that a very large percentage of the cones are attacked and most of the seed destroyed. It is often particularly bad in years of light crop. The damage is caused by the grubs of a great many different kinds of insects (28) and may affect both cones and seed, or seed only. In the former case, the presence of the grub is indicated by an abnormal shape of the cone or by an accumulation of borings and pitch visible between the scales or adhering to the outside. In the case of insects that infest the seed only there is no outward evidence of their presence and the seed must be cut open to disclose the larvae.

A good method of judging the seed content of a cone is to cut it lengthwise through the center thereby exposing a cross section of a number of the seeds. A plug tobacco cutter or a sharp hatchet are good tools for this purpose. The proportion of seeds with full kernels can then be counted; each good seed thus exposed in a Douglas-fir cone represents a yield of approximately one ounce of clean seed per bushel of cones, according to a rough rule of thumb of collectors. When the number of good seeds thus disclosed averages less than 3 per cone they are usually considered unsuitable for collecting. Size of cone is of less importance in judging quality than seed content, yet it is worthy of consideration when a choice exists between localities or individual trees. Large cones produce large seeds, and large seeds are generally recognized as of superior quality. Large cones also usually average more good seed per cone and hence make for a lower seed cost. Cones on young and middle-aged trees generally average larger than those on old and overmature trees.

Estimate of the probable seed yield for a given locality can be made by sample counts of the number of cones on representative trees and the number of trees per acre, and then applying the data given in tables 4 and 5 on the number of cones per bushel and the pounds of seed per bushel of cones. Allowance must be made for reduced yield when insect damage is excessive.

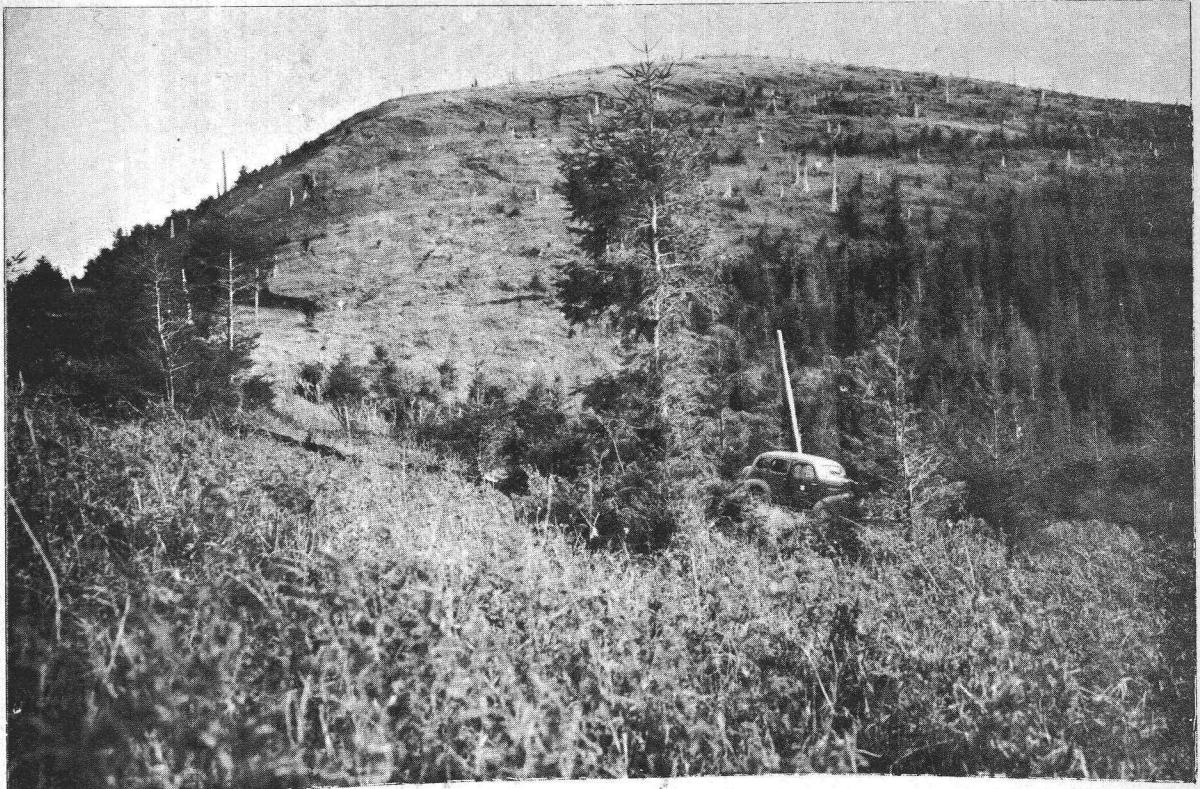


PLATE III. Two areas on the slopes of Mt. Hebo, Siuslaw National Forest, planted at about the same time and photographed in 1943.

- (A) On the wind and fog swept ocean-facing upper slopes (elevation about 2,700 feet) where the trees planted about 1915 have done very poorly due to their unsuitability to the local climate.
- (B) On the lower slopes at an elevation of about 1,200 feet where the trees are thrifty and growing very fast.

Table 4.--Measured or Computed Number of Closed Cones Per Bushel
for Various Species

(Quantities vary greatly between individual trees,
localities, and years)

<u>Species</u>	<u>Average number</u>
Douglas-fir	1,000
Western hemlock	20,000
Western redcedar	45,000
Port Orford white-cedar	35,000
Noble fir	60
Shasta red fir	50
Grand fir	240
Pacific silver fir	80
Lodgepole pine	2,500
Ponderosa pine	195
Sugar pine	20
Western white pine	75
Engelmann spruce	2,000
Sitka spruce	1,300
Red alder	13,000

Table 5.--Representative Yield for Various Species of Mill-Cleaned Seed from One Bushel of Cones, and the Number of Seed Per Pound

(Quantities will vary greatly in different localities and years)

Species	Mill-cleaned seed per bushel of cones <u>(Lbs.)</u>	Number of seed per pound
Douglas-fir	.5	40,000
Western hemlock	1.0	300,000
Western redcedar	1.5	400,000
Port Orford white-cedar	3.0	160,000
Noble fir	1.75	16,000
Grand fir	-	19,000
Pacific silver fir	2.5	12,000
California incense-cedar	1.5	14,000
Lodgepole pine	-	100,000
Ponderosa pine	1.25	10,000
Sugar pine	1.4	2,300
Western white pine	.5	22,000
Sitka spruce	.75	250,000
Red alder	.9	500,000

Methods of Collecting

Open-grown trees usually bear more heavily than those in dense stands, and because of their long crowns, are more readily climbed. Old logged-off areas, with an open stand of second growth, and partially cleared pasture lands with a sprinkling of isolated trees often make ideal collecting areas. Picking of Douglas-fir cones from felled trees on logging areas is seldom practical in dense forests when any considerable quantity of cones is desired. The number of cones per tree is relatively small; a considerable proportion of them will be shaken off and lost as the tree falls, or difficult to find in the heavy litter on the ground; those that remain attached to the branches are difficult to get at because of the great mass of impeding debris. It is a method suitable only for the larger-coned species, such as sugar pine, ponderosa pine, and western white pine, and then only when the ground vegetation is comparatively light. Falling or topping trees solely for their cones is a wasteful practice and should be discouraged.

Collecting from squirrel hordes or stores or "caches" is often the cheapest method, but is not generally applicable to the Douglas-fir region because of the scarcity of squirrels in some localities. Where squirrels are present cones will be found scattered on the ground beneath the trees or packed away in small piles along the underside of down logs, in crevices in logs and stumps, in cavities dug in the pile of accumulated cone fragments at the base of trees, or in low places subject to intermittent submergence in water. This method of collecting can be continued late in the season, some weeks after picking from trees ceases, since the cones in the caches do not dry out and open quickly.

In collecting from standing trees, a few cones may be reached from the ground, but since the majority occur in the middle and upper crowns, climbing is usually necessary. This requires the use of climbing spurs when the lower branches are out of reach. Ladders are sometimes used, but they are cumbersome and not very well adapted to rough ground or to areas where the bearing trees are widely separated.

Poles equipped at one end with various-shaped irons are useful for obtaining the cones on the extremity of branches, either by pulling the branch within reach of the hand or by detaching the cones at a distance. Several of these are described by Toumey and Korstian (57). One that has been found effective in this region may be made readily from a discarded 10-inch flat file, auto spring, or similar material, by splitting the iron lengthwise part way down from the tip and bending the two halves in opposite directions to form two crescent-shaped hooks. (Figure 2.) By sharpening the concave edges of each hook and the convex edges at the V where the two halves separate, the cones can be detached either by a pull or a push without bending the branch.

Cones within reach of the hand are usually placed in a bag carried by the picker; those cut off at a distance drop to the ground and must be picked up later. Obviously the latter method is practical only with the

larger cones, and it is at a disadvantage when the ground vegetation is so dense that the cones are not readily located after they fall. Its use with the balsam firs may lead to shattering the cones upon striking the ground, especially near the end of the collecting season when they are about to fall apart.

Since many species of cones are very pitchy, pickers should carry a supply of kerosene to wash their hands and gloves frequently. Inclusion of tree needles and other trash should be avoided, as their presence adds to the work of extraction later at the kiln. Sacked cones awaiting transportation to the kiln should be stacked with space around each sack to avoid heating and molding.

Time for Collecting

The progress of the cones toward maturity should be watched carefully if advantage is to be taken of the full length of the collecting period. Although there is evidence that the maximum germination capacity of the seed is not reached, at least for some species, until the time of release from the cone, postponement of collecting until this time is out of the question when large quantities of seed are required. The alternative is to commence collecting just as soon as the seed is sufficiently mature to give satisfactory germination. This is not readily determined by inspection of the cones alone, since most species change little in outward appearance until about ready to open, nor is the beginning of cone-cutting by squirrels a reliable index, as commonly believed. It is best to examine the seed itself. As seed approaches maturity, the seed coat darkens and the kernel changes from a milky consistency to a firm pulp with a light yellowish-green embryo in the center.^{5/}

For most species, the collecting period lasts two or three weeks and occurs between the last week in August and the latter part of September. It commences earlier at low and intermediate altitudes in the southern portion of the region and becomes progressively later toward northern Washington and at higher elevations in the mountains. Exceptionally high temperatures or low humidity after the cones are mature may shorten its duration appreciably by hastening the drying out of the cones, and the opposite condition may prolong it. A spell of rainy weather after a part of the seed has been released may cause the cones to close again temporarily.

^{5/} Recent investigations (32) of ponderosa pine seed production in central Idaho disclose a close correlation between the specific gravity of the cone as it approaches maturity and the germination capacity of the seed. As the former decreases due to loss of moisture, the latter increases until at a specific gravity of 0.86 the seed is sufficiently mature to give satisfactory germination. These findings suggest the use of specified gravity determinations of the cone as a reliable index to maturity. Since the procedure for determining specific gravity is simple and readily adapted to field use, this method gives promise of wide applicability in cone collecting when the proper specific gravity for each species is worked out.

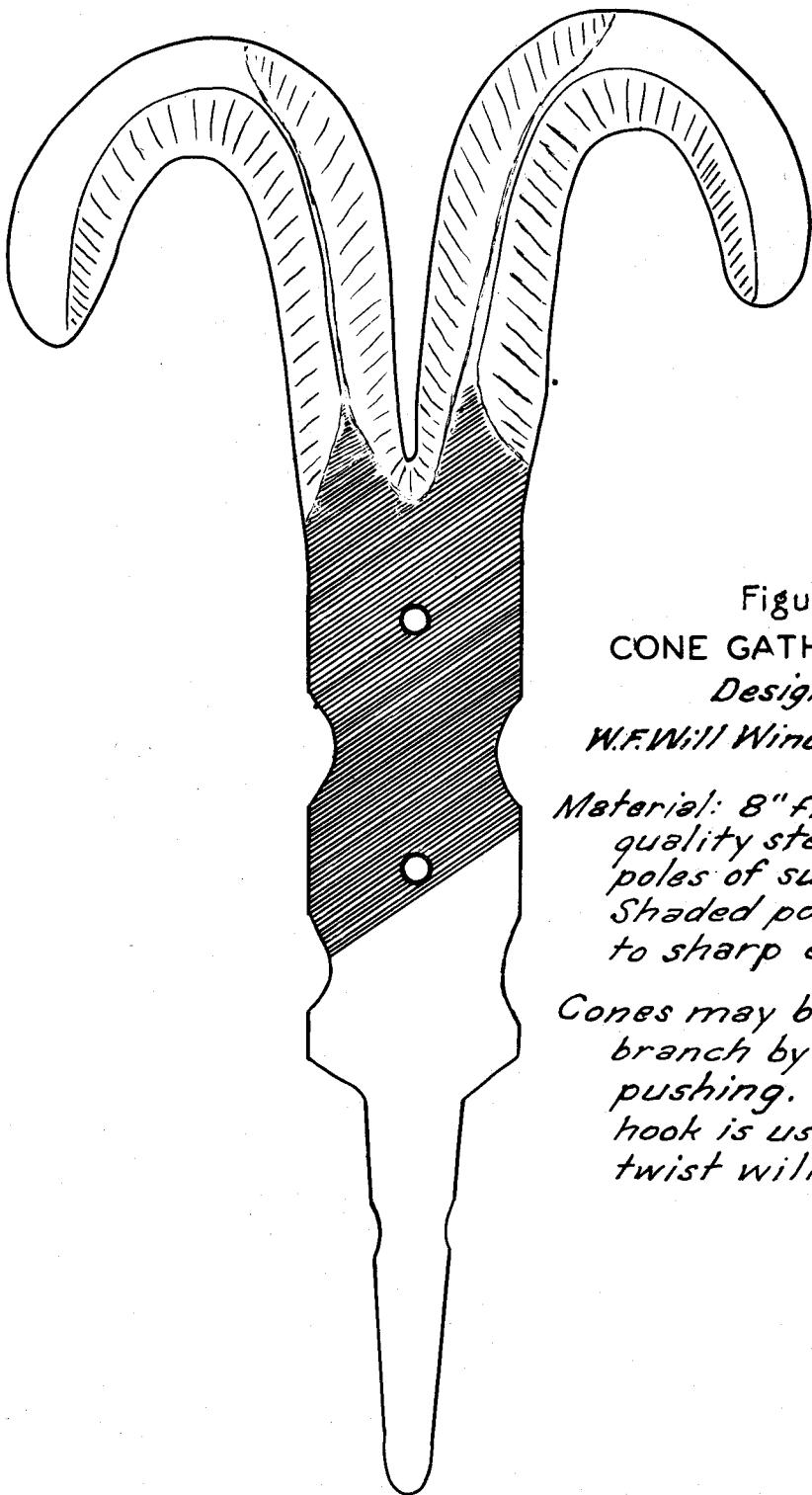


Figure 2
CONE GATHERING HOOK
Designed by
W.F.Will Wind River Nursery

Material: 8" file or similar quality steel. Attach to poles of suitable length. Shaded portion ground to sharp edge.

Cones may be cut from branch by pulling or pushing. When fork of hook is used, a slight twist will detach cone

Occasionally cone collecting can be dispensed with and the seed obtained directly from the opening cones by spreading sheets on the ground and shaking the branches of the trees. This method unquestionably yields seed of highest quality. It is especially advantageous with small-coned species such as Port Orford white-cedar, western redcedar, and western hemlock, whose cones are laborious to pick. It has also been used successfully with ponderosa pine. However, it should not be relied upon to the exclusion of other methods when large quantities of seed are desired for it requires careful coordination with the time of cone opening and a quiet atmosphere, and the collecting period is short.

Collection of Seed of Trees Other Than Conifers

Large, single-seeded fruits like acorns are readily gathered after falling to the ground. This method is suitable also for maple and ash seed when ground conditions are such that wind-blown seed accumulates in piles along sides of logs, in depressions, and in rock crevices, or where the absence of dense vegetation permits raking up the seeds. Otherwise, these species, the single seeds of yew, dogwood "heads," and the various berries are obtained by picking from the standing tree. The fact that many occur in clusters facilitates collecting by this method.

The season for collecting the seeds of the broadleaf trees is more variable than that of the conifers. While the majority of them mature their fruits and seeds in the fall, that of some species ripens earlier in the season and must be collected then before they shatter. Birch (Betula) seed is mature in late spring or early summer; red alder on the contrary is not ripe until November.

Cone Purchase

Purchase of cones from individual collectors is a common practice in the Douglas-fir region, particularly when the kinds desired are the better-known species. In good crop years, residents of the forest and rural areas are quite ready to collect and deliver cones at designated centers at contract prices. This method has the advantage of relieving the purchaser of the work of assembling and supervising a collecting organization; he knows definitely what the cost per bushel will be, and this cost is often less than that of collecting with his own organization. Its disadvantages are that he cannot positively regulate the source of the cones, except as he may confine his purchases to selected localities; only with much supervision could he have control over the character of the parent tree; and he runs some risk of not filling his entire requirements.

The prevailing unit of measurement for the purchase of cones is the bushel and they are commonly delivered in sacks of two or so bushels capacity. In some portions of the country, purchase by weight is practiced, but not favored in this region. With weight as the unit, the purchaser should guard against cones collected too green, and increase in weight due to accidental exposure to rain or to intentional watering.

With volume as the unit, he should guard against short measure and shattered seed due to partially opened cones; he should stipulate when collecting is to begin and stop. In either case, he must guard against the inclusion of undue amounts of trash.

To make contract collectors careful in their picking, to refrain from including insect-infested cones, the practice is occasionally followed of paying on the basis of the number of sound seed found in cross sectioning samples of the cones, following the hypothesis given above that each good seed exposed in a lengthwise section of a Douglas-fir cone represented an ounce of clean seed to every bushel of cones.

Shipping and Labeling Cones

The sacks used in storing and shipping cones should be seed tight, not made of loosely woven material, in order that seed shattered from the ripening cones may not be lost.

Every sack (or lot) of cones, whether purchased or collected by the user himself, should be tagged to make sure that it can be identified as to source and collector. The tag should contain at least the following items:

Species
Method of collection (standing trees,
 felled trees, squirrel stores)
Character of parent tree (mature or young,
 open or forest grown)
Locality (by land survey and by physical
 features)
Altitude and aspect
Name of collector
Date of collection

Sacked cones held for shipment should be stacked loosely; those in transit should be piled tightly for as brief a time as possible, so as to keep the danger of "heating," due to the beginning of fermentation, down to the minimum. For freight shipments, stock cars are preferable to tight boxcars.

Extraction of Seed from Cones

Seed produced in multi-seeded fruits must be extracted before it is suitable for use. Cones and capsules are dried, then shaken or threshed. Berries may be macerated in water or run through a hammer mill to remove their pulp (51). The pulp covering of the single seeds of yew and those of Pacific dogwood and cascara buckthorn may be removed thus, or these seeds may be stratified or fall-sown without the removal of the pulp. Facilities required for the treatment of cones after collection must provide for cone storage, for drying, for extraction, and for the final processing of the seed. The character of these

facilities and the equipment used will depend upon species, the magnitude of the operation, the permanence of the activity, and upon local climate.

Storage of Cones at Extraction Plant

As cones are likely to accumulate at the extraction plant faster than they can be processed, storage must be provided that will protect against rain and rodents, prevent heating and molding, and permit expeditious handling with a minimum of labor. For relatively short periods of storage, cones may be left in their original sacks stacked loosely on pole racks in an open shed with space for air circulation. (Plate IV.) If very green or wet, or if they are to be stored for a long time, it is preferable to remove the cones from the sacks, spread them on racks in layers not over 10 inches deep, and stir them occasionally. This should avoid heating and molding, facilitate precur-ing, and allow room for them to expand. With partial drying under pressure, or with molding, the cone scales are likely to become "set" and will not respond to further drying. Deep bins of large capacity are far less satisfactory than racks, and are more difficult to empty since cones under pressure of the weight of those above will not flow out readily from an opening in the bottom of the bin.

Air Drying

Drying cones at prevailing air temperatures outdoors is of rather restricted applicability to the Douglas-fir region because of the cool, damp weather usually prevailing in the fall. Air drying has the advantages over kiln drying of avoiding possible injury to the seed by overheating and of requiring relatively simple equipment, but it is subject to the vagaries of the weather; it is at best a slow process and causes cones to open unevenly or only partially. Air drying is suited best for small quantities of cones requiring little drying space and for small-coned species which dry quickly, such as western hemlock, Port Orford white-cedar, western redcedar, and alder. Under favorable conditions cones of these species will open in a few days at normal air temperatures. Douglas-fir, spruce, the balsam firs, western white pine, and sugar pine ordinarily require one to several weeks. Lodgepole pine is still more resistant to normal air drying.

For indoor air drying the cones may be spread out on a tight floor, on canvas sheets, or, to save space, on trays or shelves arranged in tiers. They may be distributed at the rate of approximately one bushel per 15 to 20 square feet. The layers of cones should be shallow, or much labor will be required to stir them frequently. Good air cir-culation from open windows or doors, or by electric fans, will hasten drying materially. Drying out of doors to obtain the benefit of expo-sure to sun and wind is feasible only in locations where clear weather and a minimum of night dew can be counted upon.

Kiln Drying

Drying with artificial heat is the common practice in the Douglas-fir region when any considerable quantity of cones is to be treated. The higher temperatures, together with the resulting lower relative humidity of the air, induces more rapid evaporation than at normal temperatures, and the operation is little affected by outside weather conditions. Shortening the drying period greatly reduces the space required. The drying plant or "seed dehydrator" may be either a temporary installation in any available building or even a tent, or a specially designed kiln equipped for permanent use. Ordinarily the temporary type will be less efficient than the permanent type, but for small operations of uncertain tenure its lower first cost may make it preferable. Whether temporary or permanent, its location should be central to the collecting area to avoid heavy transportation costs of cones, and at the same time it should be accessible to sources of labor and supplies. A lumber kiln, prune drier, or nut drier could be used if its design permits economical operation with the quantity of cones to be treated.

Temporary Seed Kilns. In selecting and outfitting a building for a temporary kiln, several considerations should be kept in mind. Space for spreading out the cones may be provided either by tiers of rigid racks or movable trays. Preferably, the bottoms should be of wire screening to facilitate air circulation. The size of the mesh may be such as either to allow the loosened seed to drop through to cooler temperatures below or to retain it within the rack. The former has the distinct advantage of lessening the danger of injury by overdrying. However, it leads to more or less scattering about of the seed and increases the difficulty of keeping the seed separate when different lots of cones are dried simultaneously. To retain seed of the native conifers, a mesh of 16 to the inch is needed; to allow it to pass through, a mesh of 2 to the inch is suitable for all except the small-coned species. With too large a mesh, the open cones tend to be caught by their tips and scales and are difficult to remove.

Fixed racks should preferably be accessible from two sides. This can be accomplished either by extending the tier at right angles to the side walls or, if placed parallel, by leaving adequate passageways between tiers. Racks accessible from only one side should not be over 4 feet wide. The vertical space between successive racks in a tier should be at least 16 inches to facilitate workmen reaching all of the cones.

Though somewhat more expensive to construct, trays have several advantages over fixed racks; they can be more easily filled and emptied; their positions can be shifted to promote uniform drying; they are easily shaken; they facilitate keeping cones of different species or from different localities separate; they are readily stored for future use. For easy handling, they should not exceed 3 feet x 4 feet in size; they may be spaced from 2 to 4 inches between bottoms and tops, depending on the size of cone.

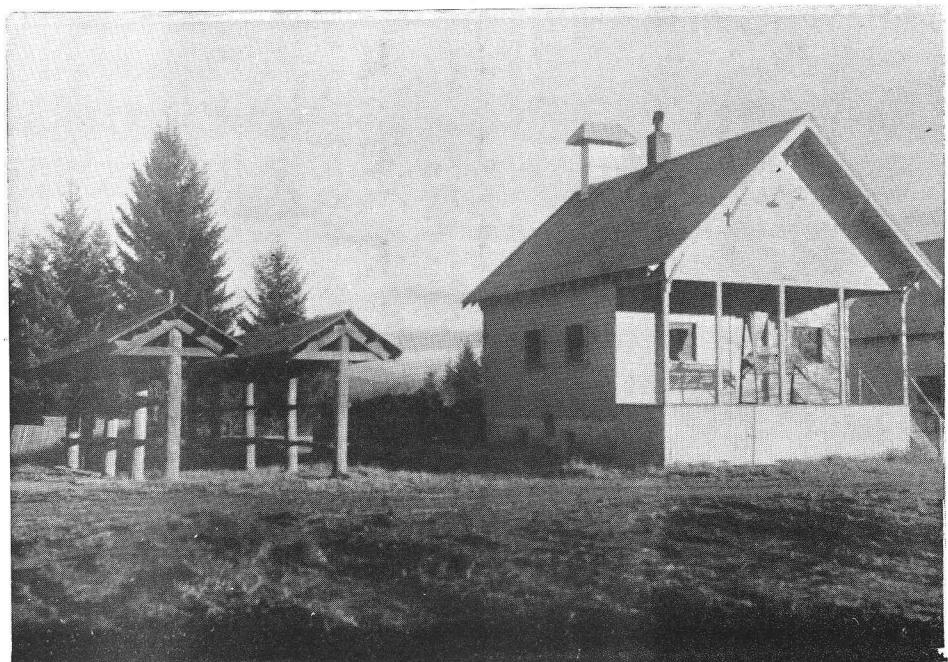


PLATE IV. The seed kiln at the Wind River Nursery, Columbia National Forest. On the left are the pole storage racks that provide for holding 3 tiers of sacked cones.

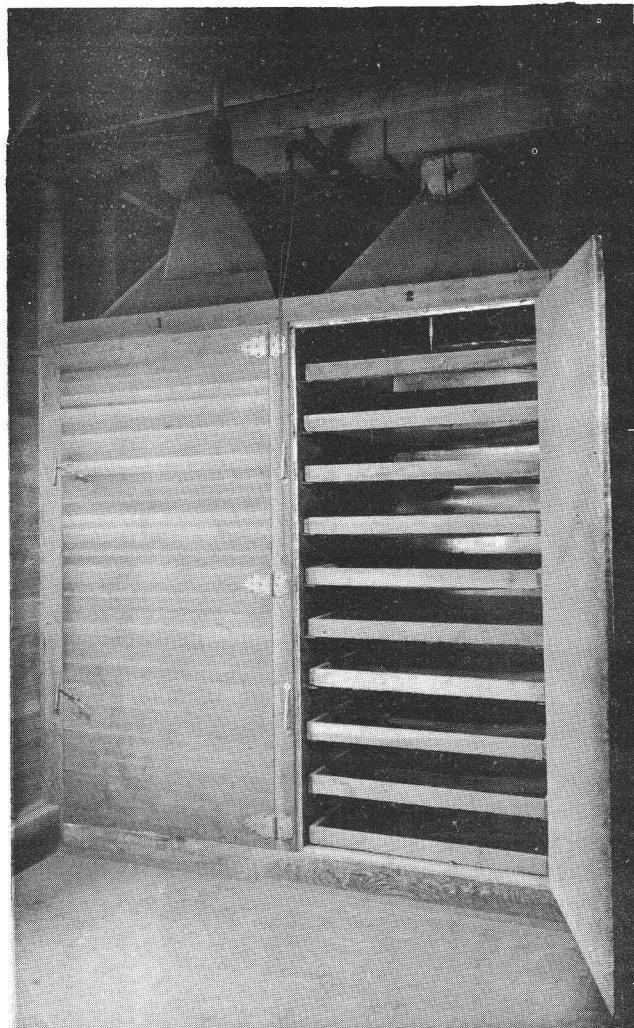


PLATE V. Two units of the Wind River forced circulation seed kiln showing through the open door the movable wire-bottom trays. About a third of the Douglas-fir seed falls through the screens to a bin on the lower story.

Increased efficiency will be obtained if the heating plant can be placed on a lower level than the drying racks with heat ducts leading to different parts of the drying room. The use of heating stoves on the same level with long lengths of stove pipe is bad practice because of the fire hazard, as well as because of low efficiency. Provision must be made for vents to exhaust the moist air to the out of doors. The best possible interior circulation throughout all portions of the drying room is also needed to promote uniform drying. The latter is difficult to obtain in a temporary kiln, but much can be done by a judicious manipulation of windows, doors, and electric fans.

Permanent Seed Kilns. A common type of permanent kiln, relatively simple and economical to build, such as that in successful use at the Wind River Nursery for several years, consists of a 2-story building with a hot air furnace and fan in the lower floor and above two or more individual compartments, each equipped with a stack of movable trays. (Plate V.) The front of each compartment is a tightly fitting door that gives access to all trays. A chute leads downward from below the bottom tray of each stack to a drawer, accessible from the lower floor, into which some of the seed falls during the drying process. Trays fit snugly on the slides at each side, but a space of 6 or 8 inches is left between the back wall and tray or front door and tray, alternately, so that the hot air rises zigzag between each successive pair of trays.

On the main floor in front of the compartments are the tumblers, fanning mill, etc., used in processing the cones and seeds. Where wood construction is used the walls of the drying chambers should be lined with fireproof material, such as asbestos or sheet metal.

The principles of seed kiln design and the specifications of two large modern plants of the Forest Service that have steam heating and automatic control of temperature and humidity have been described by Rietz in a recent bulletin (47). To this, to Baldwin's (5), and to Toumey and Korstian's (57) standard texts, and to the many other reports and articles in the literature on this subject the reader is referred for further details.

Details of Kiln Operations. It is good practice to hold cones in storage for a period of air drying before they are subjected to the heat of the kiln. This is called precuring. It is particularly desirable when the cones are green or very wet. It permits the seed to mature and so lessens the chance of injury from the combination of high temperature and excessive humidity; it reduces the time in the kiln; it facilitates subsequent opening by preventing "case hardening" which is likely to take place when wet cones are suddenly subjected to high temperatures. Precuring may be effected by placing sacked cones in open sheds with plenty of space between sacks, by storing the cones in well ventilated bins, or by spreading them in trays and subjecting them to artificial ventilation and mild heat such as that from the exhaust air of the kiln.

Since all except balsam fir cones expand 2 to 3 times in volume when drying, allowance for their expansion should be made in loading trays or racks in the kiln. A single layer is preferable for most species. Medium-sized cones, such as Douglas-fir and spruce, require about 20 square feet of drying surface per bushel of unopened cones; ponderosa pine and western white pine require somewhat more space.

Portions of twigs, bits of pitch, and other trash mixed with the cones should be removed as completely as practicable before the cones are placed in the drying trays. They interfere with subsequent cleaning of the seed and are more readily removed at this time than later.

A very considerable amount of moisture must be removed to cause cones to open. For Douglas-fir it has been found to be from 35 to 50 percent of the green weight, or from 7 to 10 pounds of water per bushel of cones.

It is of prime importance to avoid excessive temperatures within the drying chamber to prevent injury to the seed. Seed can withstand, without losing its viability, a higher temperature if the humidity is low than if it is high (37). Thus, as the cones and seed dry a higher temperature can safely be employed. For kilns without humidity control it is recommended that the initial temperature be low--considerably below the tolerance of dry seed. Exact requirements for the local species have not been determined, but no harmful effects need be feared if with properly cured cones the initial temperature does not exceed 110° F. and later temperature 120° F. For green or wet cones not properly precured before being put in the kiln the initial temperature should not exceed 100° F. The more resistant cones of lodgepole pine can withstand temperatures of at least 140° F. Balsam fir cones are apparently more sensitive to high temperatures than Douglas-fir.

The evaporation from wet cones may maintain in them a considerably lower temperature than that of the air, yet with variation in the condition of the cones it would be unsafe to raise the temperature for fear it would exceed the tolerance of non-evaporating cones.

In kilns whose humidity and temperature can be accurately controlled it is recommended (47) that the temperature be held constant throughout the run with also a relative humidity constant at the point found by trial best suited to the particular species.

The duration of exposure to heat is important since long exposure will kill seed, while a short exposure at the same temperature will not. Hence, the time the cones are left in the kiln should be as short as is consistent with opening a high proportion of the cones and not reaching a lethal temperature.

The length of the drying period will vary with species, moisture content of cones, and the efficiency of the plant. At the Wind River kiln Douglas-fir cones are given from 16 to 36 hours in the kiln, depending upon the amount of precuring they have had. Noble and silver

fir require about 16 hours and western hemlock 36. If more than 48 hours is required for Douglas-fir, spruces, hemlocks, and most pines or 2½ hours for alder, the cedars, and the balsam firs, it is an indication that the kiln is not efficient.

If air circulation is imperfect, cones in some parts of the drying chamber will open more quickly than those in other parts. When the type of kiln permits, it is good practice to shift the position of trays to promote uniform drying.

It is well also to remove the charge when most of the cones have opened rather than to prolong drying until everyone has opened. Studies with Douglas-fir cones have indicated that when drying continued to a point where the loss in weight represented 51 percent of the original weight and all cones had opened, the germination of the seed was greatly below that obtained when the loss in weight was 40 to 45 percent and only 80 percent of the cones had opened (67). The unopened cones can be separated and returned to the kiln for further drying if it seems likely that the additional seed obtainable justifies the expense of rehandling. A soaking with water will facilitate the reopening of recalcitrant cones.

With kilns that have movable trays and a bin for catching the seed below the level of the hot air intake, it is well to shake each tray, beginning at the top of the stack, two or three times during the run so as to get the free seed as rapidly as possible into the cooler temperature beneath the kiln.

Throughout all handling of cones and seed great care should be taken to maintain the identity of various species and lots and not to allow the seed of one lot to become mixed with another. A system of labeling should be adopted when several lots are being handled. Loose seed should be cleaned from drying trays and racks, the floor beneath them, and from all apparatus before commencing on a run from a different lot.

Operation of a kiln occasions a very high fire hazard because of the extreme dryness of all materials, the resinous content of the cones, the coating of pitch on all surfaces with which the cones come in contact, and the accumulation of dust. Seed kiln dust contains an abundance of pitch particles and is exceedingly inflammable. Every precaution should be taken to prevent the escape of sparks from the heating plant or their entrance from the outside through windows and doors. Fire extinguishers and fire hose should be kept ready for instant use.

Empty cones are sometimes used for fuel in the heating plant, but they have certain objectionable qualities which may mitigate against their use if other fuels are available at a reasonable cost. Their resinous content badly fouls flues and smoke stacks and necessitates frequent cleaning of flues. Cones burn up quickly and so frequent stoking is required to maintain a uniform temperature. Improper combustion arising from faulty stoking or insufficient draft gives rise to explosive

gases which have been known to wreck seed plants. Because of this fire hazard, the use of cones in stoves in temporary kilns is particularly dangerous.

Threshing, Dewinging, and Cleaning

Threshing. After the opened cones are removed from the drying chambers and before they have a chance to reabsorb moisture and close, they are passed through a tumbler or cone shaker or cone thresher to dislodge and separate the seed remaining in them. This is usually some type of revolving drum, cylindrical, square or hexagonal in cross section, and with sides made of wire screening, which retains the cones and scale fragments and allows the seed to pass through. Small blocks of wood are sometimes placed inside with the cones to assist in loosening the seed, but care should be taken that the seed coats are not cracked by too rough treatment, especially with *Abies* seed.

Tumblers may be designed for intermittent or continuous operation. The former have closed ends and are filled and emptied through a door in the side. (Plate VI.) With continuous operation tumblers, the cones enter in a continuous slow stream at one end and gradually work their way along as the drum revolves and exit at the opposite end. This lateral movement of the cones is accomplished either by mounting the drum at a slightly inclined angle or by constructing it with a gradual increase in diameter from the entrance to the exit end. Because of the great amount of dust created by tumbling, the drum should be enclosed in a separate housing with an opening leading to the outside.

Since the dust from the threshing, dewinging, and cleaning process is very annoying to some people, it is well for the operators in large plants who are long exposed to this dust to wear respirators.

It is generally advisable to continue tumbling until the dropping of the seed practically ceases. Though a majority of the seeds will be dislodged almost immediately, the number obtained by continuing tumbling is often considerable. In tests with well-opened Douglas-fir cones, two-thirds of the total number of germinable seed obtained by five minutes of tumbling were dislodged during the first minute. Thus, the additional four minutes increased the yield 50 percent. However, no amount of tumbling will extract all the seed.

Dewinging. The seed comes from the thresher with the wings still attached, and with a considerable amount of trash and worthless hollow seeds. Though the complete removal of the wings, trash, and hollow seeds is not essential for the operator who is using the seed himself, it is customary to do so in order to establish a uniform basis for determining quality, to reduce bulk for storage and shipping, and to facilitate final sowing.

Seed of the larger winged species, like Douglas-fir, the pines, the balsam firs, hemlocks, and spruces, that is marketed is universally de-winged as well as being brought to a stated degree of purity. The first



PLATE VI. The hand-rotated tumbling machine or cone-shaker at the Wind River seed extraction plant; two of the blocks of wood used to thresh the cones are shown on the floor. Doors completely house the drum during operation.

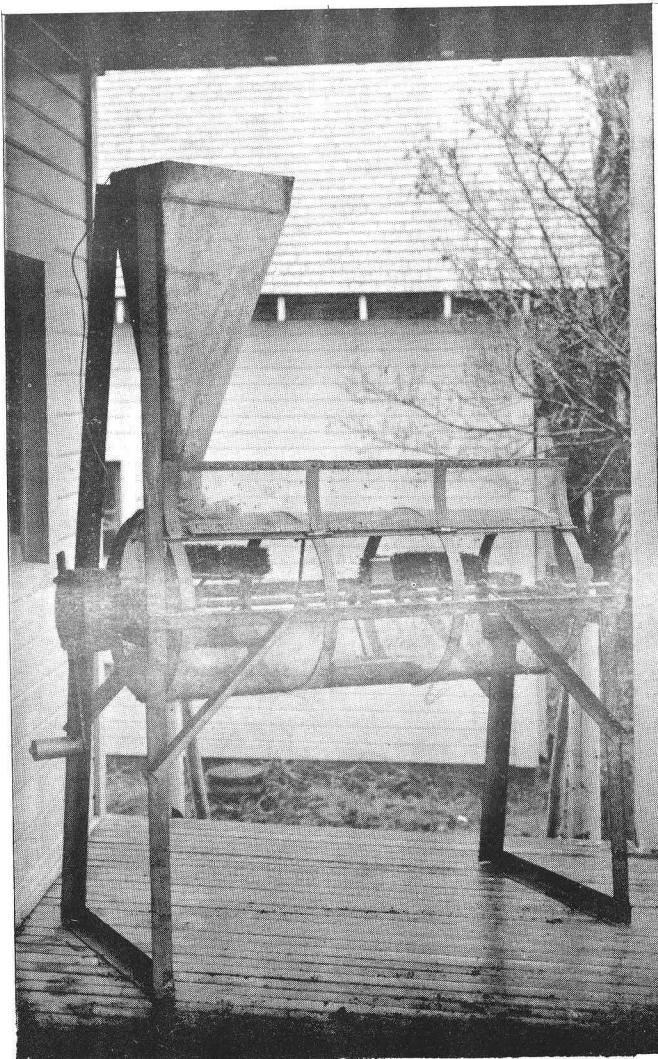


PLATE VII. The dewinging machine (set up on the porch of the Wind River seed kiln) showing, through the open door, some of the seven revolving brushes.

step in this process is dewinging. With small quantities, this may be done by rolling and pounding in a sack or by rubbing the seed over a rough surface.

The latter principle is employed in the design of a dewinging machine for treating large quantities. In this machine (Plate VII) several brushes are mounted on a revolving shaft which extends longitudinally through a cylinder of wire screening. As the shaft is rotated by hand crank or power the brushes rub the seed against the screen and free it of its wings. It facilitates this dewinging operation to screen off the trash first.

An alternative method applicable to pine seed because of the peculiar manner in which the wings are attached is to wet the surface of the seeds quickly but completely, stir vigorously, and dry quickly. Seeds with small wings, such as Port Orford white-cedar, western redcedar, red alder, and birch, are not dewinged.

Cleaning. Final cleaning is accomplished by screening out the heavier forms of trash and blowing out the lighter forms and the hollow seed. Douglas-fir seed, as it comes from the thresher, may be reduced as much as 90 percent in volume and 75 percent in weight by cleaning. Various types of seed cleaning fanning mills are manufactured, which do this very effectively (5). A fair degree of hand cleaning can be done by winnowing in the wind or in the current from an electric fan. Because of their light weight, seed of Port Orford white-cedar, western redcedar, birch, cottonwood, willow, and alder are not well suited to cleaning by air currents.

Though there are no legal standards for the purity of tree seeds sold commercially in this country, a purity of at least 90 percent ought to be expected for all the conifers except possibly the cedars. Toumey and Stevens (58) found that 21 purchased samples of Douglas-fir averaged 93.8 percent pure by weight.

Seed Yield

The yield of seed obtainable from a bushel of cones differs between species, and even for the same species. From studies of Douglas-fir seed (68) there is some evidence to indicate that the actual number of well-developed seeds found in a bushel of cones is influenced by the character of the parent tree and the environment in which it grew. Furthermore, with the same number of seeds per bushel of cones, the yield expressed in pounds will vary with the size of the individual seeds. However, these considerations are of little practical significance in estimating probable yields. For this the important factors are: Whether the cones have lost part of their normal seed content by advance opening or by the work of insect larvae, the thoroughness of the drying and extracting operation, and the degree to which the seed is cleaned of trash and hollow seed. It is the rather common experience of collectors that the yield of good seeds per cone is appreciably lighter in years of

small cone production than when the cone crop is abundant. Though this may be due in some part to the less complete development of the individual seed under unfavorable conditions, it is probably due chiefly to the greater prevalence of insect damage in poor years. The data on yield per bushel of cones given in table 5 is representative of the yields obtained when the quality of the cones and the extracting and cleaning technique are generally satisfactory.

Storage

Seeds which ripen in the spring or early summer, like cottonwood, willow, and birch, lose their viability quickly and should be sown the same season immediately after gathering. Fall-ripening seeds ordinarily remain viable until at least the following spring, if properly stored; the seed of a few species will remain viable several years in ordinary indoor storage, but prolonged viability of most coniferous seed is dependent upon control of humidity and constant cool or cold temperatures. It is important that seeds in storage be not subjected to moisture or heat that would stimulate their internal activity; changes in these factors are particularly detrimental.

Coniferous seed which is to be kept more than a few weeks should be placed in airtight opaque glass or metal containers and stored in dry cellars or storage rooms where the temperature is about 40° F. It is important that the seed be thoroughly dry before being placed in the containers; otherwise, it may mold. Surface dryness is not always an indication that it is dry enough, especially if it has had a chance to re-absorb moisture after leaving the kiln. Kiln-extracted seed can be placed directly in containers without danger of molding. If the seed is damp it should be brought to a low moisture content before storage; with some of the pines from 3 to 7 percent has been found satisfactory.

While cellar storage at 40° F. or a little more makes possible holding Douglas-fir and some other species with only a small loss of viability for several years, cold storage is more effective, certainly for some species. Years ago repeated efforts at Wind River to store seed of the balsam firs in room temperature and in cellars resulted in total loss of viability after the first year, whereas tests begun in 1921 and repeated in 1926 by the Pacific Northwest Forest Experiment Station with noble fir in cold storage at 15° gave a well-sustained germination percentage after 4 years in storage, but a marked decline in the fifth year (23). Since then storage of noble fir seed at approximately zero has been employed with success.

Douglas-fir held in cold storage in burlap sacks at a temperature of 0 to 5° F. is known to maintain a high viability for at least 4 years.

Seeds of the pines, as well as that of Douglas-fir, retain their viability rather well and dry cellar storage as above described can be advocated for as long as 3 or 4 years. For hemlock, spruce, and Port Orford white-cedar dry cellar storage of 2 or 3 years is likely to be

successful; for western redcedar and Pacific incense cedar for at least a year. Storage at below freezing temperatures is likely to prolong the period of successful storage for all these species but experimental proof is lacking.

Since the insects infesting coniferous seed do not pass from seed to seed there is no need to fumigate it in storage, since the damage has already been done--unless the seed is to be exported to a country free of the insect pest (28).

Seeds of some hardwood species, such as the oaks, dry out quickly and are not suited to dry storage. These are ordinarily stratified, that is, mixed with damp sand and kept at cool, outdoor temperatures to prevent premature germination. Bigleaf maple and Oregon ash seeds may be stored this way or placed dry in airtight containers. Red alder, dogwood, cascara buckthorn, madrone, and yew are usually stored dry in airtight containers. Red alder, bigleaf maple, Oregon ash, and oak acorns are ordinarily not kept longer than the following spring. Little is known of the keeping qualities of yew, dogwood, cascara buckthorn, and madrone seed but they are reported to possess rather persistent vitality.

Seed Testing

The purchaser or user of tree seed should satisfy himself as to the quality of his seed either by making tests of it himself or requiring certification by the vendor. In some states the law requires that the vendor of seed must show its origin, date of collection, degree of purity, and germinative energy. This is not required for tree seed now in Oregon or Washington.

The principal items about which the user of tree seed should satisfy himself are: Genuineness, purity, number of seed per pound, and viability.

Genuineness

The correct identity of each shipment of seed should be established by inspection or by comparison with samples of known identity. There is always the possibility that lots may be mixed or mislabeled, particularly since there is still some confusion as to the common names of certain trees.

Purity

Purity may be determined by weighing a sample--to be selected by a technique described in a later paragraph--separating out the apparently good seed from the impurities and then weighing the good seed. The weight of the latter, divided by the gross weight of the sample (seed plus impurities) gives the purity percentage. Percentages below 90-95 for easily cleaned species are an indication of poor cleaning. There is often an agreement between seed dealer and purchaser as to the acceptable degree of purity, as well as of germinative capacity.

Number of Seed Per Pound

It is important for the nurseryman to know the number of trees he may expect for each pound of seed, and as there is considerable variation within a single species it is desirable to count the number of seeds per pound as well as to test their viability. Although seeds of the same species sometimes vary in size between broad regions without corresponding differences in quality, it is generally recognized that within the same general region large seeds germinate more vigorously than small seeds and produce more sturdy and rapidly growing seedlings. With seed of the same size, lightness in weight is an indication of a poorly developed kernel, or of excessive dryness. Size may be judged by ocular comparison with representative samples or by passing the seed through sorting screens of different sized mesh. In ordinary practice, size and weight are usually designated according to the single factor--number of seed per pound. Number of seed per pound, when used to determine or describe size of seed should be calculated on the basis of pure seed without impurities. On the other hand, the number per pound with impurities included is a more convenient figure to use in planning for the use of the seed. When this basis is to be used it should be designated as the number of seeds per pound of uncleared seeds to distinguish it from the number per pound "pure." Representative data on the number per pound of mill-cleaned seed of various species are given in table 5.

Viability

Cutting Tests. Determination of germinability is the most difficult to make of all tests of seed. There are several methods of determining in the laboratory the viability of seed, but the simplest is the cutting test, by which may be detected sterility due to absence of a kernel or damaged kernel. This test consists in cutting open several hundred seeds and counting those that are hollow, contain insect larvae, or are shrivelled. For small-seeded species a magnifying glass may be needed. A well-cleaned consignment of seed should not contain more than 10 percent of such seeds. With fresh seed which has not been injured during extraction, a cutting test of this kind will give a rough approximation of viability although the values are invariably too high. It is of little value for damaged seed or for seed held too long in storage, for such seed may have deteriorated without visible evidence.

Germinating Tests. For an accurate measure of viability, germination tests are employed, in which a number of representative seeds are subjected to conditions favorable to germination, and the number sprouting are recorded. Germination tests require rather careful attention to detail to give consistent and reliable results. They may be of various kinds--in sand, blotting paper or other media, outdoors, in a greenhouse, or in a germination chamber. In every case the seed must be supplied with heat, moisture, and oxygen. The role of light is very unimportant with Douglas-fir, if disassociated with heat.

One of the simplest germination tests is to sow the seed in sand in nurserymen's flats, placed where they can be watered conveniently and kept at a proper temperature (63). This may be done outdoors at the right season or in a greenhouse. This provides germinating conditions similar to those in the nursery bed and thus gives values more nearly equal to those obtainable when the seed is used. The chief objections to this method are the amount of space required, the labor of sowing, usually the greater time required, and inability to watch the seed and recover the ungerminated seeds.

To overcome these objections, various types of apparatus have been devised, utilizing water-absorbing materials and depending on capillary action to bring moisture to the seed. These are described in many standard texts (5) (19) (57) (58). A common type employs a porous clay plate resting in a vessel of water; in others the seed is placed between strips of blotting paper or flannel suspended above a water surface and connected with it by wicks. Glass covers in the form of bell jars or funnels maintain a humid atmosphere about the seed. Preferably the whole is enclosed in a heated chamber in which the temperature is controlled by a thermostat. Most authorities advocate a fluctuating temperature varying between 60° and 80° F.; others advocate a uniform temperature of about 75°. Heit and Eliason (19) got best results with Douglas-fir with a daily alternating temperature of 63° to 86°. A record should be kept of the number of seeds germinating daily. To avoid errors, germinated seeds are removed as counted. In tests made merely to establish values for sowing, the percentage is based on the total number of seeds used in the tests. In those conducted to compare the effect on the seed of different treatments, such as in a study of drying temperatures, methods of storage, etc., it is preferable to eliminate the hollow seed and to base the percentage on the number of seeds with kernels. The number of hollow seed is determined at the end of the test by cutting open the ungerminated seed.

Table 6 gives examples for several species native to the Douglas-fir region of germination tests by various practitioners with seed of various ages and methods of treatment.

Pretreatment. The seed of most conifers, including Douglas-fir, will not germinate well immediately after it is disseminated from the cone. It must go through an after-ripening process for a few weeks, and then its germinative capacity is at the maximum. Hence, germination tests should not be made on absolutely fresh seed.

Germination of many species of seed may be hastened by various special treatments to soften the shell or to quicken the embryo into activity (5) (29). The seed of none of the principal conifers of this region absolutely requires pretreatment, but the period between sowing and germination can be appreciably shortened by suitable treatment, as is evidenced by some of the comparable tests recorded in table 6. Allen (2) characterizes Douglas-fir seed as "difficult to test because of the variability of its germination behavior. One lot of seed may

Table 6.--Examples of Germinative Energy of Tree Seed of Various Species in Tests
With Different Treatments by Several Agencies

Species	Source of data	Age of seed	Pretreatment	Nature of test	Length of germ. test Days	Temper-ature during test ° F.	Germination percent after -- days				
							10	20	30	40	50
Douglas-fir	1/	1	None	Incubator	50	81	16	42	61	64	67
"	"	2	"	"	50	81	21	42	53	60	60
"	"	3	"	"	50	81	8	27	48	54	60
"	"	4	"	"	50	81	17	33	51	58	64
"	"	6	Stratified 42 days	"	70	81	49	68	68	68	68
"	2/	1	Stratified 52 days at 32-38°	Germ. oven	28	40-70	70*	76*	76*		
"	3/	?	Prechill 2 weeks at 37°	Germ. chambers	60	68-86					82
"	"	"	None	"	60	68-86					85
"	"	"	Prechill 2 weeks at 37°	"	50	68-86					88
"	"	"	None	"	50	68-86					92
"	"	"	Prechill 4 weeks at 37°	"	70	68-86					82
"	"	"	None	"	70	68-86					76
"	"	"	Prechill 6 weeks at 37°	"	70	68-86					71
"	"	"	None	"	70	68-86					61
"	4/	-	None	Outdoor			42	49	53		
Sitka spruce	1/	1	None	Incubator	50	81	57	84	87	87	89
"	"	4	"	"	70	81	0	27	36	40	43
"	2/	1	Stratified 52 days at 32-38°	Germ. oven	28	40-70	62*	66*	72*		
"	3/	?	Prechill 2 weeks at 37°	Germ. chambers	50	68-86					94
"	"	"	None	"	50	68-86					88
Western hemlock	1/	1	None	Incubator	50	81	17	59	71	71	71
"	"	2	"	"	50	81	4	32	61	67	68
"	2/	1	Stratified 52 days at 32-38°	Germ. oven	28	40-70	48*	55*	56*		
Western redcedar	1/	1	None	Incubator	50	81	58	74	74	74	74
"	"	2	"	"	50	81	0	3	11	15	19
P. O. white-cedar	2/	1	Stratified 52 days at 32-38°	Germ. oven	28	40-70	66*	67*	68*		
"	3/	?	Prechill 2 weeks at 37° (2 tests)	Germ. chambers	56	68-86					57
"	"	"	None (2 tests)	"	56	68-86					52
Cascoara	1/	1	Soaked in water 2 days	Incubator	50	81	2	5	7	14	16

* In 14, 21, and 28 days, respectively, instead of 10, 20, and 30 days.

1/ Courtesy of the British Columbia Forest Service by H. J. Hodgins.

2/ Courtesy of the West Coast Lumbermen's Association by Charles Reynolds.

3/ Courtesy Seed Testing Laboratory, U. S. Dept. Agric., Corvallis, by Louisa A. Kanipe.

4/ Average of tests of various lots of seed by U. S. Forest Service at Wind River Nursery.

germinate quite readily over a reasonable period; another lot may germinate slowly over a very long period." To overcome this irregularity he proposes that Douglas-fir seed be stratified in moist sand at a temperature just above the freezing point for a period of 6 to 8 weeks, then washed, sterilized, washed again, and germinated on a surface of sterilized sand in a humid atmosphere at a temperature of about 68° F. Thus complete germination can be obtained in about 12 days. One successful operator recommends for Port Orford white-cedar stratifying in damp sand (1 part of seed to 5 of sand) at 33° for 6 weeks, remoistening and stirring occasionally, and screening before sowing. With this the bulk of the germination will come in a few days.

The germination of most seeds is quickened by mere soaking in water for a couple of days. Western white pine and cascara buckthorn are local species that are notoriously slow to germinate unless stratified in moist sand or given other pretreatment. Such treatments also have a practical application in spring sowing in the nursery and in direct seeding to shorten the period when the seed lies inactive in the ground subject to predators, fungi, and the vagaries of the weather.

Thrupp (54) in investigating the effects of the chemical content of the seed ash and of the soil upon germination found that "stratification in soil made alkaline by adding lime and magnesite is markedly superior to stratifying in peat, for both Douglas fir and western white pine."

Alpine larch (Larix lyallii) seed will apparently not germinate at all after normal storage unless given a pretreatment at low temperature for a month or more. The Boyce-Thompson Institute⁶ got germination with this seed by stratifying it in moist granulated peat moss at 41° for 2 months. Longer and shorter periods with a little higher and lower temperatures also gave results. The treatment of seed to hasten germination is further discussed in chapter 3.

Abnormal Germination. Certain seeds, particularly in old lots, only partially germinate--the seed coat cracks but the sprout fails to develop. This is called abnormal germination and it is the practice in some germination tests with tree seed to keep a separate record of this abortive germination.

Germinative Energy. Fresh seeds of good quality will usually sprout rather uniformly after germination starts. On the other hand, the germination of seed injured during extraction or otherwise and that of old seeds whose viability has been reduced by long or improper storage, often will be very irregular and prolonged. Seeds exhibiting these characteristics possess far less utilization value than quick germinating seed, even though total germinative capacity may be much the same in the end. Seedlings from late germinating seeds are liable to be winter killed at the end of the first season, or to be culled out later on account of backward development. This difference in value has led to the

^{6/} Ms. correspondence.

advocacy of two separate terms for expressing the germinability of seed, namely, germinative capacity to denote total germination, and germinative energy to denote the amount of germination in a specified time. The former standard is more commonly used but the latter deserves greater recognition. By compiling the test data in the form of curves or tables showing the course of germination at stated intervals, such as in 5 days, 10 days, 15 days, etc., the user of the seed can ascertain the germinative energy percentage for the period best suited to his needs. Table 6 gives representative data on the course of germination for several species made by several different agencies using different methods of pretreatment and germination.

Sampling Technique

In all seed-testing work, it is essential that the sample selected for testing be truly representative of the entire lot. This requires a rather precise sampling procedure, since any given quantity of seed is seldom homogeneous. The larger and heavier seeds and trash tend to accumulate at the bottom; the smaller and hollow seeds and the lighter trash at the top. Preferably the seed should be emptied from the container and thoroughly mixed. It might be run through a Boerner sample divider to get the desired quantity. One method of obtaining a representative sample is to use a bulk grain probe or trier or similar devise for getting a sample from the interior of a bin or sack. Another method is to pour the seed into a conical pile which is then flattened out into a thin layer. This layer is halved or quartered; one of these sections is removed to one side and further divided by the same procedure until reduced to the desired amount. If the size of the seed lot to be sampled is too large to be readily emptied from the container for mixing, separate samples may be taken from the top, middle, and bottom layers of the container and mixed together.

Costs

The cost of tree seed depends largely upon the expense of collecting the cones and getting them to the extractor. This is a variable item depending upon species, the current abundance of cones, their quality, and the accessibility of the collecting area to the extraction plant. With pre-war labor conditions Douglas-fir cones were commonly purchased in years of good production for 50 cents per bushel at points near collecting areas. Spruce commands about the same price and ponderosa pine half as much in good seed years. For the smaller-coned species that are slower to collect the price is correspondingly higher.

These prices imply the labor of children or of others with spare time, and are not enough under ordinary conditions to guarantee the wages that prevail for able-bodied men.

A premium must, of course, be paid for cones of rare or inaccessible species or for collections made according to restrictive specifications.

The cost of extracting will vary with the size and type of plant, the species, and the volume of any lot to be put through. It is understood that private extracting plants have done customs extracting and cleaning of Douglas-fir seed for less than \$1.00 per pound. With cones at 50 cents per bushel the cost for a pound of Douglas-fir seed would average about \$1.00 for the cones and another dollar for transportation, kiln charge, storage, etc. A price in the local market of \$2.25 in recent pre-war years was considered low for Douglas-fir in quantity.

During off-cone-crop years the price goes up and the quality presumably down. For small lots the price on the market and the cost to the producer is naturally higher than for large quantities. Naturally the value of seeds to the purchaser goes down with its age and germinative capacity.

CHAPTER 3. NURSERY PRACTICE

Much of the information presented here is based on experience at the United States Forest Service Wind River Nursery located near Carson, Washington on the Columbia National Forest. It has been in production since 1912 and has furnished practically all of the planting stock used for reforestation on the national forests in Washington and Oregon. The experience and practices at other nurseries, both in this region and elsewhere, have also been used in the preparation of this text.

Selection of the Nursery Site

The nursery site must be chosen carefully for it determines in great measure the cost and success of nursery operation and also of the reforestation job serviced by the nursery.

Location

The nursery preferably should be located close to the areas to be planted. Their proximity facilitates correlation of nursery and planting work, thereby increasing the efficiency of operation and facilitating administration of both jobs; transportation time and cost is reduced and necessity for storage of plants is lessened.

The nursery should be accessible to sources of labor and materials. Necessity for construction of housing facilities for nursery labor should be avoided because the fluctuating volume and seasonal nature of the work makes resident labor a difficult and expensive problem. The nurseryman and possibly some assistants, however, should be located permanently at the nursery; therefore, it should be accessible to schools, churches, medical, and shopping facilities. It is difficult to retain good overhead personnel if living conditions are undesirable. Commercial freight transportation should be easily available. It is desirable to have commercial electric current at the nursery.

Climate

It is important that climatic conditions at the nursery permit tree shipments as early as the planting sites will receive them. For coastal planting, the nursery should be open all winter. For higher altitude planting the nursery should hold stock dormant late in the spring for it cannot be successfully handled and planted after spring growth starts. It is practically impossible to meet all requirements at one location so the nursery seasonal climate should conform as closely as possible with that of the greatest planting area. Stock can be held dormant later than naturally occurs in the nursery by lifting it while it is dormant, and placing it in cold storage until the planting area is open or placing it in heeling-in beds or snow pits close to the planting site where natural weather conditions will hold it dormant.

Soil

The soil should be fairly light, of the sandy loam or loamy sand variety, of good depth, free from rocks and stones, and well drained. Heavy soils that are sticky when wet or that cake when dry are difficult to work and may make work impossible during the spring and fall when sowing and shipping must be done. A somewhat impermeable subsoil may be an advantage to prevent leaching of plant nutrients and to conserve moisture during dry periods. The impermeable layer should be at least 2 to 3 feet below the surface. However, it may be a disadvantage in areas of high precipitation if it prevents adequate drainage.

A good coniferous nursery soil should have a structure on mechanical analysis, composed of 60 to 85 percent sand and 15 to 40 percent silt and clay with the clay constituting no more than 3 percent to 5 percent of the total.

Virgin soil is usually better than that of an old farm or pasture. The cost of clearing and leveling new land may be higher but this may be more than offset by higher cost of operation on land that has been cleared or cultivated for many years. Old land is usually heavily stocked with dormant weed seeds, the soil is likely to be "worn out," and it is often infested with diseases and insects which damage nursery stock.

The soil should be acid having a pH value between 5.0 and 6.5. Coniferous stock prefers acid soil and detrimental soil organisms are more easily controlled on acid than on alkaline soils. Most soils of the Douglas-fir region are acid but pH tests should be made preparatory to selection of a nursery site to determine this important requirement.

An inherently fertile soil is an advantage, although proper soil texture should take predominance over fertility in selecting the nursery. Fertility can be built up but it is usually impossible to change the texture within limits of reasonable cost.

Water Supply

A supply of water for irrigation is essential even in the areas of high annual rainfall, for nature cannot be depended on to supply rain in the right amount at the necessary times. The critical periods are during germination and establishment of the seedlings, although the greatest amount of water is usually used during July and August. That is normally the dry season in the Northwest and is also the season during which seedlings are making the greatest demands on soil moisture.

The amount of water available must be adequate to meet the heaviest daily needs during the summer dry period, with a considerable margin to spare for exceptional conditions. A 25-acre nursery should

have a water supply capable of delivering 15,000 gallons an hour for 12 consecutive hours a day during the dry season. It is usually possible in the Pacific Northwest to obtain sufficient water directly from a stream. In some places, however, reservoirs must be constructed or wells drilled to assure an adequate water supply during dry seasons.

The irrigation water should be tested to make sure there are no injurious impurities in it although they are quite unlikely to be present in any surface water in the Douglas-fir region.

Topography

The nursery should be naturally level. If excessive grading is necessary to level it, the natural soil profile is destroyed, fertile top soil is likely to be covered in places, and poor grade subsoil exposed; this results in uneven soil fertility and uneven development of plants, a condition which persists for years. The site should have a uniform slope not less than 0.25 percent nor more than 2.0 percent to allow surface drainage without erosion. The texture of the soil will determine to some extent the extremes of slope that can be tolerated. If surface irrigation is used, the slope should be in one direction on one plane. Steeper slopes can be used if necessary but they usually require terracing which is costly to install and expensive to maintain.

Size and Design

Nursery Area

The over-all or gross area of a nursery is utilized by seed beds, transplant beds, paths, roads, service areas, and administrative areas. The efficiency of the nursery design or layout has some bearing on the percentage of the total area that is in actual stock production. A well laid out nursery will have 60 to 70 percent of its area available for actual stock production and 30 to 40 percent in roads, paths, and service areas.

A nursery developed to produce stock over a period of several years should be operated on a crop rotation of 3 or 4 years with a quarter to a half in a soiling crop or fallow each year and the rest in nursery production.

For the purpose of determining the area to be acquired for a nursery, the annual production of a well-designed nursery operated on a 3-year crop rotation basis can be figured at one million 1-0 seedlings or five hundred thousand 2-0 seedlings or one hundred fifty thousand transplants of 1-2 or 2-1 age class (this includes growing the seedling stock for transplanting) per gross nursery acre.

A nursery scheduled to produce four million 1-0 seedlings, 12 million 2-0 seedlings, and $1\frac{1}{2}$ million 1-2 transplants per year will require about 40 acres of land.

Layout of Seed Bed and Transplant Areas

For convenience of operation, the nursery should be laid out in rectangular units or blocks each with a service road around it. The size and shape of the blocks should be determined by the size and shape and operation plan of the nursery. A small nursery of 10 acres or less should be divided into 3 blocks with 3-year crop rotation the principal basis for the division. Larger nurseries should be divided into 3 or more blocks to best facilitate operation. It is of advantage for operation and administrative purposes further to divide, by designation only, the blocks into sections, a section usually being the area between two irrigation lines. The seed beds or transplant beds are the next divisional unit and they should be laid out in the sections to utilize the area most efficiently and at the same time provide for easy access of labor and nursery machinery. It is usually advisable to lay out the nursery so that the long dimension of the beds will be east and west to facilitate shading of seed beds should it be necessary. It is advisable to install the irrigation system with the irrigating lines parallel to the long dimension of the beds to prevent irrigation equipment installations from interfering with operation of nursery cultivation machinery.

As a result of years of practice, the nursery seed bed has assumed a standard width of 48 inches; this width allows efficient use of hand labor and machinery and is altogether satisfactory. Transplant beds are usually wider, varying from 4 to 6 feet. In some cases, transplants are set in field rows instead of beds. Paths between beds should be at least 12 inches wide and preferably 16 or 18 inches wide. Paths beside the irrigation lines should be wider, 22 to 30 inches, to allow clearance of machinery.

A nursery section 51 feet wide between irrigation lines will accommodate 9 rows of 48-inch beds separated by 17-inch paths with 22 inch paths beside each pipeline. A nursery section 53 feet wide between lines will accommodate 10 48-inch beds with 13 inch paths and 20-inch paths beside each pipeline. Both of the above layouts, with overhead pipe irrigation systems, are in common use, and are very satisfactory. Either of them is convertible to transplant sections laid out in 8 5-foot beds, 7 6-foot beds, or in field rows.

It is advisable to rotate use of the areas for seedling and transplant production rather than to lay out one portion of the nursery for permanent seedling production and another portion for permanent transplant production. An exception would be in a nursery that has an area of gravelly soil or heavy soil that can be used for transplants but not for seedlings.

Roads

Nursery roads should be kept to the minimum necessary for efficient operation. It is advisable to have a road bordering the nursery area and around each nursery block. The exterior road should be

wide enough to allow 2-way truck traffic and to turn machinery. The interior roads also need to be wide enough to provide turning room for nursery machinery. Most good nursery soils are sandy enough to make road surfacing unnecessary. Gravel surfaced roads are a continual nuisance because the gravel works into the seed bed areas.

Windbreaks

Provision should be made for tree windbreaks around the nursery where necessary. If used, they should be located outside the exterior road boundary and far enough from the beds so their roots will not compete with or their crowns shade the tree seedlings. If trees are located advantageously for windbreaks when the nursery is constructed, they should be preserved; otherwise, suitable trees can be planted. Living windbreaks and large ornamental trees should be kept out of the nursery production area. None of the present nurseries in the Douglas-fir region has interior windbreaks; if they should be found necessary during the germination period, a movable type should be used such as ordinary lath and wire snow fence. They should be quickly and easily removable when no longer needed or when they interfere with nursery operations. Snow fence windbreaks usually can be wired to the upright supports of an overhead irrigation system although it may be necessary to erect special supporting posts if the irrigation lines are parallel to the wind direction. When planning a system of windbreaks, local wind records should be studied. Windbreaks should be located as nearly as possible at right angles to the direction of damaging winds; they may or may not coincide with the direction of prevailing winds.

Service Areas and Administrative Areas

The administrative area, where would be located the nursery office, warehouse, repair shop, etc., should be on the axis between the main entrance and the center of the nursery, with the office nearest the entrance. Here these buildings may best serve their purposes with a minimum of travel through the nursery area and minimum interference with work.

Service areas such as storage yards, equipment sheds, compost pits, etc., should preferably be located away from the administrative area and outside the nursery production area where they can be screened from view but still easily accessible to the workmen.

Dwellings and labor camp buildings, when necessary, should be located outside the nursery area.

Irrigation System

A well-designed and well-installed watering system is essential to satisfactory nursery operation. Its design and installation involves some knowledge of hydraulic engineering, especially if deep wells must be drilled, if dams or reservoirs must be constructed, or if the

source of water is any distance from the nursery. It often is possible in mountainous country to depend upon gravity for pressure, thereby eliminating the need for pumps. Most water from streams, lakes, or reservoirs contains suspended material which clogs spray nozzles and which must be screened or filtered out before the water enters the pipe system. Capacities of pipes, volume delivery of pumps, pressure at delivery, and seasonal volume requirements must be carefully considered. These and other contingencies make it highly desirable that the nurseryman and an engineer collaborate on designing the irrigation system.

The principal types of irrigation systems that have been used on tree nurseries are overhead pipe, rotary sprinklers, and surface or furrow irrigation. The overhead pipe system is generally recognized as the most satisfactory. It distributes water quite evenly with very little overlapping; it does not seriously interfere with operation of nursery machinery and requires comparatively little attention. The amount of water applied is easily controlled, and it can be applied quickly in emergencies.

Rotary sprinklers overlap their applications and when of the stationary head type have the distinct disadvantage of overlapping continuously in the same places. Moreover, their irrigation pattern is seriously affected by wind. Surface or furrow irrigation is quite satisfactory for transplant areas, especially when they are laid out in field rows instead of beds. It is not as satisfactory for seed bed areas as the overhead type principally because application of water cannot be controlled within the fine limits often necessary in seedling production.

Companies that manufacture irrigation equipment are usually prepared to furnish designs, bills of material, and estimates of cost for an entire irrigation installation to suit any nursery condition. It is usually good policy to solicit their services in planning an irrigation system.

The initial investment of an overhead pipe system is greater than that of the other systems but it is usually more than compensated by its economy in operation and more satisfactory seedling production, if the nursery is to be operated over a period of several years. The investment cost of any type of irrigation system, with the exception of furrow irrigation under extremely favorable conditions, will be between \$400 and \$1,000 per irrigated acre. Some saving may be made on nurseries operated on a fallow land rotation basis by not purchasing overhead equipment for the fallow area. This requires moving a portion of the overhead installation each year, one-half of it if the nursery is operated on a 3-year rotation. It also may require provision for supplemental irrigation of the soiling crop on the idle land although there is sufficient rainfall in most of the Douglas-fir region to make that unnecessary.

Ground Preparation and Soil Maintenance

Preliminary Cultivation

If the area is uneven it should be leveled and if leveling exposes the subsoil in places, top soil should be saved for replacement over the exposed areas. The top soil in hollows also should be removed for replacement over fills of subsoil. If there is sod or other heavy vegetation on the area, it should be plowed under several months before nursery work is started. Subsequent plowing or disking may be necessary to kill the sod. It should be dead and fairly well disintegrated before seed beds are prepared. If the area is new land without sod, the top layer of humus may be plowed under or it may be worked into the soil with disks or auxiliary powered rotary tillers. The natural organic material should not be destroyed and if the layer is thin, it should be kept close to the surface. Shallow tillage no deeper than 5 or 6 inches is sometimes advisable on new land to prevent bringing sterile subsoil to the surface.

Stones, roots, pieces of wood, and other material that will not become incorporated into the soil before seed beds are prepared, should be removed. If brush, stumps, or other debris is burned on the site, the ashes should be scattered evenly before they are worked into the soil. On most sites, and especially on land previously in pasture or farm crops, a heavy weed growth can be expected after the first working of the soil. In such cases it is of material advantage to work the ground a season ahead of nursery sowing to allow germination and destruction of the first weed crop, to prevent its interfering with nursery prosecution. Weeds should not be allowed to go to seed on or adjacent to the nursery site during subsequent years of operation. Money and effort expended to prevent dissemination of weed seeds in the nursery will pay dividends in successively lower annual weeding costs.

Fertilization

The soil should be chemically analyzed when the nursery site is selected and periodically thereafter, at least before sowing each soil-ing crop to detect deficiencies that may occur through continued use of the soil. The proper balance of plant nutrients for Pacific Coast species has not been determined, but the nurseryman by knowing his soil and detecting deficiencies that develop can apply corrective fertilizers.

The principal fertilizers needed in a tree nursery are nitrogen, potassium, and phosphorus. Some of the rarer soil elements, such as magnesium, sodium, manganese, sulphur, chlorine, and iron, have been noticed to have some influence on the growth and hardiness of stock; correction of abnormal deficiencies or excesses of one or more of them has in some cases produced good results. It is advisable to consult the local county agent or the State Agricultural College regarding use of chemical fertilizers for they usually have had experience with the soil in question. Excessive amounts of any chemical nutrient will adversely affect growth and development of plants. They should be used only in amounts needed.

As a general policy, it is better to apply chemical fertilizers to the soil and thoroughly work them in before seeding or transplanting on the area than to apply them with the seed or as side or top dressings after the plants are growing. However, it may be necessary to spot fertilize during the growing period to correct deficiencies that show up through unhealthy development of plants.

Organic material in the soil is important to the soil structure; it improves tilth, prevents leaching of nutrients, increases water holding and water absorption capacities, and provides some plant nutrients. There is also some indication that it harbors and promotes growth of soil organisms which are beneficial to plants. The principal sources of supplementary organic material are commercial organic fertilizers, barnyard manure, peat, leaf mold from the forest floor, soiling crops, and green manure crops.

For large-scale use the commercial organic fertilizers are expensive. Barnyard manure, unless well rotted, is a dangerous source of weed seeds and it usually loses much of its fertilizing constituents in the process of rotting--Throckmorton and Duley (53).

Peat is very desirable and often it is possible to locate suitable bogs within trucking distance of the nursery. There are many kinds and qualities of peat, the best being a well decomposed moss peat with some natural available nitrogen and a pH value between 4.5 and 6. Leaf mold or duff is very good, but often expensive to obtain and is sometimes a source of weeds. However, weed seeds can be destroyed by composting. Leaf mold or duff from the forest floor has been found to contain mycorrhizal fungi which are highly beneficial to growth and development of coniferous nursery stock when used as a soil inoculum. However, before large-scale addition of this material into a nursery, a specialist should be consulted to make certain that there is no danger of introducing harmful organisms as well. McComb (33) reports that experiments with Douglas-fir and several species of pine support the theory that seedlings with mycorrhiza receive better nutrition because of development of a greater number of absorbing short roots and because of the growth association of the fungi and the seedlings.

Composted organic material fortified with chemical fertilizer and leaf mold or duff is probably the best complete nursery fertilizer. A good compost can be made by mixing 5 or 6 parts of peat to 1 part of forest duff and fortifying it with nitrogen and phosphorus in the amounts needed in the soil. It should be composted for 1 or 2 years, preferably in a concrete or timber pit. It should be turned completely once or twice and should be kept moist by spraying occasionally. A catchment basin should be built in the floor of the pit to collect the drainage water which should be pumped back over the compost to reincorporate the leached elements. It should be applied to the soil at the rate of 2 to 5 tons per acre every second or third year. Nurseries that have an abundant supply of compost materials can lessen, through its use, the need for and frequency of soiling crop rotations.

Soiling crops should be annual legumes of any variety successfully produced by farmers in the locality of the nursery. Perennials are less desirable than annuals as some are not killed when plowed under and plants come up in the nursery beds the following season to increase the normal weeding job.

The seed should be inoculated with nitrogen fixation bacteria to assure a good crop of nitrogen nodules. At Wind River, it has been found advantageous to sow oats or rye with viny legumes, such as hairy vetch to support the legumes and prevent them from matting down. The cover crop should be turned under when the seed pods are soft and immature and before the stems become fibrous. Disintegration of the crop should be complete before the area is used for nursery production. It is good practice to sow the soiling crop in the fall in climates where it will not winter kill; otherwise in the early spring to allow the crop to attain satisfactory development and be turned under early in the summer. Then the soil should lie fallow until it is used for nursery production the following fall or spring. Germination of weed seeds should be encouraged, by irrigation if necessary, and the soil should be worked only as needed to prevent further production of weed seeds. Soiling crops are a cheap source of organic material and nitrogen, but root rots and damping-off fungi which attack nursery stock sometimes are associated with decomposition of the crop.

Drainage

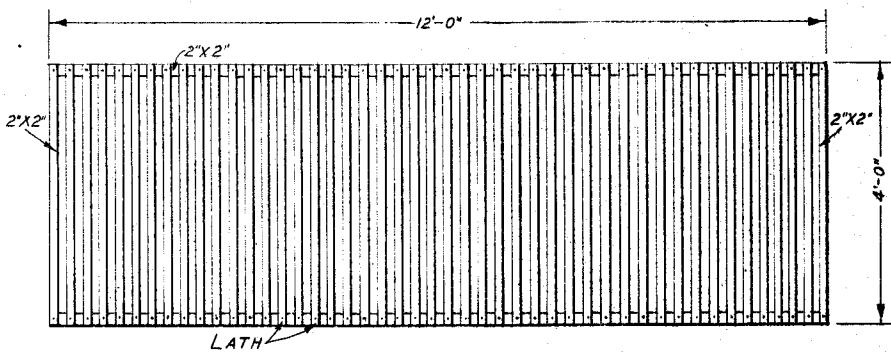
All portions of the nursery should have drainage adequate to prevent pocketing of water or water logging of the soil during the rainy season. Poorly drained spots are favorable to development of root rots and insects which feed on plant roots. They present tillage and fertilization difficulties, and plants grown on them are apt to be short rooted and chlorotic. When natural drainage is inadequate, it should be supplemented by artificial drainage.

Classification of Nursery Stock

To describe nursery-grown trees a system of "age classes" is used. This consists of two factors: (1) Age of the tree, usually measured by the number of growing seasons since germination, and (2) the treatment in the nursery, whether kept in the seed beds the entire period or transplanted. To designate age class a binomial system is used, 1-0, 1-1, etc.; the first figure indicates the number of seasons in the seed bed, the second the number in the transplant rows. If the trees are twice transplanted a third figure is added for the number of seasons they are in the second transplanting rows. Thus

- 1-0 = 1-year-old seedling not transplanted
- 2-0 = 2-year-old seedling not transplanted
- 1-1 = 2-year-old tree, transplanted for one season
- 1-1-1 = 3-year-old tree transplanted at end of first and of second years

TOP VIEW



SIDE VIEW



END VIEW

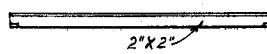
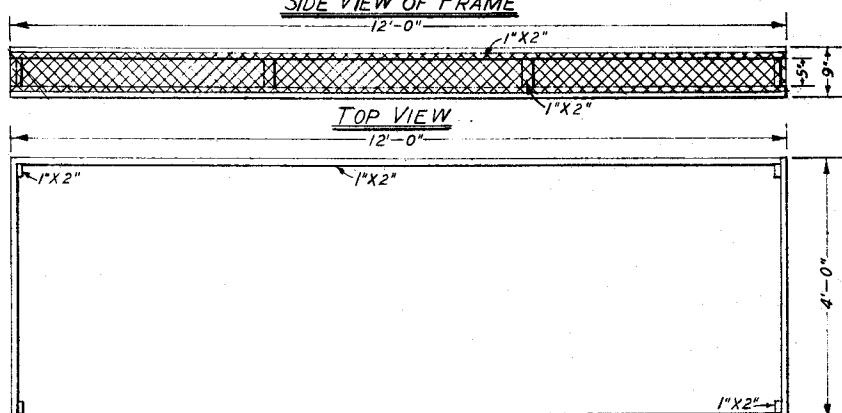


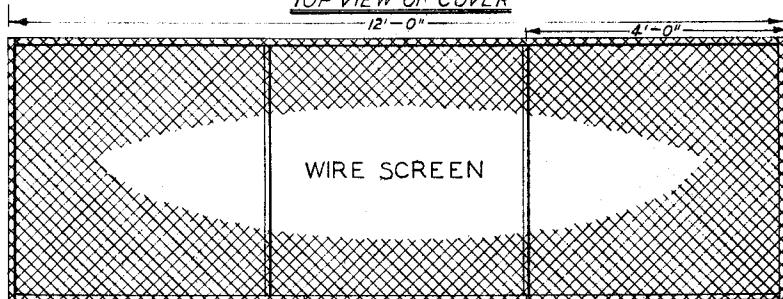
FIG. 3-A
PETTIS SEED-BED FRAME

SCALE - $\frac{1}{2}$ IN. = 1 FT.

SIDE VIEW OF FRAME



TOP VIEW OF COVER



SIDE VIEW



FIG. 3-B PETTIS SEED-BED FRAME

Drawn By K.V. Pehkoff - 6-13-44

SCALE - $\frac{1}{2}$ IN. = 1 FT.

Two other factors are sometimes compounded in this system for describing nursery stock, namely, season of sowing, fall or spring, using the prefix (formerly the suffix) "F" or "S" before the age and treatment by root pruning, inserting the letter "P" in the appropriate place; thus

F2P-0 = Fall sown 2-year-old seedling,
root pruned

S1-2P = Spring sown 3-year transplant,
root pruned in transplant row.

Sometimes forest nursery stock, like horticultural stock, is designated according to the height of the top and occasionally by diameter of stem, or "caliper size," a little above the ground line.

Seed Bed Preparation and Sowing

Types of Seed Beds

Two general types of seed beds are used commonly. One is a 4' x 12' bed enclosed in a light wood strip and woven wire frame 8 or 10 inches high, and the whole bed fitted with woven wire and lath covers (figures 3A and 3B). This is called the Pettis seed bed. The other is a continuous long bed 4 feet wide with its length determined by the length of the nursery section. This is the type of bed used at the Nisqually nursery of the West Coast Lumbermen's Association, which was developed under the superintendentship of Charles E. Reynolds as illustrated in plates VIII and X. Long beds are not enclosed in frames although light boards, usually 1" x 4" of random lengths sometimes are used to border and support the edges of the beds. These bed boards also serve to hold mulch in place and to support screens and shading materials.

The 4' x 12' Pettis seed bed frames constitute a considerable initial investment and they are expensive to handle and maintain. They are of advantage and may be justified economically in nurseries where it is necessary to protect seed beds from rodents and birds. They also may be of advantage for propagation of small lots of certain species which require special care and attention. Besides their cost, they have the disadvantage of precluding use of machinery for practically all cultural operations.

In some nurseries the 4' x 12' seed beds have been enclosed with frames made of 1" x 4" or 1" x 6" boards, instead of wire side frames; they are cheaper but reduce ventilation.

Preparation of Seed Beds

Preliminary to preparing seed beds, the soil should be worked as for any farming operation using standard farm equipment, such as plows, disks, harrows, drags, floats, etc., to bring the soil into good tilth.

Rotary tillers have been used instead of standard farm machinery in some nurseries and have proven quite satisfactory. They are especially useful on small irregular shaped areas. Some rotary tillers are manufactured with 48-inch tool bars, which do a fair job of preparing a complete seed bed in one operation.

Seed beds and paths should be laid out accurately using any convenient method, usually with mechanical markers, or stakes and strings, and if seed bed frames are used they should be set into place prior to final preparation. The seed beds, whether in frames or not, should be brought into condition for seeding by leveling and removing all soil lumps and roots or other debris that may be in the top inch or two of soil. This usually will require hand raking, although in large nurseries tractor drawn tools have been devised to do all operations.

The completed seed bed should be an inch or two higher than the paths to allow good surface drainage. Paths are depressed automatically when machinery is used for seed bed preparation. The seed bed surface may be either slightly crowned or flat; it never should be dished. After working the seed bed, it should be allowed to settle or in some cases compacted with a roller before seed is sown to obviate settling of soil or seed after sowing.

It is of great advantage that all nursery machinery be gauged to straddle the beds and track in the paths. Most tractor companies manufacture equipment that can be adjusted to the desired gauge. A 4-foot bed with 17-inch paths should have equipment 65 inches between wheel centers.

Methods of Sowing Seed

Seed is sown either in drills or broadcast, and it can be sown either way by machine or by hand. If seed bed frames are used the seed must be sown by hand and usually is sown broadcast although some nurserymen prefer to simulate drill sowing in frames by placing the seed in rows. The rows usually are formed by pressing a cleated board on the surface of the bed, cleats down, forming a series of regular-sized depressions in the bed to receive the seed. Long beds without frames are sown easily by machine. Several types of seeding machines have been made by nurserymen to sow broadcast, in drills, or in parallel bands of varying width. Machines that sow in drills (plate VIII) are designed to cover the seed with sweeps behind the drills. Seed sown broadcast or in parallel bands is covered by depositing a layer of soil or sand over the seed. This is accomplished by a separate covering machine, described by Olson (43), or in some cases by an attachment to the seeding machine. None of these seeding machines are on the market but plans and specifications can be obtained from the U. S. Forest Service or from nurserymen in private industry who have built them.

The advantage of drill sowing and band sowing is that they allow mechanical cultivation and weeding of the beds after the seedlings have germinated. They also simplify the job of covering the seed. Drill



PLATE VIII. Seeding machine at the Nisqually Forest Nursery sowing Douglas-fir seed in drills in a previously prepared long bed, covering seed with topsoil and rolling. Note overhead sprinkler system in background.

Courtesy West Coast Lumbermen's Association.

sowing in seed bed frames is of little advantage as subsequent weeding and care cannot be done with machinery because of the frames. The general practice is to broadcast by hand and cover by hand in seed bed frames and to sow in drills with a machine that sows and covers in one operation, in long beds without frames.

Even distribution of seed is of prime importance regardless of which sowing method is used. Uniform development of the seedlings depends a great deal on their having uniform growing space. Hand broadcasting should be done only by well-trained and trusted workers. All sowing, whether by hand or machine, should be inspected closely and frequently by the nurseryman to assure even distribution.

Amount of Seed to Sow - Densities of Seedling Stands

The amount of seed to be sown per unit of seed bed area must be determined accurately. Oversowing not only wastes seed but also necessitates later expenditures for thinning. Undersowing results in poor utilization of seed bed area and upsetting of the nursery production schedule.

The sowing rate is determined by the density of stand desired and the viability of the seed. A safety factor often is applied to compensate for losses that can be expected from all sources between time of sowing and time of lifting. The safety factor should be determined by the nurseryman from his experience and knowledge of his nursery.

Sowing rate can be expressed as a formula:

$$\frac{\text{Number of pounds of seed to be sown per bed}}{\text{Number of square feet per bed} \times \text{desired density per square foot}} = \frac{\text{Number of viable seeds per pound} \times (100\% - \text{safety factor percent})}{}$$

Example:

Size of seed bed: 4' x 400'

Desired seedling density: 50 per square foot

Estimated seedling losses: 10 percent (safety factor)

Number of viable seeds per pound: 24,000

$$\frac{1,600 \times 50}{2,400 \times .90} = \frac{80,000}{21,600} = 3.7 \text{ pounds of seed per bed.}$$

Seedling density is tied in with soil fertility and with quality and size of stock to be produced to such an extent that no universal figure can be used. Density (table 7) will have to be determined by the nurseryman with a view to producing the most plants of the desired size and quality per unit of nursery area.

The general trend has been toward fewer plants per square foot to produce sturdy, well-developed planting stock grown and conditioned to withstand the most adverse conditions of the site to be reforested. The densities shown in table 7 are good for average conditions. Deviations may be necessary or desirable to correlate nursery production with local nursery and planting conditions.

Table 7.--Densities in the Nursery Generally Applicable to All Conifers Native to the Pacific Northwest for Average Conditions

1-0 seedlings for field planting	50 to 70	per square foot
1-0 seedlings for transplanting	70 to 90	" "
2-0 seedlings for field planting	40 to 60	" "
2-0 seedlings for transplanting	70 to 90	" "
1-1 transplants	16	" "
2-1 "	12 to 16	" "
2-2 "	12 to 16	" "

Average density of seedlings usually can be slightly greater in beds seeded broadcast, if seed is evenly distributed, than in drill seeded beds.

Size and quality standards of plants should be established for each age class to meet the demands of the planting site, and the nurseryman should gauge density of sowing and operate the nursery to meet those standards.

Depth of Sowing and Kind of Cover

Seed should be covered slightly deeper than its diameter; seed one-fourth inch in diameter should, therefore, be sown or covered so that its uppermost surface will be slightly more than one-fourth inch below the surface of the seed bed. Very small seed and thin flat seed, such as the cedars, however, should be covered about one-eighth and not less than one-tenth inch. Lighter cover tends to wash or blow off in spots and is too light to retain sufficient moisture for good germination.

If the nursery soil is heavy or inclined to crust, small seed should be covered with sand or light sandy loam instead of the native nursery soil. The small-seeded species usually do not have enough strength to push up through heavy or crusted soils. When it is necessary to bring in cover material, it should be tested for pH value to prevent procurement of soils above neutral reaction. Soil brought into the nursery for any purpose and especially for cover material should test between 4.5 and 6.5 and preferably should be below 6.5. Cover material should be screened before it is used to remove lumps, roots, stones, and other debris that might interfere with application of an even uniform seed covering.

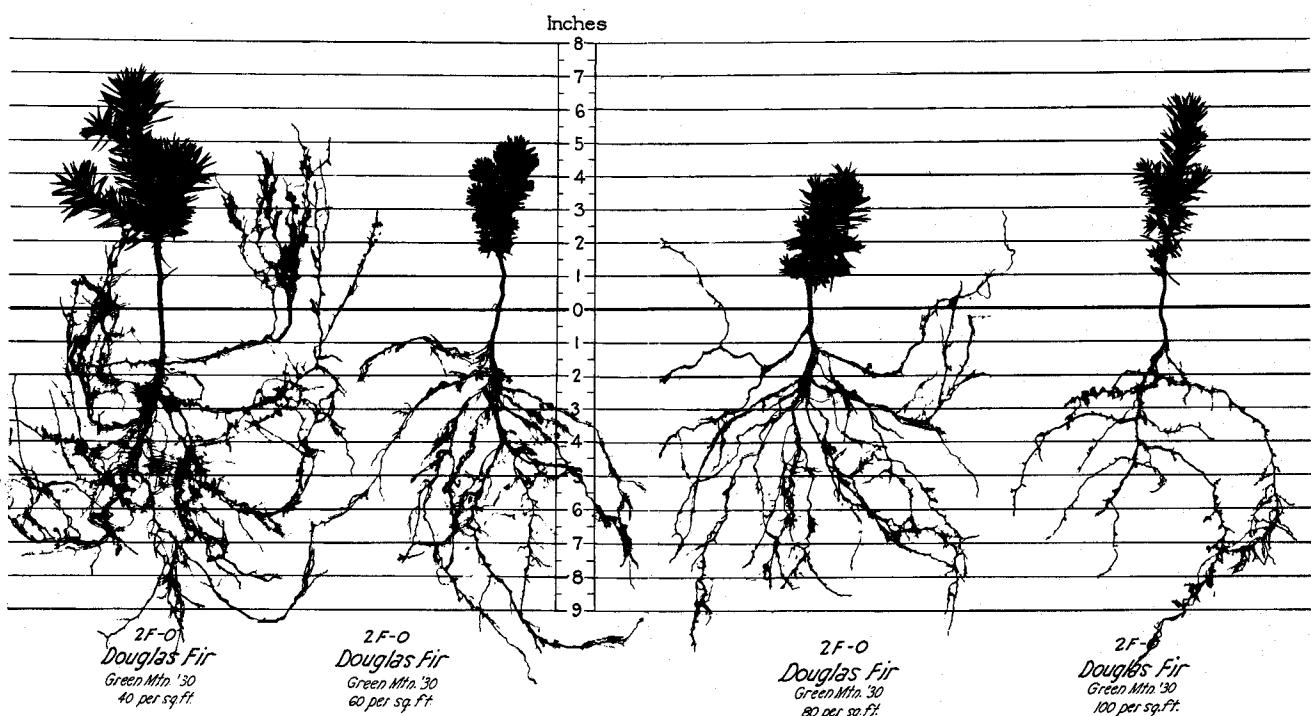
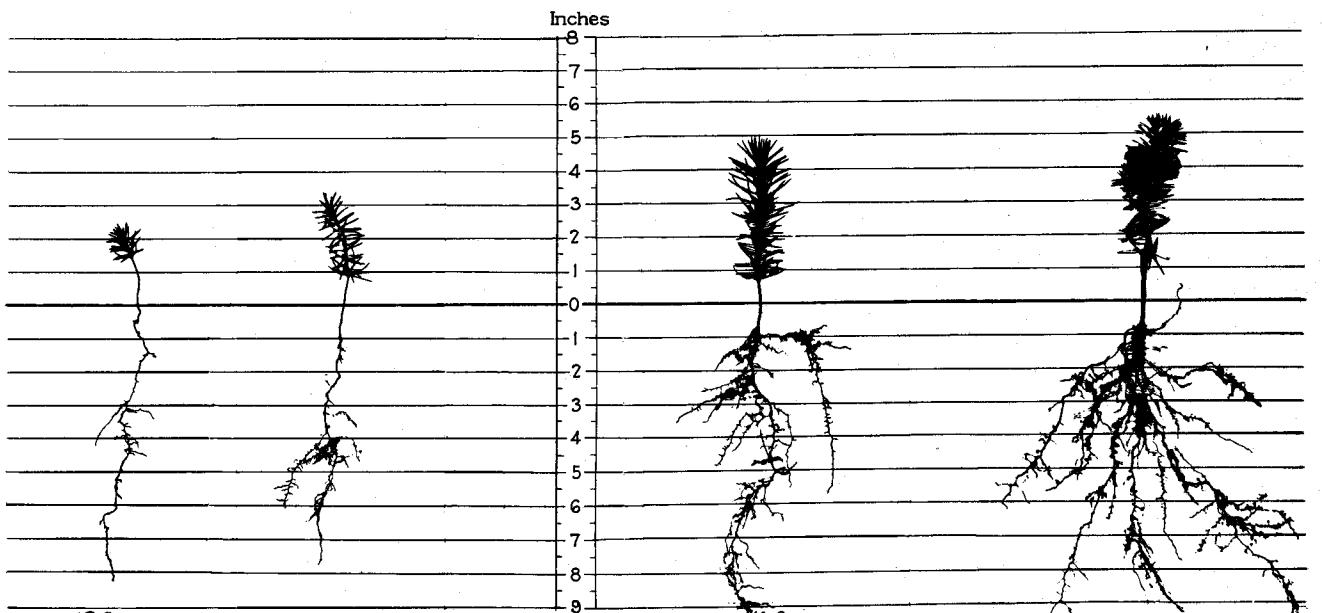


PLATE IX

Typical specimens of spring and fall sown I-O seedlings, I-I transplants, and 2-O seedlings grown at four different seed bed densities at the Wind River Nursery in 1933.

In the Oregon State Nursery ^{7/} and elsewhere, alder sawdust has been used successfully for covering the seed. It is spread to a depth of one-quarter to three-eighths inches over the seed. With spring sowing the shade frames are immediately placed over the beds. With fall sowing old burlap is spread over the sawdust and the shade frames are then placed on the burlap to hold it down. Sawdust is considered a good seed bed covering where the soil is stiff and heavy and where it may be obtained cheaply.

Time of Sowing

Normal sowing seasons are fall and spring. Fall sowing should be done after the season has advanced far enough to prevent fall germination and before frost or fall rains interfere with preparation of good seed beds. Spring sowing should be done as early as the ground can be worked. Fall sowing is of advantage in nurseries where weather and soil conditions delay spring nursery work to such an extent that germination of spring sown seed is unduly late. Where it is possible to obtain germination of spring sown seed within a week or two of fall sown seed, the time difference is of little or no advantage.

Fall sowing exposes the seed for a longer period before germination to such hazards as birds and rodents, dislocation by frost heaving, and burial or dislocation by erosion. If fall sowing is necessary, precautions must be taken to prevent those losses.

Seed of some species has a natural dormancy which, without special treatment, inhibits and in some cases prevents germination. In most cases dormancy can be broken successfully by exposing the seed in the seed bed all winter. This is accomplished by sowing it in the fall. Stratification is a satisfactory substitute for fall sowing and allows the seed to be sown in the spring obviating the disadvantages of fall sowing. Several methods of mechanical and chemical scarification have been used to break obstinate dormancy in some species but such treatment is not necessary on any of the commercially important species native to the Pacific Northwest. Stratification time and temperatures for a wide variety of species are given in publications by L. C. Chadwick (10), Lela V. Barton (6), and William Crocker (12). Scarification is described by Engstrom and Stoeckeler (15).

The only species commonly grown for reforestation in the Pacific Northwest that normally require fall sowing or stratification are western white pine, sugar pine, and cascara buckthorn. These species, if spring sown without stratification, normally produce scattered irregular germination over a period of several months and many seeds hold over to the following spring. If sown in the fall or stratified and sown in the spring, germination is rapid and complete early in the spring growing season.

^{7/} Manuscript correspondence with Vern E. McDaniel, Superintendent, Oregon State Nursery.

Stratification, while not normally necessary for any other commonly grown species, may be of advantage with lots of seed that exhibit unusual dormancy, such as old seed. Germination tests usually will disclose a tendency toward delayed germination if it exists and will indicate need for stratification. A short stratification period usually will correct the trouble. Some work has been done on hastening germination by soaking seed in water. H. M. Steven (52) found that it is not a substitute for stratification and that the greatest benefit to be obtained is a 3- or 4-day shortening of the germination period. Too long soaking is damaging to the seed. He found that soaking in water at ordinary temperatures for a period not exceeding 7 days was of some benefit in shortening the germination period of Douglas-fir and Sitka spruce. Chadwick (10) and Barton (6) report that germination of sugar pine is benefited by soaking the seeds 4 days and exposing them to freezing temperature for 48 hours.

They also report that western white pine shows best results from stratification at average temperature of 40° F. for 60 days, and that sugar pine shows best results at 40° to 50° for 90 days. The effective range of stratification temperatures are 32° to 50° for both species. No beneficial results are noticed from freezing during stratification.

Little occasion is found for stratification or other pre-sowing treatment of any species at Wind River, as sowing is usually completed in the fall. Fall sowing usually is started in October and sometimes continued into early December. Spring sowing usually is done in late April or early May.

Experience at Wind River indicated better germination of the balsam firs (species of the genus *Abies*) when they were sown in the spring and that practice was generally followed. There was at times some delayed germination of spring sown Douglas-fir indicating an advantage in fall sowing or stratifying that species. All other species, including spruces, cedars, hemlock, and alder showed no germination difference between spring and fall sowing.

The time of germination in the spring is influenced by local weather conditions and will vary from year to year depending upon the spring growing season. At Wind River it occurs between late April and mid-May in fall sown beds and from late April to June in spring sown beds depending upon the time of sowing.

Some difference has been noticed at Wind River in season of germination between fall sown seed from different altitudes. Ponderosa pine and Douglas-fir collected near the upper limits of their range commonly appeared first followed about 2 weeks later by seed from the low and intermediate altitudes. Port Orford white-cedar, Sitka spruce, western hemlock, and western redcedar all germinate about the same time as low-altitude Douglas-fir. The balsam firs usually germinate earlier, about the same time as high-altitude Douglas-fir and ponderosa pine.

Spring sown seed of all species, when weather is favorable throughout the germination period, starts to germinate 12 to 16 days after sowing and under good conditions should be complete in 20 to 24 days.

Seed Stratification

Stratification is accomplished best by thoroughly mixing the seed in a stratification medium. Sterile sand or sterile acid peat moss are recognized as the best stratification materials. Peat has the advantage of absorbing and holding moisture evenly distributed throughout. Sand allows moisture to settle to the bottom and tends to dry at the top and requires frequent mixing to maintain equal distribution of moisture. The moisture content should be just below the point at which free water can be squeezed from the material. The stratification material should be sterile to discourage growth of molds harmful to the seed. Enough material should be used to separate all seeds from each other.

Seed can usually be separated from the stratification material at the end of the stratification period by washing over a screen or by running through a regular seed cleaning machine. It may be difficult or impossible to separate certain species of small seed from the material, in which case it is usually necessary to sow it with the seed. After removal from stratification, care should be taken to prevent sufficient drying of the seed to lower the moisture content. Air drying of free water from the seed coat is not harmful and may be of advantage for machine sowing.

Mulching

It is usually necessary to mulch fall sown beds, and in some climates spring sown beds, to prevent frost heaving. Mulch usually is applied immediately after the beds have been sown, but it can be left off until the actual danger of frost heaving occurs. If the fall sown beds are covered with snow before the ground freezes and the snow cover stays on all winter, mulching may not be necessary at all. If alternate freezing and thawing occurs after the snow melts, heaving will occur and mulch should be applied to prevent it.

Straw is usually used at Wind River although burlap and paper have been tried and serve the purpose. Straw is cheap, but has the disadvantage of being bulky and difficult to handle. It is difficult to hold in place on beds not enclosed in frames. It is apt to carry weed and grain seeds which germinate in the seed bed and cause a weeding job unless they are eliminated before the straw is applied. It is common practice at Wind River to obtain the straw far enough in advance to allow the seed to germinate in it before it is used. To accomplish this the straw is loosened, partially spread, and kept wet through a period of warm weather. The same straw can be used 2 or 3 seasons in succession before it disintegrates beyond further use. It is then plowed into the soil.

Paper mulch tends to shrink and expand during alternate wet and dry periods causing it to tear in numerous places. It is difficult to hold in place during windy weather. Burlap is the most satisfactory and easiest to handle but it is expensive and requires drying and dry storage between seasons of use. For winter use in this wet climate it cannot be expected to last much more than a year.

Mulched beds should be examined frequently near emergence time so the mulch may be removed before it interferes with development of the seedlings. Straw mulch must be removed before the seedlings emerge because the tender seedlings are easily damaged by the removal operation. Burlap or paper mulch can be removed without damage after the seedlings are breaking through the soil and in this respect are superior to straw. More rapid and complete germination is obtained if mulch is left on until emergence starts.

Seedling Care

Irrigation

The seed bed should be kept continually moist during the germination period and until the seedlings have become established. This is best accomplished by frequent light irrigations rather than infrequent heavy ones. It may be necessary during dry, windy weather to sprinkle lightly several times a day to prevent the beds or portions of them from drying. Good irrigation during the germination period will do much to produce uniform germination on schedule and to prevent delayed and uneven germination. This type of watering should be continued until the seedlings have developed roots 2 to 3 inches long and have started to develop secondary needles or leaves.

After the seedlings have become established, irrigations should be heavier and less frequent. Watering during the spring and summer growing season has a direct influence on the development of the seedlings. Too much water tends to produce large succulent plants while too little retards normal development. Growth should be forced during the spring and early summer but water should be reduced gradually during the natural summer dry period to simulate the moisture stresses the plants will encounter in the plantations. Some irrigation usually will be necessary in the nursery when natural precipitation would be sufficient outside because of the density of the stand in the seed beds and the resulting heavy drain on soil moisture.

Irrigation is a valuable and effective aid to production of the size and quality of planting stock best suited to a planting site, and should be used to the fullest possible advantage to that end. Irrigation schedules and practices necessarily vary between nursery sites and nursery soils and have to be adjusted to meet changing weather conditions. Effective use of irrigation depends on the nurseryman's knowledge of the way the nursery soil takes and retains water and the availability of the water to the plants. Nurserymen, through experience,

can learn to estimate quite closely the moisture condition and requirements of the nursery by examining and feeling the soil. It is of considerable advantage, however, for the nurserymen to know the field capacity and wilting point of the soil and to make exact moisture determinations occasionally to guide their judgment.

The field capacity and wilting point can be determined in several ways. Some simple laboratory equipment is required for accurate measuring, weighing, and drying of the soils. Methods are described by Wilcox and Spilsbury (66) and by L. D. Baver (7). Assistance in making these determinations usually can be obtained through the local agricultural agent.

A simple method of roughly determining wilting point is to grow seedlings in pots of nursery soil until they are 6 or 8 weeks old, then discontinue watering until the plants wilt. Soil samples are then taken from the root zone, weighed, oven dried, and re-weighed. The weight difference is the amount of water retained in the soil at the wilting point. The amount of unavailable water retained in the soil varies with the soil texture. It is greater in fine-textured soils and less in coarse-textured or sandy soils.

Three general types of instruments have been devised for measuring soil moisture and some of them can be purchased from scientific instrument companies.

Tensiometers are based on the principle of capillary tension. Porous clay cups filled with water are placed in the soil and are connected with a mercury column. Water moves in and out of the cup through the porous walls as the soil becomes wet or dries and the movement or "tension" is recorded by the height of the mercury column. They are described by Richards and Gardner (46) and Rogers (48).

Electrical methods are based on changes of conductivity as affected by varying amounts of moisture between electrodes. Electrodes molded in porous clay blocks are placed in the soil, the blocks assume the moisture content of the soil in which they are buried and the resistance is recorded on a dial. They are described by Bouyoucos and Mick (8).

Mechanical methods employ porous clay blocks or cones which are buried in the soil to absorb moisture and their increase in weight is used as a measure of soil moisture. Their use is described by Livingston and Koketsu (30).

These instruments are a valuable aid to the nurseryman in studying and determining soil moisture requirements of nursery stock and are also valuable as a guide for irrigation schedules, especially during seasons when high moisture stresses are to be maintained to condition the plants for field planting. The instruments have to be kept calibrated to the soil in which they are used and the nurseryman using them must understand their principal and method of operation.

Water can be applied through overhead irrigation systems more efficiently during cool quiet weather than during hot or windy weather as both heat and wind cause high evaporation losses and wind causes uneven distribution, especially at ends of beds or boundaries of blocks. Strong winds during irrigation periods necessitate hand watering of "missed" places. It is, therefore, of advantage to water in the evening, or at night when weather conditions interfere with satisfactory irrigation during the day.

The overhead system is, however, a valuable tool to prevent damage to seedlings from wind and heat. Extremely hot days can build up the temperature of the surface soil to a degree that will damage or kill seedlings, especially when they are young. Watering during the heat of the day does not harm the seedlings and it cools the soil below the danger point. High winds, especially in the spring, can uncover seed and cause damage or loss of seedlings by sand blasting the tender plants. Water applied through the overhead system can stop this movement of sand quickly and effectively.

Frost damage to new growth has been lessened materially by spraying water through the overhead system onto the plants, starting before sunrise and continuing until the frost is thawed away.

Shading

Most coniferous species and especially those which in nature are tolerant of shade are susceptible to damage from too long exposure to direct sunlight and high soil temperatures. The period of greatest susceptibility is from emergence until the seedlings have developed woody stems and secondary leaves or needles. It is advisable as a precautionary measure to obtain germination of all species early in the spring to allow development of sturdy plants before hot weather. Even then it is usually necessary to shade artificially the more tolerant species through the heat of the first growing season. It is not possible to lay down definite rules governing the use of shade as the location of the nursery is a principal governing factor. A nursery located on a hot dry site or with south or west exposure will be most susceptible to heat and sun injury. Artificial shade should be used only when necessary to prevent injury. It is advisable to subject the plants to as severe exposure in the nursery after they have passed the first spring growing season as they will receive in the plantation. Too much protection in the nursery produces weak plants that are unable to survive the less favorable conditions of the planting site.

As a general rule, in nurseries located in average climatic conditions of the Pacific Northwest, it is not necessary to shade any of the pines or Douglas-fir, provided sprinklers can be turned on to cool the ground on hot days. It is usually necessary to supply shade during at least part of the first growing season to the spruces, cedars, hemlocks, and the balsam firs.

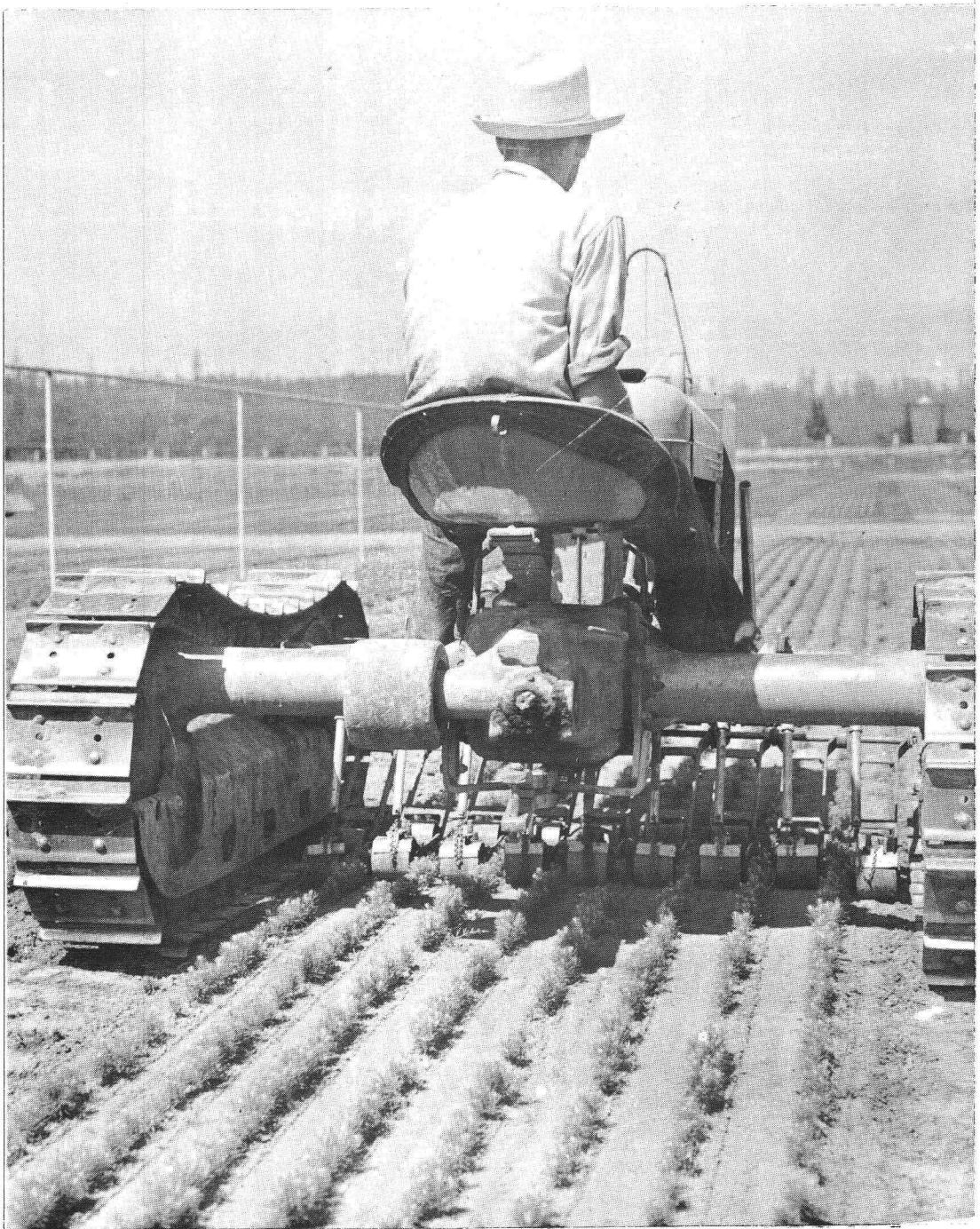


PLATE X. Cultivating machine used to weed long beds at the Nisqually Forest Nursery.

Courtesy West Coast Lumbermen's Association

The type of shade most universally used is made of lath spaced the width of the lath apart either nailed to rigid frames or woven together with wire. Commercial snow fence is often used. The shade should be supported 6 to 12 inches above the seed beds to allow free movement of air beneath it. It is not necessary to remove the shade for watering with overhead systems. For most efficient use, the lath should lie north and south across the bed to allow maximum movement of shade on the bed from morning to night.

Weeding and Weed Control

Weeds in seed beds interfere with normal growth and development of the tree seedlings. Weed growth should be prevented and weeds that do develop should be removed before they interfere with the trees. Weeding can be one of the most expensive operations in seedling culture and should be kept to the minimum for the purpose of economical operation as well as for cultural purposes.

By carefully managing the weed control job both in and adjacent to the nursery it is usually possible to reduce greatly the nursery weeding job in a few years. Weeds never should be allowed to go to seed in the nursery or on idle areas adjacent to it. If ditch irrigation is used or if water is pumped from reservoirs, it may be necessary to screen or filter the water to remove weed seeds.

Weeding of broadcast beds must necessarily be done by hand. Weeding machines or cultivators are used effectively to remove weeds between rows of drill sown beds but some hand weeding follow-up is usually necessary. No nursery weeding machines are on the market but several types have been developed by the U. S. Forest Service and private nurserymen (plate X). Plans for their construction can be obtained through the U. S. Forest Service or private nurseries where they are in use or were developed.

Various herbicides available on the market have been used with varying degrees of success. They are very effective along fences and windbreaks where it is difficult to mow or cultivate. Certain commercial acids, gases, and gas-producing chemicals can be used to kill weed seeds in seed beds before sowing but they have the disadvantage of also destroying beneficial soil organisms. In some cases they break dormancy of inactive seeds and may cause a heavy growth of certain species that otherwise would not be troublesome.

Selective herbicides that kill certain weeds without harming tree seedlings have been tried and are still being developed. However, they have not been developed to the extent that reliable recommendations can be made for their use. The age of the weeds, age of seedlings, and weather conditions at time of application affect their reactions. Hand and machine weeding should be relied on as the principal method of weed control with such supplementary experimentation with chemical control as the seriousness of the weed situation may warrant.

Flame throwers, similar to forest fire control backfiring torches, have been used with some success at Wind River to kill weeds that germinate in seed beds before the trees emerge. The flame can be passed rapidly over the surface of the seed bed without damage to the tree seedlings a day or two before the seedlings emerge.

Agricultural agents and representatives of manufacturing companies should be consulted on use of herbicides. If chemicals are used, care should be taken to prevent creation of a toxic soil condition which may counteract fertilizers and have other detrimental effects on soil and seedling growth.

Muenscher (38) describes the use of chemical weed control, but advises against use of chemicals where cultivation can do the work. Raynor (45) describes use of some chemicals and machines and methods of application.

Cultivation

Cultivation of seedlings for the purpose of working the soil as differentiated from weed control is usually unnecessary, but is of some advantage as an aid to penetration of irrigation water in nursery soil that cakes or crusts. It is practically impossible to cultivate broadcast beds, but it can be done by hand or by cultivating machines in drill sown beds. Cultivating can be done with the same machines that are used for weeding drill sown beds by fitting them with soil working attachments.

Fertilization

Plants grown under conditions of nutrient deficiencies are poor planting risks. There is evidence that nursery soils with an abundance of available essential plant foods increase the survival expectancy of planting stock. The nursery soil should be maintained in the best possible condition of fertility to develop seedlings of the desired size and quality without addition of fertilizers during the growing season. If, however, the seedlings show signs of fertilizer deficiency, side or top dressings of commercial fertilizers should be applied.

Deficiencies usually are evidenced by uneven development of seedlings, a dishing effect caused by small plants in the center of the bed, or chlorosis. Deficiencies usually show up in irregular spots of varying size. Care must be taken, however, to diagnose the trouble correctly for the same symptoms can be caused by too dense stands, insufficient or uneven irrigation, disease or insects, or in some cases by too high concentration of fertilizers, salt, or other toxic substances.

Nitrogen stimulates top and leaf growth and in a soluble form is about the only fertilizing element that can be applied to obtain quick results. It stimulates top growth and corrects chlorotic conditions. Beneficial results should be noticed in a week or 10 days after application if a deficiency existed.

Phosphorus is a slower acting element as are potassium and the rarer elements. Phosphorus stimulates root growth but it moves very slowly through the soil, its benefits are confined to an area within a few inches of its application over a period of a year or more unless it is later mechanically mixed through the soil.

Nitrogen can be applied effectively as a top dressing, as a side dressing one to several inches below the surface, or as a solution in the irrigation water. One cheap method of application is to dissolve it and siphon it into the irrigation system during a regular irrigation period. This should be done when there is no wind. Clear water should be applied after application to wash the solution from the plants.

Both sulphate of ammonia and nitrate of soda are soluble and are efficient sources of nitrogen. In soils that contain alkali, sulphate of ammonia is better because the sulphate radicle combines with alkalies making them more soluble and aids leaching while the sodium of the nitrate of soda combines with chlorides and increases the salt concentrations.

The use of ammonium phosphate for liquid application or dry top dressing is inefficient because only a very small part of the phosphorus is made available to the plants and the only benefit is derived from the nitrogen.

It is impossible to side dress broadcast beds. Side dressings can be quite easily applied to drill sown beds to depths of as much as 4 or 5 inches with commercial fertilizer drills remodeled to fit the nursery beds.

Thinning

Thinning should be done only to correct high density conditions resulting from inadvertent oversowing or uneven sowing and not as a regular practice. It is sometimes necessary in beds that are held longer than anticipated at time of sowing. When thinning is done, an effort should be made by selection of plants to leave the remainder ideally spaced. Wire or lath frames about 2 feet square are an aid to inexperienced help in thinning to desired spacing and density.

It is best to pull the excess plants, but in some cases economy of operation requires cutting them off at the ground line. The dead roots in that case are apt to become enmeshed with the roots of the remaining living plants and are a nuisance at time of stock distribution.

Root Pruning

Root pruning in the beds is done to increase the formation of lateral roots on that portion of the root system that will be lifted with the plant. It also is used effectively to retard growth of stock

that has to be held in the beds a season beyond normal planting age. It is of little value on stock to be harvested as 1-year-old trees. It does stimulate formation of lateral roots during the second year's growth on stock to be harvested at 2 years or older. The growth setback caused by root pruning should be balanced against the beneficial effect of more lateral roots. Douglas-fir on good nursery sites usually is ready for root pruning at 1 year of age in the expectation of producing 2-year-old seedling planting stock.

Pruning can be done at various levels but 4 to 5 inches is the usual depth. It should be done in the spring of the second year before spring growth starts for stock to be lifted at age 2-0. Stock to be lifted at age 3-0 should be pruned in the summer of the second growing season after spring growth ends or early the following spring. Fall root pruning increases susceptibility to frost heaving. Root pruning is accomplished by pulling a thin sharp blade through the bed at the desired depth. Several types of pruning devices have been made. William F. Will, Nurseryman at Wind River 1919-43, did much pioneering work on root pruning and development of root pruners. The most successful is similar to the nursery tree lifter described under "Stock Distribution" (figure 6 and plates XI, XII, and XIII). The pruner blade is, however, thinner, usually made from a section of a band saw or a grader blade, and it runs flat (without the tilt of the tree lifter blade) through the bed. Immediately after pruning, the beds should be irrigated to settle the loosened soil solidly around the plant roots.

Root pruning is not a successful substitute for transplanting and is not much more economical. The low density necessary in the seed bed and the difficulty of producing satisfactory spacing and stocking in the beds to a considerable degree offsets the cost of transplanting.

Top Pruning

Top pruning is used to set back excessively tall or spindly top growth which sometimes occurs in seed beds. It may, in some cases, help in a small way to increase stem diameter but there is little proof of that effect. Top pruning of excessively tall plants has no apparent detrimental effect on them except that when planted in the field, development of a dominant leader is sometimes retarded. This is a disadvantage when the plants have to compete with tall growing vegetation on the planting site.

Top pruning should be done only when necessary and should not be a common practice. It should not be employed during the spring growing season and preferably only when the plants are entirely dormant.

Mulching

Small seedlings, and in some soils even large seedlings, are subject to frost heaving during periods of alternate freezing and thawing weather. It usually happens in the spring but can take place in the fall or winter when conditions are right. Under the most severe conditions, seedlings are worked entirely out of the ground or so far out that corrective measures are impossible and the seedlings either die or are worthless. It is usually more severe in heavy than in light soil. It is prevented by mulching the beds, following the same general principles as mulching fall sown seed beds except that paper or burlap cannot be used. Loose material such as hay or straw is the only practical mulch material for seedlings. On beds enclosed in frames, the mulch is held in place by the frames. On long beds not enclosed in frames, it is subject to dislocation by wind. It can be held in place on such beds by covering with the shade frames or screens, if available, with chicken wire, poles, brush or branches, or by crossing twine back and forth diagonally across the beds over the mulch and tying it to stakes driven 12 to 16 feet apart along the edges of the beds. The same precautions for elimination of weed seeds in the mulch should be taken as for straw mulch on fall sown seed beds. The seedlings should be mulched late in the fall after they are entirely dormant and after continued cold weather is assured.

Within the climatic belt where snow lies on the ground through the winter, it is an effective mulch; if the seedlings are well covered by snow before frost heaving occurs in the fall, mulch need not be applied until spring, or in some seasons not at all if the snow cover remains on the beds late in the spring. Mulch can be applied on top of the snow; it is sometimes more effective when used this way as it is less likely to mat to the ground the seedlings which are held erect by the snow. The protective snow cover is preserved on the beds by the straw after it has melted from unmulched areas.

Shingletow and peat moss have been tried as mulch materials, but they are not as satisfactory as hay or straw. Both are difficult to remove in the spring and there is some evidence that shingletow may have a toxic effect on the soil.

Experience at Wind River indicates that 1-0 age class spruces, cedars, hemlocks, and balsam firs are, on account of their small size, most susceptible to frost heaving. The pines are least susceptible. Douglas-fir is susceptible under moderately severe conditions. Spruces, cedars, hemlocks, and balsam firs, under extreme conditions, are damaged at age 2-0. Little difficulty has been experienced with 2-0 pines or Douglas-firs.

Transplanting

Reason for Transplanting

Transplanting is done to produce larger sturdier stock than can be produced in seed beds. The need for transplants is determined by the planting site. On severe sites where survival of seedling stock is questionable, the chance of obtaining satisfactory survival is increased by the use of transplant stock. Species that grow slowly both in the seed bed and in the field are most apt to require transplanting because they are less able to overcome natural competition and other adverse conditions of the planting site.

Transplants are usually grown to age class 1-1, 1-2, or 2-1. It is, therefore, necessary to plan their use 2 or 3 years ahead. They should be used only when conditions of the planting site make them necessary. Their general use where seedling stock will suffice is uneconomical as they are more expensive to produce and more expensive to plant. It is likewise uneconomical to plant seedlings on sites requiring transplants, as under those conditions the planting can be expected to fail and replanting to sturdier stock will be necessary.

Time of Transplanting

Transplanting can be done any time of year the plants are dormant. It cannot be done successfully on a large scale when the plants are growing. The usual time is fall or spring although it can be done throughout the winter if the nursery is not frozen or too wet. In nurseries that freeze, transplanting is most successfully done in the spring as fall transplants are extremely susceptible to frost heaving which in some cases mulching fails to prevent.

Spring transplanting can start as early as the ground can be worked and should be completed before growth starts. Weather conditions sometimes make the spring transplanting season too short to transplant the required number of plants before growth starts. In that case, seedling stock should be lifted, placed in cold storage, and held dormant for later transplanting. The transplanting season in this way can be extended several weeks.

Preparing Transplant Area

If the transplant area is to be irrigated with an overhead system, it should be prepared in the same general way as for seed beds although it is not necessary to do as fine a job. A small amount of debris or some unevenness does not interfere seriously with transplanting or later transplant care. If furrow irrigation is to be used, the area should be graded carefully and laid out to assure adequate and even distribution of water to the entire area.

Preparing Seedlings for Transplanting

Seedlings for transplanting are lifted by loosening them with a regular seedling lifting machine with the blade set 5 or 6 inches below the surface. (Figure 6 and plates XI, XII, and XIII.) The loosened plants are pulled from the beds by hand and placed in small bunches beside the workman with the roots lightly covered with soil. A pickup man collects the bunches of trees, trims the roots to the desired length with the aid of a gauge and any suitable heavy knife or common meat cleaver. In trimming the roots, care must be taken to be sure the bunches of seedlings are evenly arranged so that all roots are trimmed at the same distance below the root collar. They should not vary more than one-half inch.

This supplemental trimming is necessary even though the seedling lifter severs the tap roots at an even depth because laterals usually are longer than the severed tap root.

After the roots have been trimmed the seedlings should be placed in even layers with roots overlapped in common field lugs or other suitable carrying containers. A lug 14 or 16 inches wide by 24 inches long by 5 or 6 inches deep is a convenient size to handle. At Wind River standard round metal gold-washing pans have been used with the seedling tops arranged to the outside and roots to the center. The containers of seedlings are then hauled directly to the transplanting crews or placed in cold storage if the plants are to be held for later planting.

Throughout the operation, the seedlings should be handled as little as possible, loose soil should be shaken lightly from the roots, and the roots should not be allowed to dry. The roots should not be dipped in water or otherwise washed. They should be covered with soil by the pullers and with pieces of wet burlap by the trimmers when they are placed in the lugs. No culling or sorting ordinarily is done during the lifting operation. It should be done by the transplanting crew.

The most satisfactory procedure is to have a lifting crew service the transplanting crew by taking the plants directly from the seed beds to the transplant job with no more than one day's supply ahead at any time. If it is necessary to lift ahead of the transplant job, the trees can be held in cold storage in the field lugs by cross piling or spacing to allow free circulation of air around each lug. The cold storage time should be as short as possible and preferably under conditions of controlled temperature of 36° to 40° F. and at high humidity.

Methods, Tools, and Machines

There are several different ways to accomplish the job of transplanting. Small jobs are sometimes done by setting each plant individually, using a board for a straight edge and a hand dibble to make

a hole for each plant. Larger jobs are usually broken down to several operations and utilize specialized tools. Considerable work has been done on transplant machines but so far none has been developed that is entirely satisfactory. Transplanting machines have been developed commercially to plant field crops such as celery or cabbage, but they are not adaptable to the close spacing in and between rows used in nursery transplant beds.

Forest nurseries usually use a planting board that holds many seedlings (15 to 50) correctly spaced for planting. There are two types of planting boards; one is placed in the transplant bed to serve as a guide for trenching and spacing between rows while the trench is being dug and has seedlings threaded into it while in place at the edge of the trench; the other is threaded with seedlings in a booth or on a table (figure 4), the seedlings are clamped in place, and it is then carried to the trench and held while the roots are covered.

The "in place" board or "Michigan board" is used at Wind River. With this the steps in procedure are: (1) With spade or trenching tool make a trench with one vertical side along edge of board; (2) turn board over so that metal covered edge is back and notched edge is forward; (3) thread seedlings in notches; (4) cover and tamp soil against roots; (5) slip board out and turn it over and ahead in place to serve as a guide for next row.

With the "clamp type" of board, the Yale, or Savenac board, (figures 5A and 5B) the steps are: (1) Thread seedlings into board in a booth or on a table while trench is being dug; (2) carry board to trench; and (3) hold in place while soil is tamped around roots, then release.

With the "in place" board 1 or 2 men may work; if 2, each does his share of each step of the operation, one working from right to left and the other working from left to right. With the "clamp" type of board, one or more men may work at each separate step in the operation. Booths, when used, are usually portable and are moved along as work progresses. Regardless of method used it is of prime importance to prevent the roots from drying out during the threading and planting operations.

When transplanting is done in long field rows, the trench is usually opened with a small plow or trencher pulled by horse or tractor. The plow may be of regular land side and moldboard pattern or a "V" plow which makes a slit-type trench without listing the soil out on the sides. Plows usually are made up on the job to suit the needs of the local soil. Types of plows are described by Olson (43) and by Engstrom and Stoeckeler (15). In heavy soil it is better to use spades for hand trenching and moldboard plows for power trenching, since "V" type plows leave compacted smooth soil surfaces against the plant roots when the trench is closed. Hence, the roots are liable not to grow out of the flat plane into which they are compressed and to develop badly deformed root systems. Also in heavy soils after

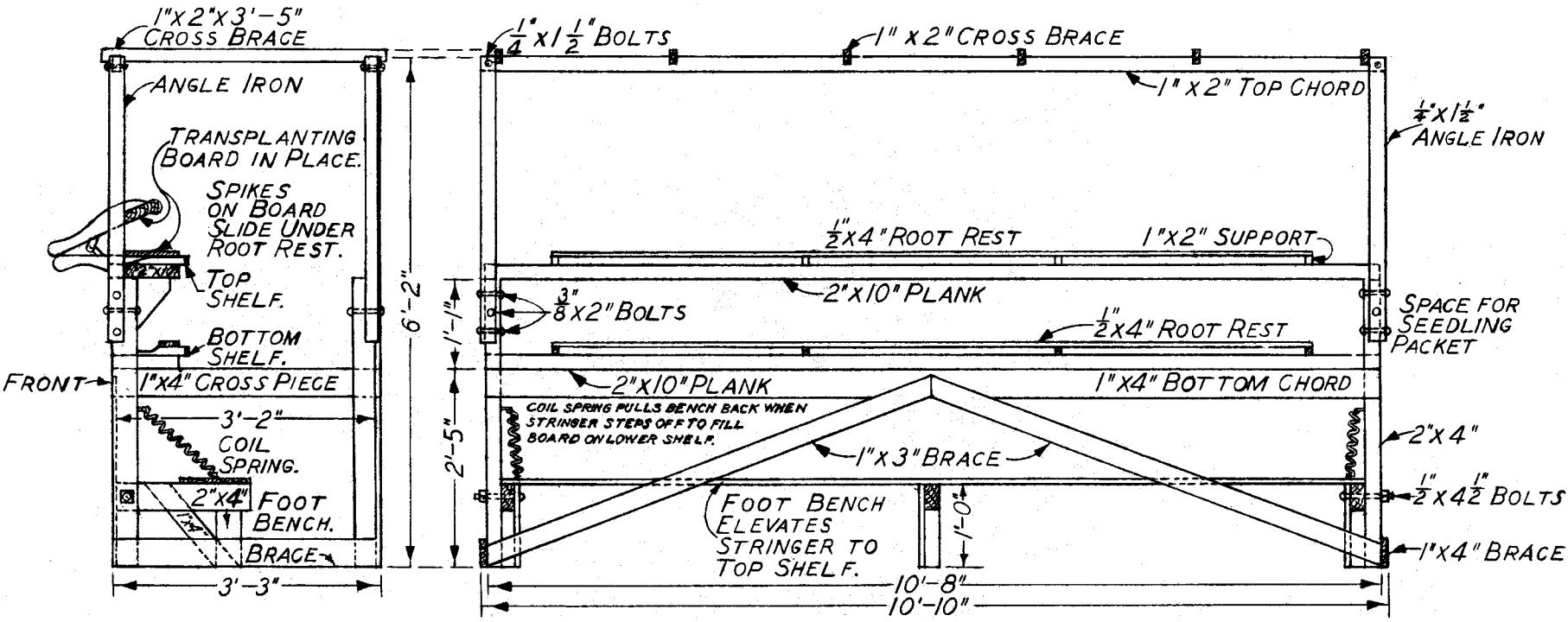


FIG 4
DETAILS OF SAVENAC STRINGING TABLE

SCALE - $\frac{1}{2}$ IN = 1 FT.

slit trenching the soil tends to crack open along the trench-cut when it dries, exposing the roots to the air, and plants growing under those conditions do not overcome susceptibility to frost heaving. The "V" type trenches are, however, quite satisfactory in light soils.

It is important that the trench regardless of method used be deep enough to allow all plant roots to hang straight to their full length without turning at the bottom. It should be formed to prevent loose soil caving into it that might interfere with the plant setting operation. Some local experimentation is usually necessary to build power plows or hand trenchers that will have the proper design to do a satisfactory job in the particular soil to be worked.

The common errors made in the setting operation are allowing the roots to dry by too long exposure and doubling, matting, or curling the roots by setting the plants too deeply or setting them in trenches that have caved in. Regardless of method used, it is of prime importance that these things be guarded against by close and diligent supervision. Allowing the roots to dry will cause lowered survival in the transplant beds. Curved or matted roots do not show up until the plants are lifted a year or two later and they may be so deformed as to make the plants worthless.

The transplant board illustrated in figures 5A and 5B is representative of the boards commonly used. Many local variations have been developed, however, to suit the needs and desires of nurserymen. One development that has been quite universally adopted is the facing of the edges of the clamp type board with strips of sponge rubber where they clamp the seedling stems.

Transplanting should be done in soil that is moist. It may be necessary in warm, dry weather to moisten the surface occasionally during the operation to prevent dry top soil or sand from sifting down into the trench. The transplants should be watered immediately after transplanting and the soil should be kept well irrigated until the plants have produced new top and root growth and have become well established. Subsequent irrigation should be controlled to produce required development, hardening, or dormancy.

Spacing

Spacing should be gauged to produce the maximum number of plants of desired quality and size per unit of transplant area and to allow economical weeding and irrigating. Whether planted in beds or in field rows, the seedlings are usually spaced $1\frac{1}{2}$ to $2\frac{1}{2}$ inches apart in the rows. The rows are usually 6 inches apart in beds and 8 or 10 inches apart in field rows. Wider row spacing is necessary in field rows as it is difficult to make plowed furrows as close together as 6 inches. Paths are not needed in field rows but they are needed between beds so the total plants per acre is about the same with either system. Spacing 2 by 6 inches will result in an average density of 12 plants per square foot or about 523,000 plants per net acre of actual planting exclusive of irrigation lines, roads, paths, and other service areas.

Age class 1-2 usually develops larger plants than age class 2-1 and, therefore, will require wider spacing. Age class 1-1 requires less space than older age classes of the same species.

Spacing in rows is regulated by the position of the notches in the transplant board. Spacing of rows in beds is gauged by the width of the board when using the open-type board or by a number 9 wire with lead pellets soldered on it 6 inches apart. The wire is stretched along one side of each bed and held in tension with a spring on one end. Each pellet marks the place for a trench. Even spacing of rows in field row planting is usually accomplished by laying out an occasional row with a line marker and providing the plow with an arm marker that scores the next row location.

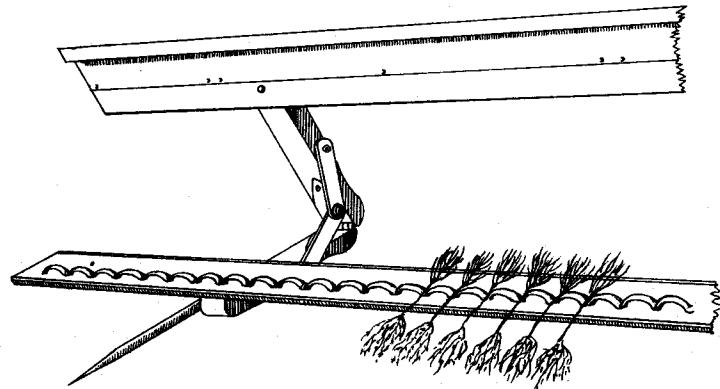
Spacing in the rows, given in table 8, is indicative for average nursery and planting conditions; in all cases the spacing between rows is 6 or 8 inches. Certain planting sites may require older age classes and certain nurseries may develop satisfactory stock of certain species a season earlier or later than other nurseries.

Table 8.—Commonly Used Age Classes and Recommended Transplant Spacing

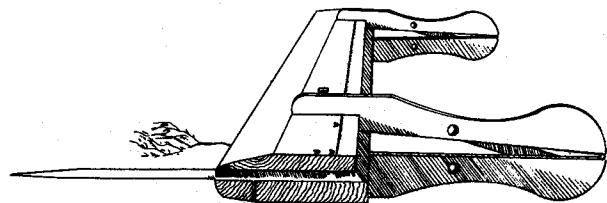
<u>Species</u>	<u>Age Class</u>	<u>Spacing in Rows</u>
Douglas-fir	1-1	1½"
	2-1	2"
Ponderosa pine	2-1 or 1-1	2½"
Sugar pine	2-1	2"
Western white pine	2-1	2"
Spruces	1-2 or 2-2	2"
Balsam firs	1-2 or 2-2	1½ or 2"
Western hemlock	2-1 or 2-2	1½ or 2"
Western redcedar	1-2 or 2-2	1½ or 2"
Port Orford white-cedar	1-2 or 2-2	1½ or 2"

Care of Transplants

Weeding, watering, cultivation, and fertilization of transplants is essentially the same as for seedlings. Frequent irrigation is important while the plants are becoming established, subsequent irrigation should be such as to develop the size and quality of plants required by the planting site.



BOARD OPEN



BOARD CLOSED

FIG. 5-A
SAVENAC TRANSPLANT BOARD

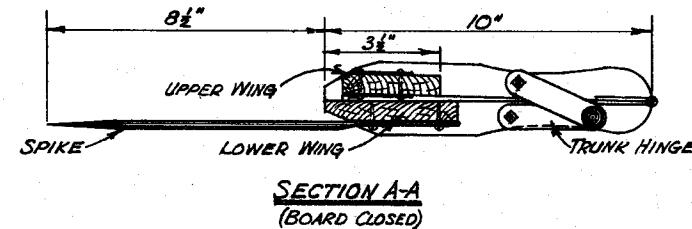
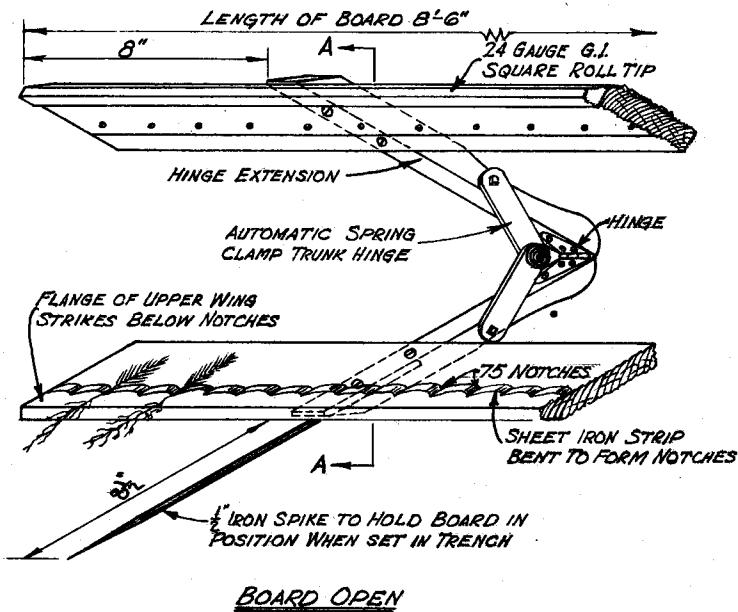


FIG. 5-B
DETAILS OF THE SAVENAC NURSERY TRANSPLANT BOARD

Weeding of transplant beds cannot be done effectively with machinery but hand tools, such as scuffle hoes, are used to advantage. Machine weeding of field rows is accomplished quite easily but hand follow-up is usually necessary to remove weeds from the seedling rows.

The soil should be fertile enough or previously fertilized to make side or top dressings unnecessary. Deficiency corrections should be handled essentially the same as for seedlings.

Transplanting done in the fall too late to allow the plants to establish a firm root system may require mulching in nurseries where weather and soil conditions are conducive to frost heaving.

Stock Distribution

Seasons, Dormancy, Hardening

Planting stock cannot be lifted and replanted successfully while it is growing actively. It must be lifted from the nursery only when it is dormant. Dormancy of the tops starts naturally in late summer and is complete by early fall, though nursery and wild plants sometimes burst their buds in late summer and make a little terminal growth. The roots do not become dormant until later in the fall. Dormancy continues through the winter until the spring growing season. Stock can be lifted and handled any time during the dormant period that weather conditions will allow. It is not good practice to expose the roots of lifted plants to freezing conditions.

Sometimes hardening is used synonymously with dormancy for describing condition of nursery stock. Hardening should be applied, however, to the conditioning of the plants by controllable nursery operations, principally irrigation and fertilization. Plants can go into dormancy with weak, somewhat succulent stems and chlorotic leaves. They can be safely handled and field planted but they are poor survival risks, especially on adverse planting sites. Hardening should develop sturdy, woody stems, healthy leaves and buds, and should store an abundance of plant food in the plants to carry them through the winter and provide them with a good reserve for start of growth the following spring. It is especially important that the plants be well hardened during the last season in the nursery before they are field planted.

Dormancy ends in the spring quite soon after the first warm weather. At Wind River the spring stock distribution season is normally much shorter than the fall because warm growing weather follows within a few weeks of the disappearance of snow and frozen soil. In the fall, plants are usually dormant by early October and nursery work is not halted by snow and cold weather until early December.

Where similar conditions prevail, nursery work must be planned carefully for the spring and fall seasons to allow completion of essential jobs. To service large spring planting projects, it is usually

necessary to increase the labor crew early in the spring, prepare seedlings for shipment while they are dormant, and place them in cold storage for later shipment because field planting usually can be continued after the plants no longer can be lifted.

Lifting

Common practice is to lift nursery stock with a lifting machine although small lots are often lifted with shovels or spades. Two types of lifting machines are in common use--the sled type (plate XI) and the wheel type (plate XII). Many modifications of both types have been developed by nurserymen, but they are all essentially the same in principle. They consist of a horizontal sharp-edged blade, to sever the roots, tilted and fitted with fingers or elevators to agitate and loosen the soil from the roots. The blade is adjustable for depth.

The blade is pulled under the bed, set to sever the roots at the desired length. Seedling roots usually are cut at 6 or 7 inches while transplants usually are cut at 7 or 8 inches.

The soil must be moist at time of lifting to prevent the roots from drying during the operation. It is difficult to pull the digging machine through heavy soil that is dry and it breaks in chunks causing damage to plant roots. A lifting machine that is doing a satisfactory job will loosen the soil and plants evenly leaving them standing erect with no roots exposed but free enough to allow them to be lifted easily from the beds by their tops without damage to the tops or stripping of fine roots. The lifting machine should be operated just ahead of the lifting crew--under ordinary conditions not more than half a day. During damp weather more time may elapse, but during extremely dry weather it should be less. If for some reason a loosened bed must be left unduly long before the plants are removed, it should be irrigated to settle the soil around the roots and it may be necessary to run the lifting machine under it again before the plants are removed.

Plants are pulled from the loosened beds by hand, the loose soil is lightly shaken from the roots, and the plants are placed in pickup boxes or lugs and covered with wet burlap or heeled in temporarily pending later disposal. When the plants are pulled, less damage is done to them by pulling many plants at once than by pulling one or few at a time. Work should progress systematically through the bed, always working the plants out toward the vacated portion. The job should be organized to obtain maximum efficiency and output according to local practices and labor conditions. Since plants can be damaged seriously during this operation and the damage not become evident until they fail to survive in the plantation, diligent supervision is essential.

The following points are of prime importance:

- (a) Do not let even the fine roots become dry.
- (b) Handle the plants as little as possible; handle them in bunches, not individually.

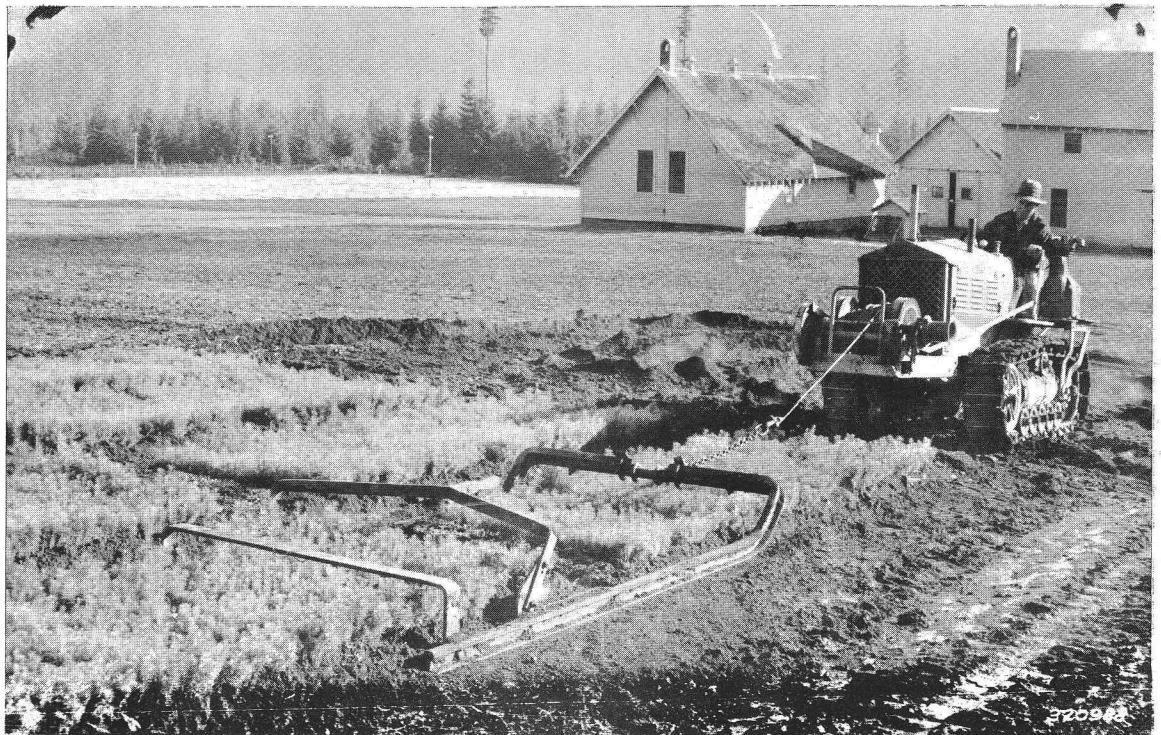


PLATE XI. Seedling lifter being drawn under 2-0 Douglas-fir seed beds by a stationary tractor at the Wind River Nursery, Columbia National Forest. This equipment, except for the blade, is identical with the root pruner.



PLATE XII. Wheel type of seedling lifting machine with the tractor straddling the long beds.



PLATE XIII

Nurseryman lowering into the soil the blade of the seedling lifter. Pulled by a tractor this equipment runs 8" below the surface, loosening the tree roots so that the trees may be taken up without injury.

Courtesy, West Coast Lumbermen's Association.

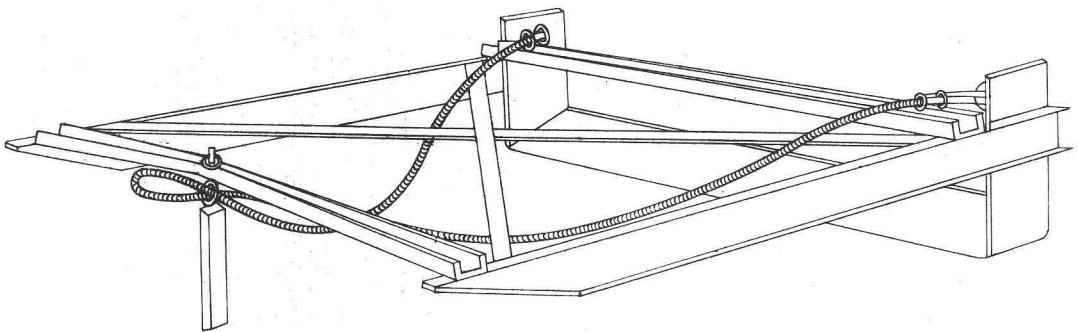


FIG. 6
TREE-DIGGER FOR A FOREST-TREE NURSERY

Drawn By K.V.P. 6-6-44

- (c) Be sure no roots are being stripped.
- (d) Do not whip the roots or hit them against objects to remove soil. It is good practice to leave soil particles adhering to the roots.
- (e) Roots should be exposed as short a time as possible; they should be kept covered with wet burlap in the lugs.
- (f) Plants should be laid evenly in the lugs; special care should be taken to prevent roots from becoming tangled or disarranged.

Culling and Grading

Culling is accomplished more efficiently at the nursery than on the planting job. As nearly as possible, all plants leaving the nursery should be within the established standards of size and quality. The culling operation is done either in connection with and as a part of the lifting job or by a special crew trained for it.

The method used depends to some extent on the amount of cull. Stock that has a low cull percent usually can be culled cheaper and more efficiently as a part of the lifting job; stock that has a high cull percent usually requires culling as a separate operation.

If done in the field, each lifter should be trained to recognize culled and should be supplied with a simple handy gauge to check his judgment of size. Culling for size is based principally on diameter of the stem at the ground line. Plants culled because of small stem caliper should be removed after the plants are lifted from the bed and before the soil is shaken from the roots. A double handful of plants is lifted from the loosened bed with soil adhering, and laid on the ground in front of the worker. The stems are then clearly visible and the small plants easily removed by pulling them straight out without disturbing the good plants or exposing their roots.

A simple caliper gauge is made by filing a notch of the proper size in a flat piece of metal. Sharp and rough edges should be removed to prevent damage to the stems. After culling for caliper, short-topped or damaged stock should be removed. Then the soil is shaken lightly from the roots and the trees placed in the field lugs. It seldom happens that short or poorly rooted stock remains after culling for caliper and top size but the worker should glance at the roots after removing the soil and discard such plants as may have poor root systems. The same piece of metal that serves as a caliper gauge can be marked for root length and top length.

When culling is done as a separate operation, no attempt should be made to cull in the field. The filled lugs are taken to a sorting shed where the sorting crew works at tables or benches (plate XIV). In this procedure each plant is handled and judged separately. Gauges usually are fastened to the benches or tables in positions handy to the workers. The plants are kept moistened by wetting as needed. Some nurseries with big culling jobs have installed conveyor belt sorting tables. All plants are spread out on the belt at the head end, sorters remove culled as the belt carries the plants past them, and the good plants are collected and packed at the other end of the belt.

Ratio of tops to roots with separation made at the root collar generally is accepted as a criterion of quality for coniferous stock. The ratio is based on weight of top to weight of root either on a dry or green basis. Stock with greater weight of roots than tops has been found to be of superior quality, equal weight of roots to tops or a 1 to 1 ratio is under most conditions quite satisfactory while a 3 to 1 ratio is considered poor, although there will be some variation between species and age classes.

Satisfactory top root ratio is attained through good nursery culture and the stock whether seedlings or transplants should be uniform in this respect. Culling for size, as gauged by stem caliper, usually will remove plants of poor ratio along with under-developed plants. If, for some reason, stock develops unsatisfactorily, and there is a large percentage of poor ratio stock, top root ratio has to be considered as a cull factor. Plants of unsatisfactory top root ratio usually cannot be satisfactorily culled in conjunction with the lifting operation.

In all culling operations, mechanically damaged plants should be culled out. Plants with forked roots or forked tops are not ordinarily undesirable. Forked top plants do not necessarily develop into double stemmed trees.

Grading stock of any age class or species into 2 or 3 size classes sometimes is done to advantage when stock development is uneven and the planting area is varied. The larger, sturdier stock is assigned to the more adverse sites and the smaller stock to the more favorable sites.

Counting

It is necessary to have some estimate of the number of plants being shipped. When orders are received for a certain number of plants, usually in units of 1,000, for a certain planting job they should be filled within reasonable accuracy to prevent over-shipment or under-shipment.

For small shipments of a few thousand plants, or for orders shipped for sale, it is usually advisable to count all the plants. When this practice is followed it requires little extra work in the



PLATE XIV. Sorting and packaging trees at the Nisqually Forest Nursery. The two women are placing trees on the moving belt ready for the inspector who throws out the inferior trees; the man in the foreground wraps the roots of each bundle of trees in wet moss and parchment paper.

Courtesy West Coast Lumbermen's Association.

nursery to tie the counted plants in bundles of 50 or 100. The tied bundles are of some advantage on the planting job as they facilitate handling.

For large non-commercial shipments, a 100-percent count and tying in bundles is an unnecessary refinement and results in added cost and unnecessary extra handling and exposure, except possibly where it can be done in conjunction with a special indoor culling operation. Under ordinary conditions for fairly large shipments, satisfactory and close estimates can be made by counting only 5 or 10 percent of the total. One method commonly used is to count the plants in 5 to 10 percent or so of the bed area to be lifted and apply a cull percent. Another method is to select at random 5 or 10 percent of the bales or crates after the trees are packed, break them open, count the plants, and apply the count on a percentage basis to the entire shipment.

Packing

Nursery stock is prepared for shipment by packaging in burlap rolls (plate XVII) or in light wooden crates similar to commercial vegetable crates. Burlap bales have the advantage of being easily transported to the planting job by pack animals and the burlap is easily returned to the nursery for re-use or disposed of on the job. Crates are more expensive but are an advantage when long rail or truck shipments are necessary.

Packing is done most economically as an integral part of the lifting operation in one of the nursery buildings or sheds or occasionally in portable booths. The field lugs are carried to the packers who keep up with the lifting crews, using easily portable packing equipment. With this system the plants are packed for shipment a very short time after they have been lifted. Where indoor culling is done, the packing job is accomplished in conjunction with the culling operation. It is essential in this operation, as in all others, that the roots not be allowed to dry and the plants should be handled as little as possible and in such a manner as to prevent tangling of tops or roots. It is advisable to handle the plants in large double handfuls instead of in small groups or singly.

Whether packaged in bales or crates, the tops should receive free ventilation. If the tops are covered or smothered, they are liable to heat and mold and sometimes lose their needles. The roots should be packed in wet moisture-holding material; sphagnum moss, tree moss, or cedar shingletow are the most commonly used materials. They are used pure or in mixture with each other. Sphagnum moss is the most satisfactory but may be difficult or expensive to obtain. Shingletow is quite satisfactory but fresh or new tow should not be used. It preferably should be obtained from a pile that is a year or two old and has become well waterlogged. The packing material should be saturated with water, not only superficially wet, when it is used.

If the plants are to remain in packages more than a few days, they should be lined with waxed paper to retard loss of moisture from the packing material.

The type of package used at Wind River is commonly known as the "burlap bale." The baling machine (figure 7) is similar to those in common use in most nurseries although there are many local variations of the same device.

The plants are arranged in layers with roots overlapped in the center. Wet packing material is placed between each layer and at all places between the roots and the wrapping material. The strip of burlap is lined with a strip of heavy waxed paper. Three or 4 wooden slats are spaced between the wire and the burlap to add rigidity to the bundle and to protect the tops from injury if the bundles happen to be dropped or jammed endways. The bundle is tightened and held together by winding the ends of the burlap and paper around one of the slats and by 2 strands of number 12 wire. Common commercial wire tying or strap binding machines usually are used instead of the wire tying device illustrated. A completed bale weighs about 75 pounds and contains 1,000 to 3,000 plants depending on their size.

Material for one bale consists of:

A quantity of wet packing material.

One piece 8- or 10-ounce burlap 18 inches wide and 6 feet long.

One piece lettuce craft paper 18 inches wide and 6 feet long.

Two strands number 12 double annealed wire 5 feet long with a loop on one end or ordinary hay baling wire.

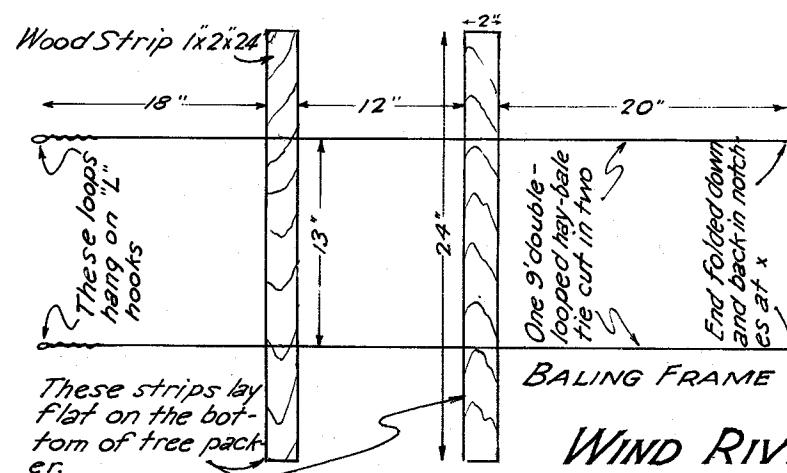
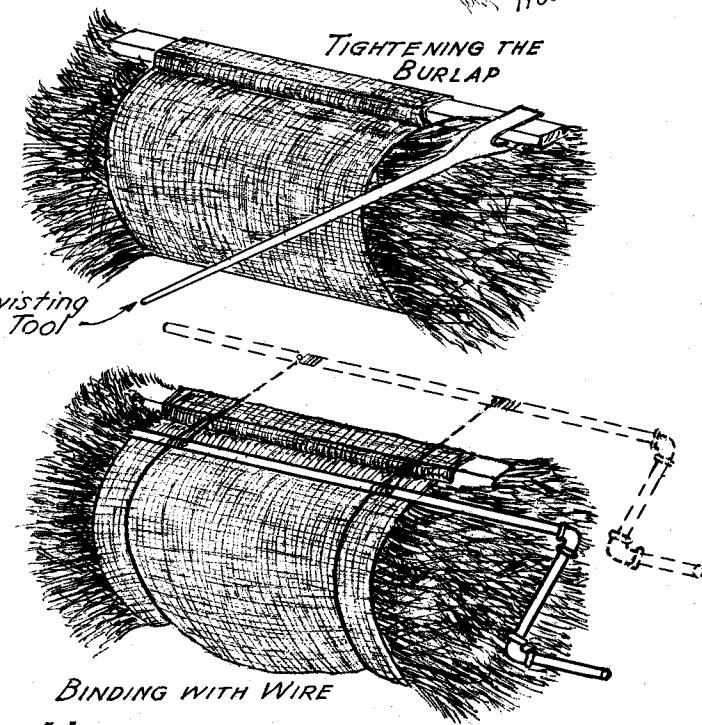
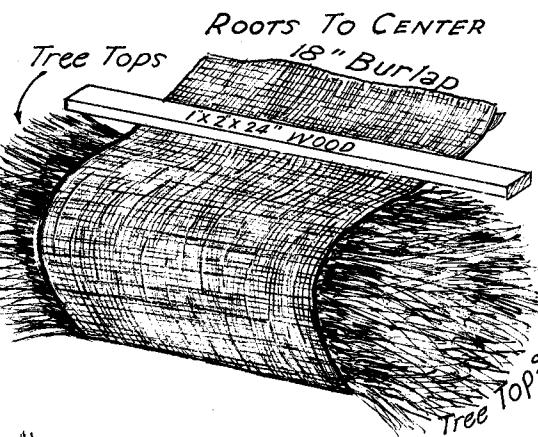
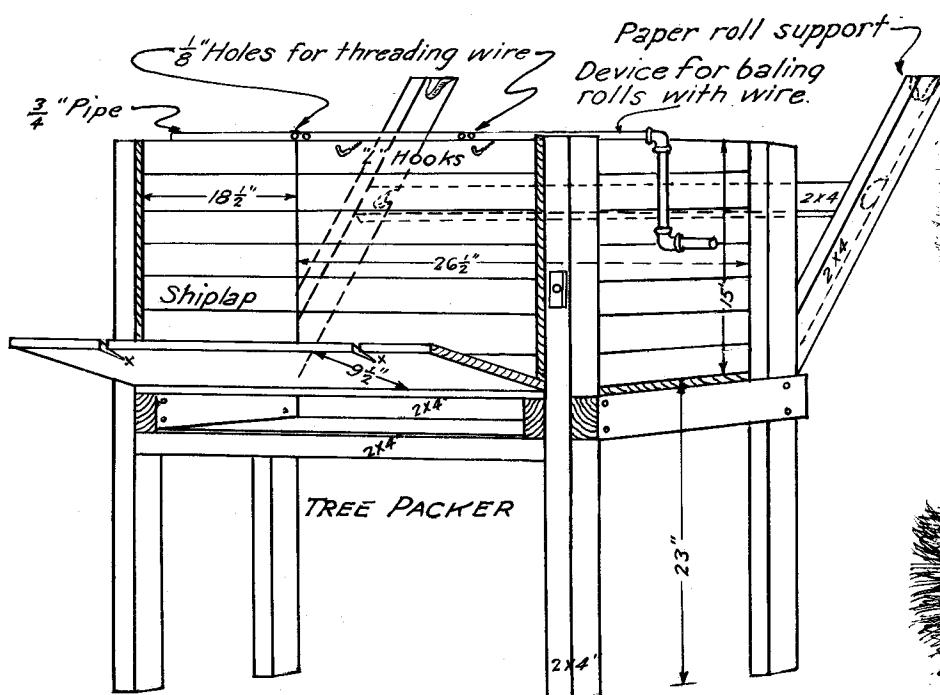
Three or 4 strips of wood 1" x 2" x 24" or 30".

Eight wire staples 3/4-inch long.

Storing

If reasonable care is taken to protect the bales from exposure to sun and wind, the trees will remain in good condition in the bales for 10 to 14 days in weather usually prevailing during the fall and spring shipping season. It is, however, poor practice to hold the bales that long; as short time as possible should elapse between lifting and planting. Water should be added through the ends of the bales when needed to keep the roots and packing material moist.

If it is necessary to hold the plants more than a few days after lifting, they should be placed in a refrigerated building or for relatively short storage a cold cellar will suffice. Temperature in storage should be between 35° and 40° F. Top and root rot fungi do not grow at temperatures below 40° F.



WIND RIVER NURSERY
TREE BALER
METHOD OF PACKING NURSERY STOCK

FIG. 7

Data furnished by W.F. Will

PORLAND, ORE.
Jan. 21, 1928 F.F.

At Wind River the storage cellar is built almost entirely underground, under a warehouse building. It has concrete walls, insulated ceiling and earth floor. Several sheet metal ventilation flues for entrance of cool air are arranged along the side walls with openings from the outside just above ground level and interior openings a foot above floor level. A second system of flues extends from the middle line of the ceiling upward through the roof for exit of warm air. By keeping all ventilators closed during the day and opening them at night, the temperature in the cellar is maintained within a few degrees of the minimum outside night temperature.

Table 9 is a record of the storage cellar temperatures typical for the spring shipping season. Table 10 gives the record of moisture loss from a number of bales kept for various periods up to a month in the cellar storage. The variation from bale to bale is considerable, but most of the loss took place the first day from free water.

Table 9.--Record of Storage Cellar Temperatures at
Wind River Nursery

Period	Cellar temperature		Outside temperature		
	Minimum	Maximum	Minimum	Maximum	
March	17-18	39	39	30	65
	19-22	41	41	31	70
	23-26	39	43	33	50
	27-29	42	43	36	49
	30-31	39	41	34	47
April	1-4	38	40	32	44
	5-8	37	40	26	64
	9-12	40	42	32	60
	13-16	42	43	36	58
	17-21	39	43	31	54
	22-27	43	45	33	70
	28-30	44	45	30	55
May	1-4	43	44	37	69
	5	44	45	37	78

Table 10.--Moisture Loss from Baled Stock Stored in
Wind River Storage Cellar

Packed with tree moss		Packed with shingletow	
Days in storage	Total loss per bale (Pounds)	Days in storage	Total loss per bale (Pounds)
1	8.0	4	7.7
2	8.6	6	7.0
3	8.7	9	5.9
4	8.8	14	5.2
5	7.9	22	3.0
6	5.3	23	5.1
12	11.4	24	4.0
13	8.1	26	6.6
14	10.3	27	5.7
15	9.2		
21	3.9		
31	4.4		
32	7.8		

Shipping

Transportation of trees between the nursery and the planting areas is accomplished usually by truck or express, but shipment by freight is permissible if prompt delivery can be depended upon. If an open-top truck is used, the bales should be covered with a canvas to protect them from the sun and from excessive air movement occasioned by the speed of travel, as drying may be a severe drain on the trees. If, however, the truck remains stationary for several hours, the canvas should be removed to allow ventilation.

Causes of Loss and Injury

Much of the loss and injury in nursery stock is caused by parasitic diseases (9) (14) and insects (28), whose presence and identity is not easy of determination and whose control involves highly specialized treatment. It is well, therefore, for the nurseryman who encounters losses from causes which are not clear to him to consult with specialists, particularly with representatives of the local offices of the U. S. Department of Agriculture, Bureau of Plant Industry (especially the Office of Forest Pathology), and Bureau of Entomology and Plant Quarantine (Forest Insect Field Laboratory) or with technicians of the State Agricultural Experiment Stations and State Colleges.

Damping-off

Damping-off is the common term used for the damage caused by a number of soil inhabiting fungi that injure and kill seedlings during the early stages of their development. Pre-emergence damping-off occurs

(1) Checked by E.Wright prior to publication.

during the germination period before the seedlings break through the surface of the seed bed. Post emergence damping-off occurs for a period of 2 to 4 weeks after emergence until the seedling stems are no longer succulent; other types classed as root rots cause damage to older seedlings.

The damage is difficult to detect during the pre-emergence period as the evidence is all underground and is generally not noticed except as it has lowered the expected emergence. Post emergence damping-off usually causes constriction of the seedling stem at the point of infection at or just beneath the ground line; very young seedlings topple over but older ones may remain erect. Losses caused by damping-off usually occur in irregular spots in which all or nearly all seedlings are killed. The damage seems to be most prevalent during periods of warm damp weather which is favorable to growth of the fungi. Losses are less apt to occur in seedlings that germinate early in the spring as they have usually developed beyond the state of highest susceptibility by the time weather conditions are optimum for damping-off. Early sowing is, therefore, a good precautionary measure. Damage is greater in dense beds than in lighter sown beds. Soil acidity has a bearing on the prevalence of the disease, and it is less likely to reach serious proportions in soils of low pH.

Post emergence damping-off can be retarded by allowing the surface of the bed to dry out and remain dry for short periods; this is more easily accomplished in sandy soil than in heavy soil; seed beds that have been covered with sand at time of sowing react most readily to this treatment. The surface can be allowed to dry to depths of one-fourth inch or more for short periods without damage to very young seedlings and to greater depths for longer periods as the seedlings develop. Free circulation of air over the bed surface is an advantage. Beds enclosed in board frames that inhibit air circulation seem to foster temperature and moisture conditions favorable to damping-off.

Soil disinfectants have been used for many years as a preventive measure and may be necessary where the disease cannot be controlled by other methods. Many have been tried and used with varying degrees of success. They include sulphuric, hydrochloric, acetic, and nitric acids, aluminum and ferrous sulphates, copper acetate, sodium, zinc, and mercuric chlorides, formalin, tannic acid, and several commercial soil disinfectants that are on the market under trade names. Exhaustive experiments have been conducted and reported on, most of them by Hartley and others (14) (17) (18).

Soil disinfectants should be used only when necessary and then only with a full understanding of their reaction on the soil and the possible damage they might cause to the seed or seedlings, as determined by small-scale tests. All of the disinfectants are toxic to young seedlings in strengths of application necessary to kill damping-off fungi. Some of them remain effective in the soil longer than others and are more difficult to leach out or counteract; their use may damage the soil

materially and can damage more seedlings than the damping-off fungi if they were employed to destroy. They react very differently in different soils, making it necessary to work out an application formula for each nursery.

Some of them are capable of killing dormant seeds if applied on the seed bed after sowing. With these it should be the practice to apply the disinfectant several days before sowing and then sometimes it is washed or leached from the soil by heavy irrigation before the seed is sown. This practice limits the time of effective protection; in heavily infested areas, post emergence damping-off may occur in beds that were treated prior to sowing. The acids usually do not damage dormant pine seed if applied to the bed at time of sowing but mercuric chloride and formalin have been found to kill dormant pine seed if applied at time of sowing (17). Sulphuric acid has been applied successfully in light concentrations on sown beds several days before germination starts, but the practice should be tested thoroughly before it is used extensively. Application after emergence or shortly before emergence invariably results in severe damage to seedlings. Care should be taken not to use alkaline sand as a seed bed cover since this may counteract the benefit of acidification.

The disinfectants are washed more easily from sandy soil than from heavy soil. They tend to move with the soil water and concentrate in areas of poor drainage and the rise of water through capillary action tends to concentrate them at the surface of the seed beds. Where they remain in the soil or become concentrated, they cause injury to the roots of seedlings by killing the growing apex of the radicle. This usually is fatal to very young seedlings and if the seedlings do survive, their root growth is stunted and deformed.

There is some evidence that certain of the acids and salts by combining with fertilizers applied to the seed beds lose their value. Nitrogenous fertilizers should not be added to seed beds until the seedlings have passed the damping-off stage since nitrates have been shown to increase the damping-off hazard.

Lime on occasion has been applied to counteract the concentration of applied acids but the excess use of lime in coniferous nurseries should be avoided as it upsets the naturally desirable pH value of the nursery soil.

Sulphuric acid and aluminum sulphate are among the most commonly used disinfectants. They have been used with success at Wind River where sulphuric acid is applied to the surface of the seed beds at the rate of one-fourth fluid ounce of acid with 1 pint of water per square foot of bed, and aluminum sulphate at the rate of three-fourths avoirdupois ounce per square foot of bed. In recent years the use of aluminum sulphate has largely superseded sulphuric acid at Wind River.

Commercial disinfectants, usually prepared in the form of powders, have been found to be effective against pre-emergence damping-off when dusted on vegetable seed immediately prior to sowing. As yet they have not been tried thoroughly on coniferous seeds.

Heat Injury

Heat injury is sometimes called sun spot or sunscald or stem girdle. It is caused by burning the stem either by direct heat of the sun or by the intensified heat of the surface soil. It occurs when the seedlings are very young and is sometimes mistaken for damping-off. It occurs at the ground line after the seedlings are erect or on the curved stem of the seedlings as it emerges from the soil before it straightens. It most usually occurs in late germinating beds. It can be prevented by shading, or in the case of high soil temperatures, by irrigating and shading.

Chlorosis

Chlorosis sometimes is caused by nitrogen deficiency and in such cases can be corrected by applying nitrogen fertilizers, as described under "Seedling Care." It may be caused by poor drainage or high concentrations of salts, acids, or in some cases chemical fertilizers. Corrective measures are better drainage and leaching by heavy irrigations.

In some nursery soils it is an indication of too high densities in the seed beds.

White Grubs

White grubs is the name applied to the larvae of several species of large beetles, known as June bugs or June beetles or May beetles. They do serious injury to a variety of plants, including tree seedlings, by feeding on the roots. In some eastern nurseries they are major pests and require for their control specialized drastic measures. So far as known they have not done material damage in tree nurseries of the Douglas-fir region.

Strawberry Root Weevils

Strawberry root weevils, of which there are several species, have been the most important insect pests of forest nurseries in the Pacific Northwest. Considerable damage has been caused by these weevils at the Wind River and other nurseries.

Damage is caused by the small, white, curled grubs which live in the soil and feed upon the roots of the developing seedlings. Within one year these grubs complete their feeding and develop into adult weevils which are black, wingless, and approximately one-fourth inch in length. In early summer these adults crawl about and lay their eggs at the root crowns of various plants, including coniferous seedlings, and the cycle then begins again.

Strawberry root weevil larvae are frequently abundant in sod-covered land; hence, in order to minimize damage it is a good practice to clean fallow such land one year prior to the planting of seed beds. Likewise, rotation of seed and transplant beds and periodically clean fallowing for one season between crops are measures that will reduce weevil-caused losses.

Where damage persists in spite of preventive measures, control may be necessary. Poisoned bait applied when the adults are migrating in early summer gives good control. The most effective bait for this purpose is prepared in the following proportions: Bran 50 pounds, water 5 gallons, sugar 10 pounds, and calcium arsenate or sodium fluosilicate 5 pounds. Application is at the rate of 50 to 70 pounds per acre.

Sympylids

Sympylids, small white centipede-like animals, are widely distributed and are exceedingly destructive to a great variety of field and garden crops of this region. They have been damaging to the broad-leaf trees in the Oregon State Nursery, but as yet not noted in the conifer beds. There is under way much experimentation on methods of control, but so far no practical means of control have been found.

Rodents

Small rodents, such as mice, gophers, moles, and ground squirrels, sometimes seriously deplete seeded beds by stealing the seeds before they germinate. Damage can be severe in mulched fall sown beds as the rodents live and feed under the mulch all winter. Destructive rodents should be exterminated in the nursery and an area about 300 feet wide around the nursery should be kept baited to prevent migration. Ground moles and pocket gophers usually have to be trapped. Poison bait is effective for most of the surface rodents.

An effective bait for mice is made by mixing:

1 ounce strychnine sulphate
8 pounds grain
 $\frac{1}{4}$ ounce oil of anise
4 ounces heavy molasses
8 ounces hot water

An effective bait for ground squirrels is made by mixing:

1 ounce strychnine alkaloid
2 ounces powdered borax
1 ounce wheat flour
1 ounce dry glucose
 $1\frac{1}{4}$ pints water
2 ounces glycerine
15 pounds whole recleaned oats

Poisoned bait is most effective when planted along logs, under roots, and other places where rodents naturally hide or travel. Care should be taken to keep it away from places where it can be picked up by animals for which it is not intended.

A number of cats kept at the nursery will do much to keep down the rodent population.

Birds

Birds of various species often seriously deplete the seed beds by feeding on seed before it germinates and by picking off the tops of seedlings before they shed the seed. Little good is accomplished by poisoning birds for most of the offenders are migratory and stop to feed as they travel through. Also, the harm they do is usually offset by their aid in controlling weeds and insects.

Where birds are a serious menace, it is necessary to screen the beds, or in large nurseries, to post guards to frighten them away during their feeding hours.

Frost Heaving

Frost heaving is a serious cause of loss and damage in nurseries subject to freezing. It not only lifts the trees out of the soil but also strips the bark off. It is caused by alternate freezing and thawing of the soil and is most severe in the fall and spring. The only protective measure is mulching as described under "Seed Bed Preparation and Sowing" and "Seedling Care."

Miscellaneous

Coniferous stock is not normally subject to damage from insects or diseases that attack the tops of the plants. Certain rusts sometimes occur on spruces but they are usually quite seasonal and cause little damage. Leaf eating worms sometimes attack the larches but they succumb to any common leaf insect spray.

Records

Procedural and Historic

This type of record should be maintained as an aid to better nursery management. Nursery procedures, tools, and machines that are used as common practice or that are tried experimentally should be written up including such comments by the nurseryman as may be of value for future reference.

A continuous record should be maintained of the treatments the nursery soil has received. This record should be supplemented with nursery maps showing graphically the areas and treatments. The records should include such information as the amount and kind of fertilizer

and dates applied, kind of soiling crops with dates sown and dates plowed under, a history of fallowed areas, and any special treatments given the soil for control of insects or diseases.

A similar continuous record of the stock produced, supplemented by nursery maps, should be maintained. It should record date of sowing, source of seed, production by species, age classes, and quantity with such information on quality as may be of value in tying it back to soil treatments.

Cost Accounting

This type of record should be maintained as an aid to efficient and economical operation. The minimum requirement should be the cost of producing each age class of stock, the cost of lifting and packing, cost of soil maintenance, and cost of maintaining the physical improvements.

It is advisable to run short cost studies on certain operations, such as sowing, weeding, irrigating, etc., as an aid to simplifying procedures and reducing costs of individual operations. An annual cost statement should be prepared giving a summarization of the costs and expenditures for the year.

Inventories

The number of plants produced is the greatest single factor controlling production costs as the costs of all operations are about the same regardless of the number of plants produced. It is, therefore, good business to produce the maximum number of plants possible per unit of area, within limits of size and quality standards.

To compute costs and to plan disposition of stock it is necessary to take stock inventories. They should be taken in the late summer or early fall when the plants start to go dormant. The plants increase very little in size after that and there is little chance for subsequent losses. The inventory should be taken on a percentage basis, counts of 5 percent or less are usually sufficient if the stock is uniform as to size and density. Seedlings usually are counted with the aid of a frame made of wire or light wood 1 foot wide and 4 feet long. It is placed across the bed and the plants counted inside the frame. The number of counts is determined by the percentage inventory required. The pattern of counts should be determined either by mechanical or randomized selection.

The inventory should record the total number of plants by grades or size classes that will be used at time of shipping. The people making the inventory should be equipped with suitable gauges to make accurate segregation of the sizes. It is usually advisable to dig a certain percentage of the inventory plots to detect root conditions that may affect the cull percent or separation of grades.

The inventory should be recorded by units of nursery area in which the counts were made, i.e., beds, sections, and blocks. Each inventory should be summarized and kept as a permanent record. It is of some advantage to supplement the tabular inventory record with maps of the nursery prepared to show graphically the history of stock production.

Costs

Production costs are dependent on so many variable factors that it is practically impossible to establish standard figures. Good management can do much to reduce costs of each operation. In no case should quality be sacrificed for the cost of nursery stock is only one item in the total reforestation job. The saving of a dollar on the cost of stock, if it is done at the expense of quality, can result in plantation losses, extra plantation care, or replanting that will amount to many times the saving in the nursery. Standards of size and quality should be established and production costs should be kept to the minimum necessary to produce stock within the required specifications. For example, the expense of certain operations can be cut almost in half by growing twice as many plants per square foot, but if at time of planting a high percentage must be culled because of size deficiencies or if undersized or under-developed plants are planted and they fail to survive, the small saving amounts to a net loss to the entire job.

The principal items that go into cost of stock are:

- (1) Depreciation of investments.
- (2) Overhead supervision, service charges, and central office charge backs.
- (3) Maintenance of soil and soil fertility.
- (4) Maintenance of improvements.
- (5) Seed.
- (6) Operational costs such as:
 - (a) Seed bed preparation and sowing.
 - (b) Weeding, thinning, mulching.
 - (c) Irrigating, shading.
 - (d) Transplanting.
 - (e) Lifting and packing.
 - (f) Miscellaneous seedling care and protection.

Average costs for Douglas-fir under normal conditions, assuming a pre-1941 wage rate, are about as follows:

\$2.00 per M for 1-0 seedlings.

.30 per M to carry them to 2-0.

.75 per M for transplanting.

.30 per M to care for transplants for 1 year.

.65 per M to lift and pack seedlings.

1.00 per M to lift and pack transplants.

Therefore, Douglas-fir 1-0 seedlings packed for shipping would represent an investment of \$2.65 per M; 2-0 seedlings \$2.95 per M; 1-1 transplants \$4.05 per M; and 2-1 transplants \$4.35 per M.

These costs include all charges, direct and indirect, incident to the production of the plants. Adverse conditions such as a heavy weed crop, unusual irrigation requirements, or lowered production caused by insects or disease will increase the costs, favorable conditions will decrease them. Good management and supervision can do much to lower the costs by forestalling adverse conditions and by handling efficiently all difficult situations that do arise.

Cost of other species may be expected to vary in relation to Douglas-fir, depending upon whether the seed cost is more or less and whether they require more or less special care and treatment than Douglas-fir.

CHAPTER 4. FIELD PLANTING

Character of Areas in Need of Artificial Reforestation

Ordinarily the lands in the Douglas-fir region which will be artificially reforested are those not suited to agricultural development. They will be chiefly of two classes--burns in virgin timber which have not become restocked naturally, and logged-off lands usually burned two or more times which are not likely to reforest by natural seeding.

Planting of land once cleared for agricultural use is likely to be rare in this region and mostly a phase of farm forestry. The afforestation of sand dunes is a special localized problem discussed briefly in a later chapter.

The major portion of the lands to be planted are on rough or rolling topography, often steep and mountainous. The range in altitudes will be that of the commercial forest zone, namely, from sea level to 4,000 to 6,000 feet, depending on latitude with most of it probably falling within the most productive timber zone, namely, below 2,500 feet in the north and 4,500 in the south. The soils range from the shallow rocky soils and volcanic sands of the mountains to the deep loams and clays of many of the lower slopes. The ground is usually littered with the remains of the former forest; old burns that have not been logged are bristling with snags. A rank vegetation of weeds and brush covers the ground; the amount of woody brush increases with the time since the last burn. In places old burns are covered with a thicket of evergreen and deciduous bushes that present a special problem to the planter, this condition intensifying to the southward.

Exposure of the ground surface by logging and fires has accelerated sheet and gully erosion and many of the planting sites are suffering from loss of top soil, which makes planting difficult but doubly necessary. Hard and repeated burning, the usual cause behind the need for planting, furthermore has an unfavorable effect upon the physical condition of the soil (26).

Planting is sometimes employed as a means of reforesting logged-off land when, after a term of years, natural regeneration has failed. In such cases the forester is confronted with the dilemma whether to plant quite soon after logging even though there is still a chance that the area will regenerate naturally or wait until all hope of natural reseeding is gone and the area has then become so brushy that planting is difficult.

It is most important that areas suggested as in need of artificial reforestation be thoroughly examined before any work is done, to determine their restocking status, their prospect for natural regeneration, and their physical condition, as discussed in the next section.

Mapping of Planting Projects and Preparation of Planting Plan

Some time before planting is to be started a detailed reconnaissance and map of the area proposed for artificial reforestation should be made to determine which areas are already stocked with seedlings and which are not and to give a basis for preparing the planting plan. On a large tract the pattern of the nonstocked land is often very irregular, following the outlines of a second burn, of the area logged during a poor seed year, or of the drier and hotter slopes. There is also a variety of sites, aspects, and soils which the examiner should map to the extent that they may affect the planting plan.

Money for a detailed reconnaissance is well spent, for without advance mapping of the planting project there is danger that the planters will set trees on areas already adequately stocked, and this is wasteful of labor and trees.

Mapping Procedure

The first step in examining and mapping a tract in need of reforestation is to select an area that from quick inspection appears to be devoid of seedlings or saplings and is not likely to reforest naturally. Areas within range of a seed supply which have not yet had time since logging and burning to become reseeded naturally--4 or 5 years--would ordinarily not be selected.

The best time for field work is the late fall, winter, or early spring, when the weeds are dead and the leaves off.

The field reconnaissance mapping is done by one man working alone. He gridirons the tract with traverses in cardinal directions not over 5 chains apart, his equipment being compass and staff, tally register, the best existing base maps, a sketch board or map sheets in a holder; a contour map is desirable but not essential. The scale should be 1 inch to the mile as a minimum.

Proceeding along the strip, the examiner maps the stocking of conifer seedlings as he sees them by close examination on his line and by more casual examination for a distance of 165 feet on either side. In areas of questionable stocking the examination must be particularly thorough.

For the purpose of mapping and designating areas to be planted, natural stocking should be recorded on the basis of density to suit the standards of the project. Two or more degrees of stocking may be recognized.

The following is an example of procedure based on the stocked quadrat concept of stocking: Consider the whole area to be examined as a checkerboard of 13.2 x 13.2 foot squares (each 1/250 of an acre).

If there is at least one established tree seedling on a square, that square is considered stocked. If there are no seedlings or saplings on a square it is nonstocked. The proportion of squares that are stocked determines the degree of stocking for the strip, the compartment or the whole area. As a convenient standard, if less than 10 percent of the squares have seedlings the area is considered nonstocked, if 10 to 40 percent have seedlings the stocking is unsatisfactory, over 40 percent acceptable, i.e., not in need of complete planting. The standard and intensity of the stocking classification and mapping can be altered to suit each project.

In traversing the area the examiner stops every one or two chains and considers his stopping point the common corner of 4 squares. He then examines all 4 and tallies the number that are stocked; thus, "0" means no square stocked, "1" means 1 of the 4 stocked, etc. These tallies are entered on the map sheet in place and give the examiner a precise figure of the degree of stocking on his line and a good check on his ocular estimate of the degree of stocking at the sides of the line and of the location of the transition from stocked to nonstocked areas.

Mil-acre quadrats, squares 6.6 feet on a side, may be used instead of the 13.2-foot squares, especially if the natural reproduction is very small and hard to see. If this size of quadrat is used the proportion of stocked quadrats that denotes nonstocked, acceptable stocking, etc., would have to be adjusted.

One-year-old seedlings are not considered as "established" and three 1-year-old Douglas-firs or at least five 1-year-old hemlocks per square will be rated as equivalent to 1 established seedling. By a combination of the actual counts of stocking on the squares on the line traversed and of ocular estimation the examiner will prepare a stocking map, using as many classes of stocking as desired.

On completion of the stripping, a map or plat can be prepared (in color) showing the nonstocked, the stocked, and the intermediate poorly stocked areas for the guidance of the planters. The last class may or may not be planted according to the policy on the project. More detailed typing of the degrees of stocking may, of course, be done.

If there are material differences in soils that might affect choice of species or methods of planting the examiner should map them. Soils too rocky or thin to be planted should be mapped in; also those too wet or too dry. If the herbaceous or brush cover or down timber on parts of the area is such as to affect the planting it should be mapped in according to density or type. The examiner should also indicate on his sketch map features that may affect the conduct of the planting, such as roads, trails, creeks, swamps, rock outcrops, and bodies of standing timber.

The Planting Plan

On completion of field work the examiner should prepare a concise plan for the conduct of the planting project. A well thought out plan or set of instructions is an important prerequisite for a well-executed job.

For convenience of description large projects should be divided into compartments on the map; each can then be considered separately. The text of the plan, based on the map, should discuss:

Roads and trails that need to be opened up or built.

Camp construction, if any.

Acreage in need of complete planting and of partial planting.

Foreign ownerships within project.

Fire lines to be built and snags to be felled.

Other pre-planting preparations.

Species, class of stock, and spacing to be employed on each compartment.

Season for planting.

Size of crew desired.

Equipment needed.

Estimated cost of project.

In undertaking large formal projects which are planned considerably in advance and must be rated for priority by comparison with other projects like those on the national forests, it may be desirable to have a detailed description of the physical conditions of the area, its history, growth potentialities, chances of natural reforestation, argument for planting, etc.

Site Preparation

After the area in need of planting has been examined and mapped and before the work commences there may be certain preliminary preparations to make, such as establishing transportation, falling snags, building firebreaks, reburning the cover, "brush busting" with power machinery, grazing with sheep or goats.

Establishing Transportation. For the efficiency of the planting job as well as for the better subsequent protection of the area from fire, it is highly desirable that the planting site be made readily accessible. Existing roads, railroad grades, and trails should be made passable and if all parts of the planting project are not within a mile or so of some kind of a road or trail it is well to build at least enough trails to make the whole project accessible to the planters. It is axiomatic that the central planting camp or working base will be accessible at least by trail so that trees, tools, and supplies may be brought in by pack horse or trail tractor.

On one of the Oregon State forests in an old deforested burn a network of firebreak truck trails, passable in summer for an automobile, was built prior to planting and before the war at a cost of about \$125 per mile. These are run over annually with a grader; they serve both to make all parts of the area accessible and as fire lines for backfiring in case of need.

Falling Snags. Planting projects in old burns are likely to be bristling with snags. It would be desirable to fall all as a precaution against reburns and to forestall the damage from falling bark and chunks. However, that would be exceedingly expensive and a compromise is necessary, namely, falling all snags on lines 200 yards or more wide so located that they may be used as firebreaks, i.e., on ridges and along roads and streams. These fire lines should be so spaced that the planting site is divided into compartments of not over 300 or 400 acres each.

On cut-over land, it being the practice in recent years to fall all large dead trees currently with logging, the snags are not likely to be a bad menace, but if there are more than 1 or 2 per acre they should be felled at least on firebreaks.

Building Firebreaks. Other than falling snags and building truck trails it is not ordinarily economically feasible to do much more in "fireproofing" a planting site before planting. Roads and trails should be kept open and free of debris so that they can be used for access and for backfiring lines in case of need. The fire control measures essential after planting are briefly mentioned in a later section and fully discussed in other existing texts (40) (64) (65).

Removing the Cover. Where an area in need of planting has grown up to a thicket of woody vegetation, it may be useless to plant it without first reducing the cover. This may be done by chopping out the brush by hand, by tearing it out on lines by machinery or by burning. The first is very expensive and if done at all will be incidental to the planting operation itself. The "brush busting" by machinery is mentioned as a special problem in a later section. Burning is precarious work and cannot often be advised. Occasionally areas are so located that they can be fired without risk of the flames spreading beyond the limits intended. It must be done when the brush in the

open will burn hard, yet fire not run in green timber or restocked areas. The usual precautions and techniques of slash burning will be employed. Such burning does not kill all the woody brush; it merely thins it out temporarily and represses it long enough to give the planted trees a start. Where the competitive cover is herbs rather than woody shrubs, burning is not advised unless the dead matted vegetation is very heavy.

Sheep or Goat Grazing^{8/} (22). Where a proposed planting area is rank with herbaceous vegetation palatable to sheep or goats and such stock is available, it may facilitate the planting to run a band of these animals on it for a season or two. Both sheep and goats will clean up much of the weeds, but not the bracken, and goats will lessen the woody vegetation, especially if they are concentrated, thus making it easier for the planted trees to survive. The grazing animals must be withdrawn as soon as the trees are planted.

Choice of Species

Native vs. Exotic Species. Planters in the Douglas-fir region have the choice of a large number of species that might be used successfully. There are several local species that are outstanding among the conifers of the world for rapidity of growth, density of stands, great size, and superiority in technical qualities. There are also many exotic conifers that are adapted to this climate and by actual test have been found to start well, but it is not yet known whether in the long run they will be successful.

By and large the species native to the site are recommended for extensive plantations. The native species are not surpassed by any exotic trees in desirability, and their products will probably be more acceptable to the manufacturer of the future than exotic products with which he is not familiar. As a notable exception to the above generality, the planting of Port Orford white-cedar considerably outside the limits of its geographic range promises success and is recommended. The general policy of confining extensive planting to native species need not prevent the use of exotics for special purposes or the experimental planting of promising trees.

Factors to Consider. On the principles stated above of using native species mostly in extensive plantations, the selection of species will be guided largely by two considerations: (1) The products or purposes desired, and (2) the suitability of the site.

According to the present outlook the products most desired in reforestation in this region are all-purpose saw-timber woods like Douglas-fir, but a certain amount of other products are desirable, like cedar for posts and poles, hemlock and spruce for pulp; some speciality

^{8/} Reid, Elbert H., Isaac, Leo A., & Pickford, G. D. Plant succession on a cutover, burn, and grazed Douglas fir area. Pacific Northwest For. Expt. Sta. Forest Research Notes No. 26. 1938.

woods like alder and even cascara should be planted. To satisfy special demands, like Christmas trees or aesthetic effects, appropriate species should be used. For preventing erosion or fixing moving sand, species excelling in those qualities will naturally be selected.

The character of the planting site is important in choosing the species even in this region where Douglas-fir is so universal and so well adapted to a wide range of conditions. Variations in altitude, exposure, and soil should be noted and perhaps mapped, and the species or combination of species suited to each set of conditions chosen accordingly. A large planting project might well employ several different species and combinations.

Mixtures of Species. There is good reason for planting a mixture of species rather than to use one tree exclusively; there is less danger of heavy losses in the event of an outbreak of some disease or pest attacking a single host; with certain mixtures there are greater yields and a larger variety of products from mixed stands. However, Douglas-fir is so well adapted to a great range of sites and does so well in pure stands that it has been the favorite tree for artificial reforestation and probably 95 percent of the plantations so far made in the region are of this species alone. It is also likely to be the basis of most mixtures. Since it is an intolerant tree and very rapid-growing, it should not be planted with another intolerant tree. The most desirable combination where species are in intimate mixture is Douglas-fir with a minority amount of one or more tolerant and slower-growing conifers.

Suggestions of Species to be Used

Douglas-fir. From sea level to the limits of its natural range in the Cascades, on all exposures, except the most severe in southern Oregon, and on practically all soils, this tree can be planted successfully. It is the mainstay of artificial reforestation in this region. Though it will flourish in the fog belt it is not recommended there, largely because other species are optimum there and not elsewhere. It should not be planted in swamps or on very acid soils. It complies well with Toumey and Korstian's admonition (57), "to depend upon the best species indigenous to the immediate vicinity."

Western redcedar is a desirable species to supplement saw-timber and pulp species because of its value for poles and posts. It is recommended for planting in mixture with Douglas-fir on the well-watered and more humid parts of the region within its natural optimum habitat, and sometimes pure on wet and "sour" soil. Being tolerant of shade it is a good species with which to underplant or to put in brushy places.

Port Orford white-cedar, a native of southwestern Oregon that endures well the climate of the lower altitudes of all of western Oregon and Washington, and responds easily to artificial regeneration. It is

recommended for its valuable technical qualities for planting in mixture with Douglas-fir or Sitka spruce in the moister and milder parts of the region, particularly the coastal region and the foothills of the Cascades. Where moisture conditions and soil are not good its growth will be slow.

Sitka spruce, an all-purpose tree, with wood of superior technical qualities, which is first choice for planting within the fog belt of both states, but not outside its limited natural range. It could be planted pure but there may be some advantage in mixing in either western redcedar, Port Orford white-cedar, or western hemlock--never with Douglas-fir. A possible mixture for special localities, which has not been tried, would be Sitka spruce and red alder alternating, the latter to be taken out on a short rotation, while the former is held a few decades longer.

Western hemlock, the second most important tree of the region. It is somewhat difficult to grow and plant (in comparison to Douglas-fir) and up to now has been planted only in a very small way. Where a pulp species is desired in the mixture this tree could well be used as a filler with Sitka spruce, with the cedars, or with Douglas-fir on the more humid and cool sites, particularly in the coast region and in Washington.

Balsam Firs. On the upper slopes of the Cascade Range, above the optimum range of Douglas-fir, the better of the balsam firs, namely, noble fir, Shasta fir, and silver fir, may be used pure or in mixture with Douglas-fir. Since these species, especially the first two, are fastidious as to habitat and are limited to a narrow altitudinal zone they should be planted only within their native range, for safety. A series of tests on the Rainier National Forest (now Columbia National Forest) showed that they were even more sensitive to differences in exposure than Douglas-fir; on northerly aspects survival was very much better than on southerly aspects. This suggests reserving these trees for the moister and cooler exposures and using more Douglas-fir on the hot slopes. They are rather slow-growing and will require close spacing to make a quick coverage.

Western White Pine and Sugar Pine. In view of the prevalence of white pine blister rust, the control of which is expensive and uncertain, it seems unwise to plant these highly desirable trees in this region where there are plenty of other good species not subject to any acute disease hazard.

Ponderosa Pine. On the hot dry exposures of the Oregon Cascades and of southern Oregon this hardy tree, which rapidly grows a long tap root, would seem to be the preferred species for planting, probably in pure stands, even as a replacement to Douglas-fir. Where the latter species thrives ponderosa pine cannot compete with it, however.

Red Alder. Being the only native commercial hardwood tree that forms extensive stands it is desirable to propagate it. It is recommended for planting (or seeding) on the well-watered, deep-soiled, lower slopes of the coast region, such as where it naturally forms saw-timber stands. It could be planted pure, or in mixture with spruce, cedar, or hemlock to form a two-storied forest. The planting of alder as firebreaks in coniferous plantations is a meritorious suggestion which, as yet, has been tried only in a small way. This practice would have to be confined to areas where alder rapidly develops a cover of tall trees.

Other Hardwoods. None of the other native hardwoods are likely to be planted except incidentally. Bigleaf maple, the second most important native broadleaf tree, forms desirable stands only on the kind of land that is more valuable for agriculture. Black cottonwood was planted in a small way for pulp years ago on sand bars and river bottoms and made excellent plantations, but there is available only a limited quantity of the kind of land suitable for this species. Cascara is recommended as a filler in plantations or possibly for small pure plantings on very good land in the foothills or coastal region, especially for farm forestry.

Exotic Conifers. In the gardens, parks, and arboreta of the region conifers from all parts of the world are growing well; there are places at low altitude where 200 exotic conifers could be easily established. However, there is none outside the native species of these states that has technical qualities and proven adaptability to the region that now justify recommending it for extensive reforestation projects in place of native trees discussed above.

Exotic Hardwoods. The paucity of native broadleaf forests and the mild and humid climate have prompted the suggestion many times that some of the superior eastern hardwoods, like northern red oak, American basswood, yellow poplar, black walnut, hickory, black locust, sugar maple, should be planted here. Such species do fairly well on watered lawns and as street trees in cities. Some of them have been tried repeatedly on forest soils in the foothill region, but without success. The broad conclusion has been reached that these hardwood species will not make trees of desirable form and rate of growth here under unattended conditions because of the summer drought and the cool summer nights characteristic of the forest zone. They are not recommended, therefore, for commercial planting on forest soils, but might be planted as a novelty on extra good sites, especially where they could be tended.

Age Class of Stock for Planting

Because of the great differences in soil fertility and climate at various nurseries, age class alone is not a very good index of size, though within a given nursery, stock of a certain age class should be quite uniform.

Transplants are ordinarily shorter than seedlings of the same age because transplanting checks height growth and stimulates the formation of a more finely branched and fibrous root system. Likewise root pruning checks height growth and encourages a fibrous root system, but to a less extent than transplanting. Fall-sown Douglas-fir stock is larger during the first 2 or 3 years than spring-sown, because of its earlier germination.

1-1 vs. 2-0 Douglas-fir. Following precedents in other regions the Douglas-fir stock grown during the first years of operation at the Forest Service's Wind River Nursery was nearly all transplanted and shipped out as 1-1 plants.

In 1926 a satisfactory device was made for root pruning trees in the seed beds and an elaborate series of tests was initiated at the Wind River Nursery to determine the comparative merits of 2-0 and 1-1 stock. Seedling stock grown at various densities, both fall and spring sown and of various seed sources, was compared by measurement and by performance with 1-1 stock. Tests were repeated on three successive years and the field planting watched for three seasons. Some 49,000 trees were involved in these tests, distributed over 25 classes of stock.

When the results were compiled^{9/} the low-altitude 2-0 seedlings showed a higher survival than the 1-1 transplants if they were grown at a 40- or 60-per-square-foot density in the seed bed, a lower survival if they were grown at a density of 120 per square foot or higher. The high-altitude 2-0 seedling stock gave a higher survival than the 1-1 transplants regardless of its seed-bed density for reasons which are not apparent. It was also found in these tests that diameter of stems at the ground surface is the best mensurational index of quality of stock and its likelihood of surviving.

As a result of these tests it was concluded that entirely satisfactory stock for most planting jobs could be raised at this nursery without transplanting but with root pruning. The standard output of this nursery now is, therefore, 2-0 RP stock either spring or fall sown.

It is the general consensus now among planters in the Douglas-fir region that by proper nursery management a grade of 2-0 Douglas-fir can be grown that will make satisfactory plantations at less cost than with 1-1. Two-year-old seedling stock, therefore, forms the bulk of the planting now being done. This is true of most of the other conifers, though the balsam firs may take 3 years, and in some soils the hemlocks, cedars, and spruces, and this implies transplanting. Three-year-old Douglas-fir at most West Coast nurseries are so large in both top and roots that they are too expensive for forest planting except for very special purposes.

9/ Kummel, J. F. Value for planting of root-pruned two-year-old seedlings of Douglas-fir. 1942. Ms.

One Year Olds. In some regions 1-year-old seedlings of some species have been found satisfactory for out planting, but the Forest Service's experiences with Douglas-fir stock of this age grown at Wind River has not been encouraging. Tests by the Wind River Experiment Station (predecessor of the Pacific Northwest Forest Experiment Station) showed on favorable sites, a north slope and a flat, survival of 1-0 stock, spring sown, at the end of the fifth year of only 30 percent and 25 percent respectively, compared with a survival rate of over 90 percent for 2-0 and 1-1 stock. On a very dry south slope the 1S-0 stock was distinctly inferior the first year and finally all classes were almost a complete loss because of the midsummer drought and heat. A second series of tests gave no better results.

The fall sown 1-year-old stock gave encouraging results on the better sites. At the end of the fifth year in one series 80 percent survived on the north slope and 76 percent on the flat; in the second test on the same sites survival was even better. On the unfavorable south slope, survival of the 1F-0 stock was almost equally as poor as that of spring sown stock. The better survival of the fall sown is to be expected and is due to their being larger, sturdier, and more woody stemmed than the spring sown yearlings.

The conclusion is reached that it is risky to use 1-0 Douglas-fir stock generally, but where a large sturdy plant, particularly fall sown, can be produced it may be safe to do so on favorable sites as a measure of saving time and nursery costs.

Plate IX shows on a reduced scale silhouettes of various classes of Douglas-fir grown at the Wind River Nursery in 1933.

Of other species there has been little experience with yearlings. It is thought that 2 years is the minimum that most of them should be in the nursery, but that, of course, depends on the soil and climate of the nursery and the favorableness of the planting site. Alder and cascara will usually be out planted as yearlings.

Where the planting project has a variety of conditions, an intelligent planting plan might well provide for varying the class of stock, as well as the species, so as to use the most economical and appropriate class on each site.

Use of Wild Stock in Planting

The abundance of small seedlings on logged-off lands and in the forest, where they often form a veritable carpet, suggests the possibility of digging up these small "wildlings" and planting them, instead of nursery-grown stock. This has been done in a few instances in this region as well as elsewhere, but is not to be advised as a general practice. The digging up of wild stock is usually not as cheap as it would at first appear to be; such stock is uneven in size and quality and requires careful sorting; it is inferior to nursery-grown stock in root development, bud development, and vigor. The mortality in plantations of wildlings is usually heavy. If used at all they should be collected close to the locality where they are to be planted.

It may sometimes be practicable on a small scale to dig 1-year-old wild seedlings and transplant them to nursery rows for a year, thus saving time, the cost of seed collecting, and the first year's care of the seedlings. Where seedlings of one age are very abundant, as where found in clumps sprouting from squirrel caches, fair results may be obtained this way at a net saving over using wholly nursery-grown stock.

Season for Planting

Basic Considerations

Forest planting should be done during the time of year when top growth is dormant, namely, from mid-fall to early or mid-spring depending on altitude. Planting should not begin in the fall until the ground is thoroughly wetted by rain, nor can it begin in the spring at the higher altitudes until the winter snows are gone. Winter planting is out of the question on account of snow above a certain contour on the mountains.

There is considerable difference of opinion as to which season--fall, winter, or early spring--is best for forest planting in this region. There are certain physiological considerations, and certain considerations of administrative convenience that must be weighed.

In the snow belt, such as on much of the national forests of the Cascade Range, the period between the disappearance of the snow and the coming of dry hot weather is some years very short, giving planted trees very little time to become established to resist the summer drought. Likewise, in the fall the period between the wetting of the ground by the fall rains and the coming of snow is some years very short. At the lower altitudes, in the valleys and on most of the Coast Range, planting is physically possible for 5 or 6 months from fall to spring. There is considerable administrative advantage in organizing a planting job for a long period, especially conducting the work through the winter when woods labor is more apt to be available.

But there are controlling physiological considerations. With evergreen conifers moisture is constantly being given off through the needles, even during the dormant period, necessitating its replenishment by the plant's roots. If the planting is done late in the fall or in the winter when the soil is cold and the roots are not active the tree may not make connection with the soil through its root hairs and may be unable to absorb moisture as fast as it is evaporated from the foliage. "Winter killing" then results. Though sowing and cloudy weather are prevalent through the winter, there are occasional periods every year of dry, cold weather which are very desiccating to freshly planted trees, unless they are covered by snow.

Planting, furthermore, must not be started in the fall until the trees in the nursery are thoroughly hardened down; from this time until the period when root activity ceases is relatively short. Spring planting, or late winter planting, has the advantage that root growth

is about to commence (it commences before top growth) so that little time elapses after planting before the roots are functioning sufficiently to supply the needs of the plant.

It has been pointed out elsewhere that rodents are serious enemies of freshly planted trees, especially when other food is scarce. Fall planted trees, therefore, have several months more exposure to these pests than spring planted.

In national forest operations planting has usually been conducted in the spring. Various trials, however, have been made of fall and a few of mid-winter planting. Some of these were small experiments designed to test season of planting on specific sites; others were extensive operations covering hundreds of acres and a variety of sites. The results of these many trials will be described separately for the coast and for the Cascade regions.

In the Coast Region. Trials of planting in every month from October to May (except February) were conducted years ago for 4 consecutive years on the Mt. Hebo planting project, Siuslaw National Forest. This lies 7 miles from the ocean on the Coast Range divide at altitudes ranging from 750 to 3,000 feet, where the climate is humid and mild, freezing weather is rare except at the higher altitudes, and snow does not commonly remain on the ground except above the 1,800-foot level.

Table 11 gives the survival data for fall and spring plantations on closely similar areas. It is noticeable that neither season shows consistent superiority over the other. Spring planting led in four instances; fall planting in the other two. In the extensive plantations, listed at the bottom of the table, exceptionally heavy mortality from winter killing occurred during the months immediately following planting and it is believed the trees were received from the nursery before they were fully hardened.

A comparison of winter and spring planting on the Mt. Hebo project is presented in table 12. Here again no consistent superiority of one season over another is evident; in only one instance was survival on the winter plantations very low; in several it was high. From this it seems safe to conclude that at the lower elevations in the coastal region, except for rodent damage, planting in the fall or winter is about as likely to be successful as spring planting.

In the Cascade Region. On the west slope of the Cascades the climate is more vigorous, more subject to extremes, than in the coast region. In the Cascade region and in the valleys between the Coast and Cascade Ranges the growing season commences later than on the coast, terminates earlier, winter temperatures are lower, summer droughts are more severe and commence earlier, and winter cold, dry spells are more severe and frequent.

Table 11.--Survival in Fall and Spring Plantations of Douglas-fir in the Coast Region,
Planted With the Same Kind of Stock and on the Same or Closely Similar Areas^{1/}

Characteristics of planting area	Fall planting		Spring planting		
	Date planted	Survival percentage 1st season ^{2/}	Date planted	Survival percentage 1st season ^{2/}	2nd season ^{2/}
Level bench, 2,200' altitude. Good soil. Exposed to SW winds	Nov. 1914	79	Apr. 1915	100	99
In small protected draw, but soil very rocky. Altitude 2,200'. Rather favorable site	"	76	"	95	91
Exposed bench, 2,200'. Soil rocky. Rather severe site	"	79	"	91	88
Steep SW slope, stony soil. Altitude 3,000'. Severe site in all respects	"	88	"	54	40
Level ridge top, fair soil. Altitude 3,000'. Better site than one next above	"	98	"	77	63
Includes level mountain top and steep east, south, and west slopes. Altitude 2,000-3,000'	Oct. Nov. 1913	34	Apr. 1914	65	58

^{1/} All plantations were small test plots installed under control conditions, except the last one listed, which covered several hundred acres as part of an extensive operation.

^{2/} In fall plantations, the elapsed time from planting end of first season, comprises both a winter and summer period whereas in spring plantations it embraces the summer period only. Hence comparisons on the basis of first season survival are somewhat prejudicial to fall operations. A more accurate basis is to compare first season survival in fall plantations with the mean of first and second season's survival on spring plantations.

Table 12.--Survival in Winter and Spring Plantations of Douglas-fir in the Coast Region,
Planted With the Same Class of Stock and on the Same or Closely Similar Areas^{1/}

Characteristics of planting area	Winter planting		Spring planting		
	Date planted	Survival percentage 1st season ^{2/}	Date planted	Survival percentage 1st season ^{2/}	2nd season ^{2/}
West slope, medium altitude. Rock more plentiful in soil of spring plot	Dec. 1911	87	Apr. 1912	97	97
Several plots on various aspects	"	90	Mar. 1912	82	68
Winter plots at lower altitudes and on better soil than spring plots	Jan. 1912	58 80	Apr. 1912	74	68
Steep south slope near ridge top, classed as severe site: altitude 1,600'	Dec. 1912	94	Apr. 1913	89	83
Gentle south slope, altitude 750'.	"	92	"	-	88
Winter plot south slope, spring plot west slope. Both rather rocky soil; altitude 1,700'	Jan. 1913	75 ^{3/}	May 1913	-	82 ^{3/}

1/ All plantations were of relatively small size.

2/ In winter plantations the elapsed time from planting to end of first season is somewhat longer than in spring planting; hence, comparisons on the basis of first season survival is slightly prejudicial to winter planting. A truer basis for comparison would be to use percentages for spring planting intermediate between those indicated for the first and second seasons.

3/ Second season survival.

Tables 13 and 14 present some examples of fall and spring planting on 8 typical denuded areas on 5 different national forests distributed from the Snoqualmie Forest on the north to the Cascade (now Willamette) Forest on the south. In some instances comparison plots of spring and fall planting were installed using the same class of stock. Table 13 gives the results of 36 separate small-scale tests of fall planting, in some cases paired with spring planting. Table 14 gives the survival rates for some extensive operations both in spring and fall, using several different age classes of stock.

A perusal of these tables indicates that survival in the fall plantations was inferior to that in the spring plantations, both experimental and extensive. In most instances the difference was pronounced. None of the large-scale fall plantations gave satisfactory results. The success obtained with fall planting on the Columbia Forest and on one of the Rainier Forest experiments indicates that perhaps under just the right set of conditions fall planting may be successful. But the large number of failures shows pretty conclusively that the occurrence of these necessary favorable conditions is, in the long run, the exception rather than the rule, and that fall planting on the west slope of the Cascade Range is less likely to give satisfactory survival than spring operations.

Informal reports of the experience of other agencies bear out the conclusions reached on the national forests, that late fall and early winter planting is attended with more hazards than late winter and early spring planting. However, the differences are likely to be less pronounced on the better sites at lower altitudes such as comprise the great belt of privately owned logged-off land than they are on the higher altitudes and poorer sites within the national forests where these Cascade region tests were conducted.

Summary of Principles Regarding Seasons for Planting

The principles fixing the planting season might be summarized in the following set of rules for getting the best results on the average, considering only the physiological, not the administrative, aspects of the operation:

- (1) Do not commence fall planting until the trees are hardened down.
- (2) Do not plant until the soil is thoroughly wetted.
- (3) Discontinue fall planting by the time the ground is cold and root activity has ceased, unless the trees are sure to be covered with snow all winter.
- (4) Commence late winter planting after the extreme cold, dry spells are probably mostly over--perhaps mid-February.

Table 13.--Survival in Carefully Conducted Test Plots of Fall and Spring Planting of Douglas-fir in the West Side Cascade Region^{1/}

Location and major site characteristics	Date of planting	Average survival percentage			Remarks
		End of 1st season	End of 2nd season	End of 3rd season	
6 sets of companion plots on variety of sites on Mt. Hood Forest at altitudes varying from 3,150 to 4,700'	Early Nov.	49	45	-	Spring plots led in survival in every set
	Early May	93	88	--	Fall plots suffered from heavy mortality the first winter
4 sets of companion plots on southerly slopes on Cascade Forest, at altitudes ranging from 2,350 to 2,900'	November	40	26	-	Ditto
	April	94	76	-	
1 set of companion plots on north slope on Rainier Forest at 2,250' altitude	Early Nov.	91	88	87	
	April	99	99	99	
1 set of companion plots on south slope on Rainier Forest at 2,250' altitude	Early Nov.	78	65	60	
	April	79	70	66	

^{1/} In companion plots of fall and spring planting the trees were of the same age class and source of seed and sites were similar.

Table 14.--Survival in Large Spring and Fall Plantations of Douglas-fir in the West Side Cascade Region

Location and character of plantation	Date of planting	Average survival percentage			Remarks
		First season	Second season	Third season	
280 acres fall planting, 302 acres spring planting; all on Mt. Hood Forest at altitudes 3,200 to 4,500'	October April and May	29 83	- 77	13 76	Fall planting mostly northwest slopes; spring planting southerly slopes
1-1 stock on Buck Cr. project, Snoqualmie Forest, southerly slopes	Oct.-Nov. April	- 96	- 90	131/ 90	Spring plantation at considerably higher altitude
2-0 stock on Buck Cr. project, Snoqualmie Forest, southwest slope	Oct.-Nov.	64	-	61	
1-2 stock on Buck Cr. project, Snoqualmie Forest, southerly slopes	April	98	96	93	
1-1 stock on Granite Mt. project, Snoqualmie Forest, south slope, 2,800 to 4,000'	October	54	-	45	
" " "	"	23	-	23	
" " "	April	64	-	-	Trees reported injured during transit
2-0 stock on Granite Mt. project, Snoqualmie Forest, south slope, 2,750 to 4,300'	October	47	-	28	
1-1 stock on west slope Santiam Forest at 3,500 to 3,800' altitude	October	77	57	51	Trees dug in nursery in late October
" " "	"	37	33	24	Trees dug in nursery in late September
1-1-1 stock on east and west slopes, Santiam Forest, 2,800 to 3,800' altitude	May	66	-	62	

1/ Fourth season survival.

- (5) Discontinue spring planting before the buds swell on the stock and before the planting site has become dry.
- (6) The earlier the trees are planted in the fall and winter the greater is the probability of rodent damage.
- (7) Fall and winter planted trees are more subject to frost heaving than spring planted trees on soils subject to this process.
- (8) There is less difference in the coast than in the Cascade region between fall-winter and spring planting; fall-winter planting is more likely to be successful in the former than in the latter region.

Spacing

General Considerations. In forest planting in the Douglas-fir region, spacing will usually be what is called semi-regular spacing (57). The trees will be set in rows at intervals, judged by eye, and the distance between rows gauged by each planter keeping the proper distance from his neighbor on the left or right as described in another chapter. Precise regularity of spacing will be subordinate to selecting a suitable spot for setting each tree. The great quantity of down logs, stumps, bushes, mounds, holes, and rocks on old burns and logged-off lands makes it very desirable to allow the planter to deviate from his line or the spacing in his row even 3 or 4 feet to avoid such unfavorable spots. Furthermore, deviation from the precise spacing is desirable to take advantage of the shade of stumps and logs, a factor important to survival, as discussed later. The average distance between trees should, however, closely approximate the chosen standard, so that the desired number of trees per acre will be attained.

Irregular spacing will be practiced only in filling in open spaces in a plantation or natural stand, in underplanting, and sometimes in planting for aesthetic effect, as along roads or about campgrounds.

Determining Factors. There are many silvical advantages in close spacing; a quick closing of the forest canopy shortens the period of acute fire hazard, it promotes quicker dying of the lower limbs and, therefore, smaller knots on the lower bole, it assures quicker suppression of competing brush. On the other hand costs run up rapidly with decrease in spacing distance; there are twice as many trees in a 6 x 6 foot plantation as with $8\frac{1}{2} \times 8\frac{1}{2}$ foot spacing, and the direct labor cost of the former would, therefore, be almost twice as much. Beyond a certain degree of crowding, diameter and height growth of the individual trees are inhibited.

Decision as to the spacing to use must be a compromise between silvicultural ideals and reasonable costs, avoiding a spacing that is so costly as to be uneconomic and on the other hand one so wide that it does not attain the silvicultural objectives.

Within this range there are certain specific factors to be considered:

- (a) Purpose of the plantation. If quick coverage for watershed protection or abatement of the fire hazard are major objectives a closer spacing may be indicated than were timber production the sole object.
- (b) Probable mortality. Where there is likelihood of losses in planting as on exposed sites the spacing should be proportionately closer than on favorable sites. It would be good technique to plant somewhat closer on hot south exposures than on north-facing slopes, to compensate for the almost inevitable higher mortality. (See table 18.)
- (c) Opportunity for thinning. If there will be opportunity to market at a profit products of an early thinning, like Christmas trees or small poles, there may be justification in close spacing; the benefits to the stand in its initial years will be attained without financial loss if the profit from the thinning pays for the extra cost of close spacing, and the inhibiting effects of crowding will soon be overcome without sacrifice of quality growth.
- (d) Opportunity for pruning. If there is no other reason for close spacing than to promote early lower limb dying and hence a better quality log in the lower bole, and if pruning at an early age seems practicable, wider-than-normal spacing may be in order. It has been argued that under these conditions the saving in cost of quite wide spacing will pay for the cost of 18-foot pruning when the plantation is 30 years or so old and its canopy closed.

Pattern. The ordinary pattern of planting in this region is rectangular with the trees spaced in the rows the same distance as between rows. Where traversing the planting tract is particularly arduous because of big logs, brush, or steep slopes, it may be economy of the planters' time to space the rows wider than normal and the trees closer in the rows, and thus having the same number of trees per acre, but less walking. For example, a $6 \times 10\frac{1}{2}$ foot spacing would require 24 percent less trips across an area, and accomplish almost the same silvicultural effect as an 8 x 8 foot spacing.

Forest Service Experience. In order to compare the development of plantations of various spacings, several plots were planted carefully in 1925 in the upper Wind River Valley on a rather typical site III area which had been logged and twice burned (plate XV). The following spacings were used and the failed places replanted to maintain that density: 4 x 4 foot, 5 x 5, 6 x 6, 8 x 8, 10 x 10, and 12 x 12. A nearby area of natural reproduction with about the same number of trees as the 6 x 6 foot plantation afforded a comparison.

After the trees had been planted 15 years Isaac and Petersen^{10/} report the comparative results, which are summarized in table 15. Generally, the wider the spacing the taller the trees, the wider their crown spread, the larger their diameter, and the larger their branches. The lower limbs of the trees in the three closest spacings had already been shaded out. The herbaceous vegetation had in even 10 years been reduced to about 10 percent of that in the open, and this has a profound effect on the fire hazard. In the wide-spaced plantations and in the natural stand after 15 years the amount of vegetation was considerable and was about proportional to the voids between the crowns, but in all plots was less than on the unstocked, unplanted areas.

Spacing Recommended. Most of the planting which has been done in this region of late years has been 8 x 8 feet. The measure of the adequacy of the spacing is the time required to attain a closed canopy and full stocking in relation to cost per acre. As a broad average 8 x 8 foot spacing seems to be the best compromise between cost and silvicultural objectives for this region under present conditions. Where high mortality is feared it should be closer. On rapid-growing sites it could be wider. Likewise, rapid-growing species or extra large planting stock will give quicker coverage than trees of reverse qualities and so can be planted at wider intervals than standard.

Commonly used spacings require the following number of trees per acre:

<u>Spacing in feet</u>	<u>Number of trees per acre</u>
6 x 6	1,210
7 x 7	889
8 x 8	681
8 x 10	545
10 x 10	436

Where natural reproduction is present it is needless to plant a tree closer than the spacing interval to any existing tree. On some areas with a spotty sprinkling of natural seedlings this may result in some saving of trees but without much saving in planting crew time.

10/ Isaac, L. A. & Petersen, W. G. Fifteen-year progress report of study of spacing in Douglas-fir plantation. Ms. January 18, 1940.

In a large planting project there will surely be a certain percentage of the area occupied by unplantable areas--roads, water courses, rocky areas, swamps, building sites, etc. Furthermore, good multiple-use land management ordinarily calls for leaving unplanted glades and occasional openings suitable for deer pasture and viewpoints along ridges, trails, and roads for both protection and scenic reasons. Hence, the total number of trees required for a project will be somewhat less than the standard number per acre multiplied by the acreage. Wastage may more than make up for this, however.

Table 15.--Comparison of Plantations of Various Spacing 15 Years After Planting, Site III, Logged and Doubled Burned, Wind River Valley, Washington

Spacing Feet	Average height Feet	Crown width Feet	Average d.b.h. Inches	Branch ¹ / diameter Inches	Height to live crown Feet
4 x 4	13.9	2/	1.6	.34	1.5
5 x 5	14.1	2/	1.7	.38	.8
6 x 6	14.7	2/	1.8	.40	.7
8 x 8	14.0	6.1	1.6	.41	0
10 x 10	16.3	8.4	2.4	.60	0
12 x 12	17.3	8.8	2.6	.64	0
Natural stand	13.2	6.2	2.0	.42	0

¹/ Diameters of two largest branches just above and below breast height.

2/ Canopy closed before 15 years of age.

Care of Planting Stock

Storage on the Planting Area

If the season at the nursery does not synchronize with that of the planting area it will be necessary to hold the trees after they are dug up, possibly digging them in early spring for late spring planting or in the fall for winter planting. Such storage can best be done at the nursery in a naturally cooled cellar or an artificially cooled storehouse, as described in an earlier chapter. To prevent vegetative activity of the trees and the growth of damaging molds they should be held in a temperature below 40° F. They cannot be held dormant or safely stored any length of time above that temperature.



PLATE XV. Two 11-year-old plantations established to test the effect of spacing; they were side by side in the Wind River Valley, Washington.

- (A) 4 foot x 4 foot spacing
- (B) 10 foot x 10 foot spacing

On the close spacing all weeds and some of the smaller trees are being crowded out by closing crowns while the 10 x 10 spacing still shows weed growth between trees.

But even when the trees can be planted at the same time they are being dug from the nursery it is desirable to maintain on the job a supply of trees in excess of immediate requirements. The nearer the planting area is to the nursery and the more dependable the transportation, the smaller the supply need be. The care of the trees on arrival at the planting camp thus is an important phase of the operation.

Provided the trees come well packed, with plenty of damp moss or other moisture-retentive material about their roots, they may be kept safely for a few days in their original containers by placing them in a cool, shady situation out of the wind and sprinkling them daily. Otherwise it is desirable to remove them on arrival from their containers and heel them in. Suggestions for heeling in are as follows (plate XVI):

- (1) At the planting camp or other place convenient to the job, select a level area in the shade or part-shade and out of the wind, if possible, where the soil is easily dug and well drained, and a water supply is at hand.
- (2) Dig one or more parallel trenches about a foot wide and a foot deep, with one side sloping at a 60° angle and as long as needed.
- (3) Open the crates, bales, or boxes of trees, and remove the packing.
- (4) If the trees are tied in bundles do not cut the string unless they are very large, the trees show a tendency to mold or heat, or are to be left heeled-in over 10 days. Place the trees in a thin layer along the sloping side of the trench, with their normal ground line just below the level of the ground. Place a 2- or 3-inch layer of dirt on the roots and pack down with the heel; add another layer of trees by digging from the opposite side of the trench. Repeat until there are not over 6 or 8 layers in one trench, then fill the trench with soil and pack down firmly so that drying air is excluded from the roots.
- (5) Wet the soil thoroughly at once and, if the soil or air is dry, every day or two thereafter as needed.
- (6) Different species or lots should be kept in separate blocks, and the oldest lots used first.

(7) If the heeled-in trees are not in the shade and they are to be left several days, erect over them a framework 2 feet high covered with evergreen brush or boughs. Do not cover with a tarp, because that shuts off ventilation but not heat.

A handy method of heeling-in that sometimes may be workable is to select the cut bank of a road or creek, where the soil is deep and sandy or loamy, and on its north-facing side dig a little shelf near the foot of the slope, lay the trees on it tops out, slide a layer of dirt over their roots and pack down, lay on another layer of trees, another layer of dirt, etc.

Even with good heeling-in on the planting site trees cannot be held dormant after growth of the species has started locally. If planting must continue after this time the stock should be kept in cold storage at the nursery or elsewhere as long as possible.

If, because of lack of timely transportation or storage facilities at the nursery, it becomes necessary to ship the stock to the project considerably in advance of planting time, special arrangements for storage in the field must be made. On several occasions stock has been shipped in early spring to high altitude planting projects and the trees stored amid snow banks and covered with boughs. On one occasion some Douglas-firs were heeled-in in trenches flanked by snow, moved to a higher elevation as the snow receded, planted after 69 to 75 days in such storage, and showed a survival of from 78 to 94 percent at the end of the first season.

On another occasion 75,000 Douglas-firs were shipped from the nursery on April 19 and held on the planting site until June 17 in their original shipping crates, laid in an improvised cold storage shelter built of boards and boughs, and banked with snow except the top. Sample rows in this plantation showed a survival at the end of the first season of from 86 to 98 percent. Other attempts in late spring storage in snow at high altitudes have been less successful, so it is not a practice to be advised if cold storage at the nursery or elsewhere is available.

Douglas-fir stock has on several occasions been shipped in the fall from the Wind River Nursery to the coastal region for winter planting (because it could not be dug and shipped later) and heeled in for several months. On one occasion the trees' roots were badly damaged after 2 or 3 months in the heeling in trenches apparently by an excess of rain water which precluded soil aeration in spite of a sandy surface soil and careful heeling-in. The practice of long heeling-in during the rainy season is, therefore, not recommended. Clay soils and poorly drained ground are particularly to be avoided.

If a long period must elapse between digging at the nursery and out planting in the field some provision must be made for storing either in a cool cellar or in cold storage. Douglas-fir and Port Orford white-cedar have been held during the winter in the cool cellar at the Oregon State Nursery for 2 months without deterioration, according to one test.



PLATE XVI. Heeling-in trees at the planting camp; the small bundles of trees are opened and the trees spread in a thin layer since they are to be held there some time.

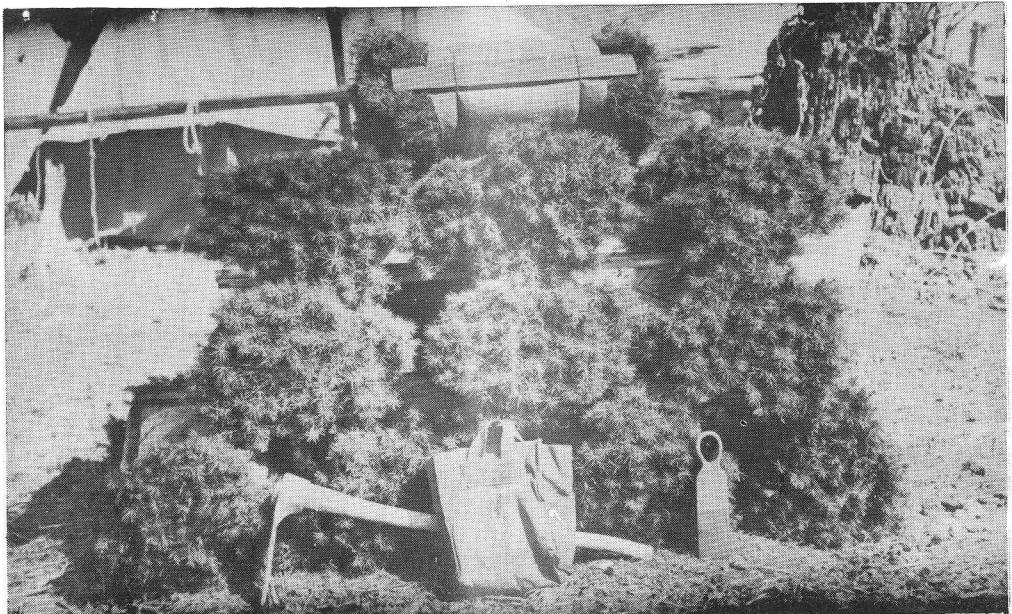


PLATE XVII. Planting hoes, planting bag, and 12 bales of Douglas-firs -- 3,600 trees at the planting camp.

Regardless of the method of heeling-in or storage employed it is well to keep to a minimum the time between digging up and planting; there are many hazards to the trees when they are out of the ground and there is almost sure to be some deterioration.

Care by the Individual Planter

The roots of coniferous trees are very sensitive and cannot survive being dried out. Scrupulous care must, therefore, be exercised at all times to impress upon those handling the trees the necessity for keeping the roots covered and moist at all times. In heeling them in, in transferring them to the planting site and while in the hands of the individual planters the bare roots should not be exposed for even a minute. On sunny and windy days the hazard to the trees is particularly great.

Each individual planter should have a container in which to carry his trees; the trees should all be kept in this container at all times; the inclination to carry a few in the hand should be restrained. The best form of container is a bag made of waterproof canvas or other stout waterproof cloth, with two loop handles, and divided into two compartments (plate XVII). In one compartment is kept a small bunch of trees from which the planter draws one for each setting and in the other compartment is his reserve supply. In both compartments should be enough wet moss or shingletow to cover the roots. A canvas water bucket can be used, but this does not shield the trees as well as a collapsible bag. Metal pails are not convenient and also do not protect the trees and packing as well from sun and wind. An old 2-gallon canvas water bag, slit open across the top, makes a good improvised 1-compartment container for a small number of trees.

Organization of a Planting Project

Reforesting a large acreage of wild land is a highly technical and expensive operation that demands careful selection of project superintendent, foremen, and laborers, and good organization throughout. Assuming that a planting plan has been prepared and that the trees have been provided, the following suggestions are made for the selection, organization, and supervision of the crew:

Selection of Planters

The size of the planting crew should be governed by the number of trees to be planted and the length of time that the weather will allow for the job. In figuring the number of men needed assume that each planter will plant from 350 to 900 trees per 8-hour day, depending on soil, topography, weather, crew efficiency, and size of stock.

A crew of less than 10 men is inefficient, except on small projects where there are 2 or 3 experienced men who can work without overhead and without maintaining a camp or special transportation facilities.

The best type of laborers for this work are young, able-bodied men who are used to bending their backs, are quick on their feet, and are interested in the job, like local residents and forestry students. The planters should be organized into squads of 10 to 12, or at most 15, men, each with a foreman, who should be a good instructor and leader.

Duties of Foremen. Men of leadership ability who preferably have had experience on former planting projects should be engaged in advance and paid slightly more than the planters. The duties of a foreman are:

- (1) To take care of the supply of trees and the tools.
- (2) To see that his squad covers the area prescribed in the planting plan.
- (3) To keep his men properly lined up by setting guide flags or otherwise.
- (4) To instruct his men in planting technique and to give constant supervision to see that each man does good planting and that the trees in his planting bag are properly covered and wet.
- (5) To see that no unnecessary planting is done on stocked areas or on unfavorable ground.
- (6) To plant occasionally in the place of a man who needs to take 5 minutes off, so as to keep the line moving uniformly.
- (7) To arrange to have drinking water at stated intervals so that the men may not have to carry canteens.
- (8) In small projects employing only one squad the foreman will act as project superintendent also.

Duties of Project Superintendent. In projects of 20 men or more there should be a project superintendent, preferably a technically trained man with executive ability. His duties are:

- (1) To arrange for transportation of men and materials and to run the camp, if any.
- (2) To allot the areas to be planted by each squad and keep track of the area covered.
- (3) To currently inspect the quality of the planting workmanship of each squad. To do this he should pull up at least 100 freshly planted trees per

day, selected at random, and record the results--if poorly tamped, too deep or too high, roots crooked, hole slanting, poor location of tree, etc.

- (4) To check spacing, by counting the planted trees on sample plots here and there, and then comparing number of trees planted on a known area with number of trees issued.
- (5) To prepare necessary progress maps and reports.

Tools

Each planting squad of 10 planters and a foreman should have the following equipment:

- (a) Ten (and some extra) planting hoes made for the purpose or grub hoes with a $3\frac{1}{4}$ - to 4-inch wide blade, the blade of which has been straightened and lengthened by a blacksmith to a right angle with the handle, 8 to 10 inches long depending on circumstances.
- (b) Ten bags, of canvas or other stout waterproof cloth, in which to carry the trees and some wet packing, preferably with 2 compartments; canvas waterbuckets or old water bags will do; metal pails are not convenient.
- (c) Two water bags (or individual canteens), unless creeks are abundant, for wetting the trees and for drinking, to be kept at the end of the strips.
- (d) For the foreman, a compass, map, notebook, belt axe, tally register, cloth for guide flags, 6- or 8-foot measuring pole.

At the camp there should be an emery wheel for sharpening the planting hoes, shovels for heeling-in the trees, axes, and the other tools and equipment ordinarily needed at camps or work headquarters in the woods.

Instilling Proper Attitude in Planters

The success of any plantation depends considerably upon the attitude of the planters. If they are enthused with a desire to make every tree survive the trees have the optimum prospects of doing so. It should be one of the special concerns of the foreman and

superintendent to inspire the men to have interest in doing well a task of starting a new forest. The laborers should not be crowded so that they do not have time to do a good job, yet the training should teach them to work rhythmically and efficiently. They should be paid fair going wages for good workmen.

Planting Procedure for Each Squad

A conduct of the planting job which has been found successful is about as follows: The crew is divided into squads of 10 or so and not over 15 men each; each squad has a foreman. Under his direction the planters, when ready to start work in the morning, should each take enough trees to last until refills can be made without loss of planting time.

One bundle of trees should be opened, the trees separated, and put in one compartment of the planting bag with a double handful of wet moss, shingletow, or other wet material; the unopened bundles should be put in the other compartment, also with wet packing. At intervals during the day the material in the planting bags should be moistened. The trees in the planting bags should be kept covered and so handled that no root will dry out even for a moment.

A reserve supply of trees should be taken from camp by the foreman and heeled-in near the job, with which to replenish each planter's supply.

When the several squads have arrived at the area to be planted the planters are lined up 8 feet apart (or whatever is the interval between rows) and proceed across the area being planted as a unit, approximately abreast, observing the following principles:

- (1) A good, steady, systematic worker should be put on either the right or left end; he is the guide for the others, sets the pace, and plants the first tree on each course. An experienced, good worker should also be on the other end of the line.
- (2) The man next to the guide keeps the proper distance from him and abreast or slightly behind him (but never ahead) and so on across the squad, so that the squad advances with a diagonal front.
- (3) To assure good spacing between rows, each man should be slightly behind his neighbor on one side, so that the planter on the end opposite the guide will be 2 or 3 trees behind him.

- (4) In order to take the proper course across the area to be planted, the foreman may desire to set a flag or series of flags--pieces of white or yellow cloth--stuck up on poles or bushes for the guide to steer for on the first row. After the crew passes a line marker flag, the foreman will move it over to mark the line for the return trip of the planting crew, or, if the foreman is otherwise engaged the guide will pick up the flag and have it passed down the line to the man on the opposite end who will set it up on the line of the first row for the return trip.
- (5) On small tracts in easy topography, flags may not be needed; instead the foreman can point out a landmark for the guide to steer for, or sometimes there is a natural boundary like a creek, trail, or ridge for the first row; then each succeeding course can be followed by paralleling at the proper distance the last row planted.
- (6) When the strip across the area to be planted has been completed the squad will move over and reverse its direction; the guide man will go back next the last row planted, following the new line of flags, if any. Each planter will have the same men next to him.
- (7) In steep country it is better to proceed up and down the slope, than along the contours. In very steep country (where downhill travel is rapid) it may be advantageous for the crew to walk back to the foot of the slope and plant only on the uphill trip.
- (8) There should be no smoking on the line, but at stated intervals, usually once an hour preferably at the end of a row, a 5-minute rest will be taken and smoking allowed with proper precautions against fire.

Selecting the Right Spot for Each Tree in the Row. The spacing of trees in plantations has been discussed in an earlier chapter; the distance between rows adopted for each project will be prescribed in the planting plan. The laborers will be instructed as to the average distance apart that the trees should be in the row. But this distance should not be followed rigidly regardless of obstructions, cover, and soil, but some judgment used in placing each tree in a good spot.

Picking a good location for setting a tree is more important than adhering to uniform alignment or spacing. Hence, every planter should feel that he has a latitude of 3 feet or so in either direction to avoid unfavorable spots, but he must be sure after departing from his alignment or spacing to get back to it on the next tree.

The spots to select for setting a tree are:

- (a) Where there is good, deep soil.
- (b) On the north side of logs, stumps, bushes, etc., where the planted trees will be shaded.
- (c) Where soil is stabilized.

The spots to avoid in setting a tree are:

- (a) Mounds that might dry out.
- (b) Depressions that might fill up with soil.
- (c) Rotten wood and rocks.
- (d) Spots where the soil is burned red by an extra hot fire.
- (e) Spots of dense vegetation.
- (f) Proximity of colonies of rodents and animal burrows.
- (g) Within 8 feet or so of an established seedling in areas where there is a sprinkling of natural reproduction.

Planting Methods and Tools

The manner in which each tree is set in the ground is of great importance in determining the success or failure of a plantation. Should a large proportion of the trees die or fail to make good growth, the project is a failure. Reasonable survival and rate of growth are not the only requirements; cost must also be considered. If only a few trees were to be planted, such care could be taken as to assure almost complete survival. But in forest planting large numbers of trees are involved and speedy methods must be employed which will keep the cost within sound limits and at the same time afford each tree a reasonable opportunity to survive and make normal growth.

From the standpoint of survival the four outstanding essentials for successful planting of conifers in the Douglas-fir region are:
(1) The roots must be kept moist at all times, (2) the roots must not be doubled up in the hole, (3) the soil must be well packed about the

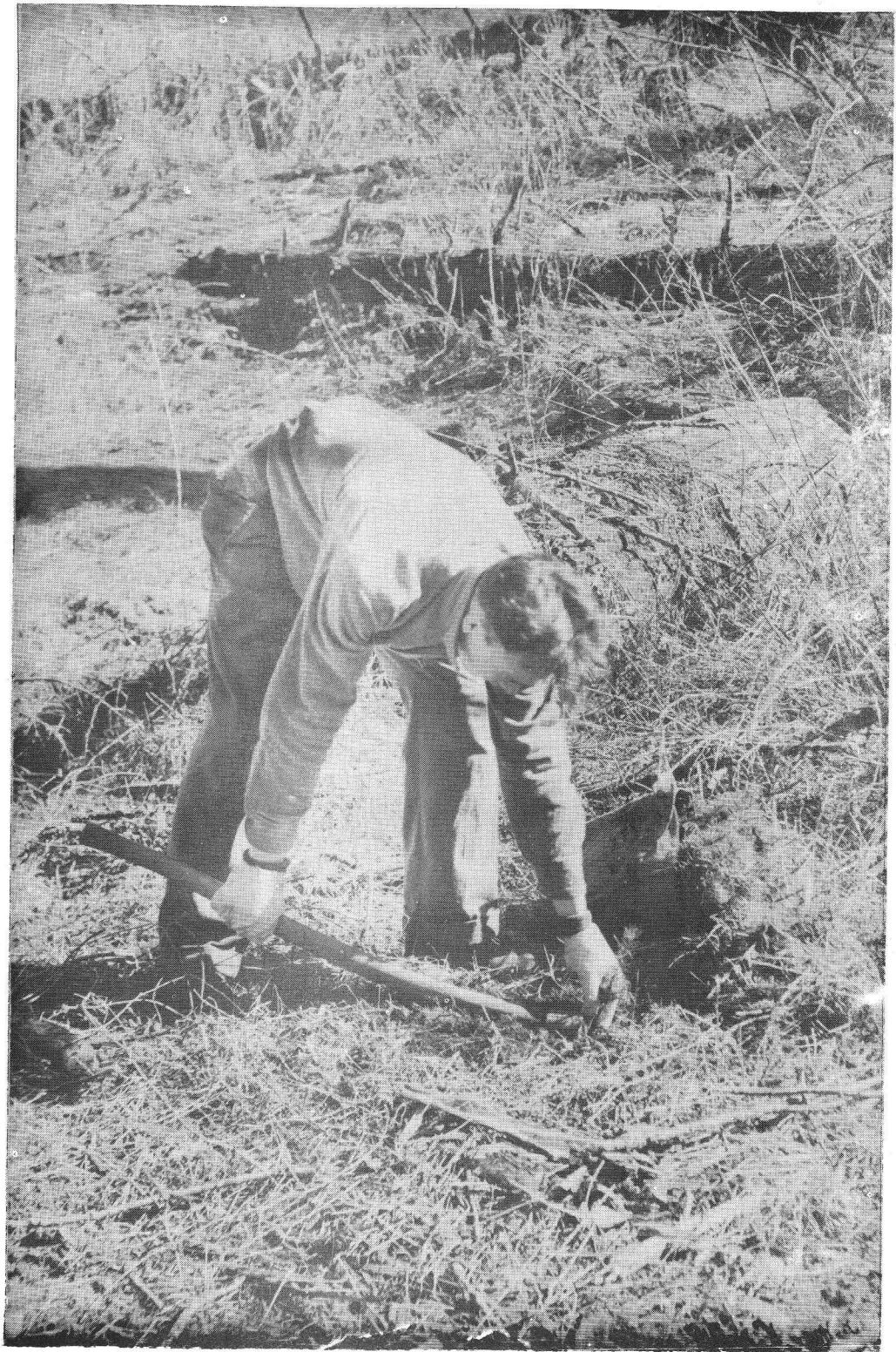


PLATE XVIII. Step 4 in tree planting by the one man grub hoe method.

roots at the bottom of the hole as well as at the top, and (4) the tree must be set no higher and not more than a little deeper than it was in the nursery.

Keeping the roots moist is particularly necessary with evergreen species, which even when dormant are transpiring. The roots should never be exposed for more than one minute; if they become dry even for a very short period, the tree is likely to die. For this reason it is an essential practice for each planter to carry his supply of trees in a container that will protect them from sun and wind and in contact with some wet packing such as moss, shingletow, or burlap. The type of waterproof canvas bag, described above, is recommended (plate XVII).

The necessity for placing the roots in a straight position in the hole is twofold: First, to enable them to reach down into the zone of permanent moisture when in midsummer the top few inches of soil become too dry to sustain a tree, and second, to assure proper functioning of the roots, for curled and doubled-up roots inhibit the passage of nutrients from root to top and fail to give the tree stability against wind throw. To assure a straight root system it is obvious that the hole must be of adequate depth to accommodate the roots without bending.

Firming of the soil about the roots is the third essential of good planting. Doing this, by tamping with heel or tool, so that the bottom of the hole is solid, prevents air pockets which would hasten drying out of the roots, restores capillary action in the soil, and puts the fine roots in close contact with the soil particles. The advantages of setting the tree at the right depth are obvious.

The method of planting which best lends itself to the accomplishment of these four essentials, and at the same time is reasonably rapid, is the one to select. It will not necessarily be the same in tools and technique in all classes of soil and with all sizes and species of trees. There are various methods of setting out a tree in extensive forest planting, e.g.: (1) inserting the tree in a slit made with a planting bar or straight spade, a technique especially good in light soils but undesirable in stiff clay; (2) digging a hold with a shovel, hazel hoe, planting hoe, or modified grub hoe, setting the tree in the middle of the hole and replacing the dirt, a slow method but justified in some soils and with some species; (3) making a slit or half-hole with a planting hoe and inserting the tree while the tool holds back the dirt.

The last method, which has been named the "grub hoe-slit method," or the "side-hole grub hoe method," has been adopted as standard on the national forests of the Douglas-fir region. It is applicable on most of the common soils for small planting stock and is susceptible of being modified to suit a variety of soils and root forms.

It derives its name from the tool used and the character of the opening into which the tree is inserted. The tool is manufactured for this purpose or may be a standard grub hoe with a single blade $3\frac{1}{4}$ to 4 inches wide which has been straightened and lengthened by a blacksmith so that it sets at about right angles to the handle (plate XVII).

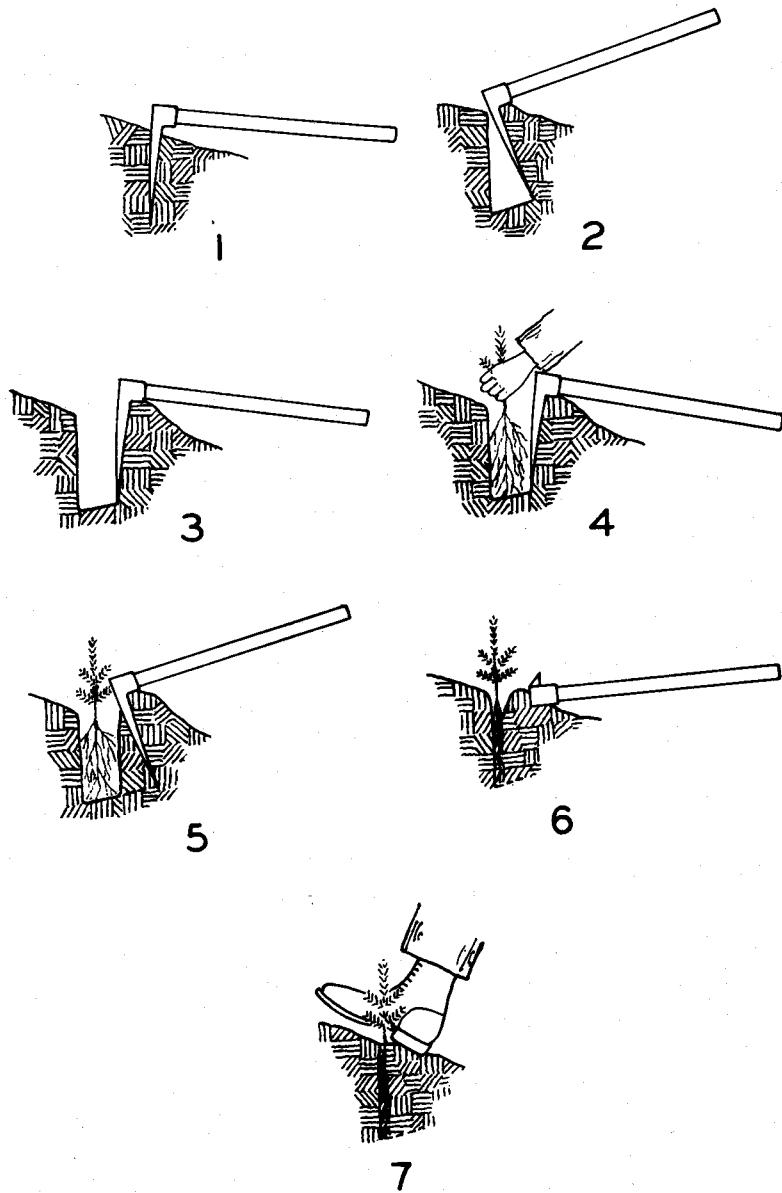
The procedure in using this method consists of 7 steps as follows (figure 8):

- Step 1. Planter drives his planting hoe blade into the ground perpendicularly, its full length if possible in one stroke.
- Step 2. Planter raises up on the handle to open hole at bottom.
- Step 3. Planter thrusts the handle downward and at the same time draws the blade toward him, making thus a clean square hole.
- Step 4. Keeping blade of hoe in hole (to hold back the soil) he inserts 1 tree vertically; roots should be spread in the hole as naturally as possible, not twisted or allowed to hang together like a rope (plate XVIII).
- Step 5. Still holding the tree with one hand so that its former ground line is slightly below the ground line on the downhill side of the hole, he partly pulls out the blade and by reinserting it at an angle and giving a downward thrust presses a wedge-shaped mass of soil against the lower roots, filling the bottom of the hole.
- Step 6. Remove the blade and with a downward push at the side fill the hole with soil full and solidly.
- Step 7. Before moving to the next tree, stamp with heel (not toe) beside the tree to firm soil. If this causes a depression scrape a little soil with hoe or shoe to fill up hole.

By this method the roots are set largely in a single plane (which is not desirable in stiff soils) but only on one side are they up against a hard wall of undisturbed soil because of the loosening of the dirt by the preliminary strokes of the grub hoe. The method is well adapted to a variety of soils.

When planting in sod or dense vegetation this should be cleaned away by scalping the surface of an area a foot or two square before opening the hole. The hole itself should be large enough to accommodate easily the spread roots and should be free of obstructions that might catch or tangle the roots of the tree being planted.

**FIG. 8- SEVEN STEPS IN TREE PLANTING
BY THE ONE-MAN GRUB HOE METHOD**



In rocky soil it may be necessary either to make 2 or 3 tries before getting a deep enough slit-hole or to dig a hole with 2 or 3 strokes and place soil about roots in conventional fashion, separating out the rocks.

In sandy soil, which has a tendency to slide back into the slit, it may be best to remove some of it to get the hole deep enough for the roots. Do not allow dry surface sand to fill in around the roots.

On very steep ground where the soil is loose and unstable a little "shelf" may have to be built with a few strokes of the grub hoe upon which to set the tree; otherwise a small tree has no chance to survive the sliding soil. It is important that the hole be vertical and that neither the roots nor the top be set slantwise.

It is believed by some experienced planters that covering the freshly planted tree with a bit of dry fern or other weeds may help to hide it from marauding rodents, and so improve its chances for survival. In areas subject to rodent damage this practice is suggested; it only adds a few seconds to the planting time for each tree.

The grub hoe-slit method is fairly rapid. Under most favorable conditions where the soil is loose and contains little rock, the ground cover is light, the topography gentle, and there are not numerous down logs to impede the workers as many as 900 trees can be planted per man in an 8-hour day. Under average conditions for this region the rate would be about 700 trees per day; under difficult conditions it may drop below 500.

Comparison of Grub Hoe-Slit Method with Other Methods

Before deciding upon the method of planting most suitable for prevailing conditions in the Douglas-fir region, the Forest Service made a number of tests to compare different methods. Methods used in the Mt. Hebo (Siuslaw National Forest) project in 1912 and 1913, besides the grub hoe-slit method were the spade method, the combination grub hoe-spade method, and the center hole method. The spade method consisted in inserting a spade vertically in the ground, rocking it back and forth, inserting a tree in the wedge-shaped hole, and closing the aperture by stamping with the foot in an oblique direction. The method was rapid but had several faults. The slit, instead of being wedge-shaped, had the cross section of an hour glass and the cavity at the bottom was hard to close. By this method the ground cover was not removed, and this made it difficult to firm the soil about the tree and to gauge the proper depth to set the tree; in rocky soil or where there were tough roots it was next to impossible to force the spade into the ground.

The grub hoe-spade method was devised in the hope of removing the impediment to good planting occasioned by the ground cover, and of preserving the speed of the spade method. The ground cover was removed by a man with a grub hoe working in advance of the planters, who set the trees by the spade method.

The center hole method consisted in digging a hole and setting the tree in the middle of it, in contrast to the grub hoe-slit method that puts the tree against the side of a slit or partial hole. Judged on the basis of survival only, not speed or cost, the grub hoe-slit method was superior to the others. First-year survival in 5 tests of the grub hoe-slit method gave 95 percent survival against 85 percent in 5 comparative tests of the spade method, and 92 and 87 percent for the grub hoe-spade method and the center hole method respectively in one test each. Three-year survival showed a similar advantage of the grub hoe-slit method over the spade method.

It may be that a form of planting bar or other tool will be devised which will overcome the disadvantages of the spade and yet give a record for speed and survival that betters the present grub hoe method, at least for certain types of soil. In the coastal sand dunes, for example, a tile or drain spade is the preferred tool. In the sandy soils of the Lake States the Michigan planting bar is favored and it may have application in this region.

It may be necessary to modify the method of planting to suit each species, not all trees being as easy to transplant as Douglas-fir. The Crown Willamette Paper Company used a "specialized planting method for young spruces in which a bed is prepared for each tree and the roots carefully spread out before the soil is tamped down. While expensive their plan has been found preferable to the grub hoe method commonly used in reforestation with firs. Under the Crown Willamette method a good workman plants about 450 trees a day, as against from 600 to 1,000 by the grub hoe method" (44).

Effect of Workmanship on Success of Planting

Whatever the method of planting, satisfactory results can be obtained only through careful workmanship. Careless, slovenly planting without regard for the essentials discussed above will mean high mortality. In large operations where many planters of varying ability and conscientiousness are employed there is likelihood that there will be considerable range in survival from row to row unless thorough and repeated drilling is given by the foreman to all planters to keep each individual's work up to standard (plate XIX).

As a test of the effect of workmanship on survival on a project on the Rainier National Forest a count was made of the first-year survival of the trees set by one very careful planter in comparison to those set by the whole crew. The careful planter's trees showed an 86 percent survival, the average for the crew was 50. The season was characterized by a prolonged drought, which undoubtedly increased the losses above normal but affected the extra-well planted trees less than the average planted trees. This case, while perhaps extreme in its differences, illustrates the desirability of careful workmanship in planting, regardless of method used.



PLATE XIX. A distorted root, the result of careless planting. This specimen was dug up 10 years after planting.



PLATE XX. Douglas-fir sapling 7 feet high, all of whose branches have been gnawed off by mountain beaver - Hamlet State Forest, Oregon.

Courtesy Oregon State Board of Forestry.

Effect of Speed on Success of Planting

Mention has already been made of the importance of speed in planting as a means of decreasing costs. To the man in charge of a planting project the question as to what constitutes reasonable speed under prevailing conditions is most perplexing. He knows that if planting can be hastened without detriment to survival and growth it would be economically advantageous. He may feel that a moderate speeding-up would not be injurious, but that much emphasis on speed might give the workmen the idea that number of trees planted is more important than good workmanship. Close supervision of the planters will accomplish much, but cannot prevent faulty planting entirely if the pace is too rapid.

On national forest operations the rate has normally varied between 500 and 900 trees per 8-hour day with an 8 x 8 foot spacing. Loose soil, free from rock, a light ground cover, gentle topography, and absence of down logs favor rapid planting, while a hard or rocky soil, dense ground cover, brush, steep and rough topography, and numerous down logs all tend to impede the workmen.

As a test of the effect of speed on survival and growth, one lot of trees in the Mt. Hebo project (Siuslaw National Forest) was planted at the rate being employed by the regular crew, namely, about 700 per day, while another lot was planted about one-third faster or 900 per day. These speeds on the basis of no time out for rest periods or interruptions were equivalent to 120 and 158 trees per hour respectively. The survival was slightly better, but not significantly better, for the rapid planting, namely, 80 percent for the average planting and 86 for the rapid at the end of the first season and 80 and 84 percent respectively at the end of the third season.

The height growth, however, at the twelfth year was slightly better for the slower planted trees. These differences are not considered significant and only indicate that there can be some speeding up over the "normal" gait, under proper supervision, without loss of quality of planting and survival rate. A sound compromise between speed and quality of workmanship must be the objective.

Survival of Planted Trees

Methods of Determining Rate of Survival

Every agency engaging in a program of reforestation should make some systematic follow-up study of the success of the undertaking, and learn the causes for any abnormal amount of failure. This is best done by examining a selected number of trees in representative parts of the plantation, and recording those dead and if possible the cause thereof. The first examination should be made toward the end of the first growing season. This will show the trees that survived the transplanting. Subsequent examinations will be made as frequently and

for as long as the needs of the operator require. An examination two growing seasons after planting will reveal mistakes made in establishment or initial care of the plantation. By the end of the third season, barring fire, excessive rodent or deer damage, or brush competition, the degree of ultimate success of the plantation can be fairly well determined.

To make a worth-while record of mortality it is absolutely imperative to stake the trees--except in very open country free of brush, weeds, and natural seedlings. Otherwise the planted trees, or their remains, cannot be found, there will be confusion with natural seedlings, and the count will be unreliable and laborious to make. Stakes should be high enough to overtop the weeds, preferably white-tipped by dipping in paint, and driven into the ground so as not to be knocked over by deer.

The sample count can be made either on a rectangular plot or in a row. To get results for any set of conditions each sample plot or staked row should be homogeneous throughout as to site, aspect, soil, etc. To get average results for the whole project the plots or strips should be several and chosen at random or by mechanical selection. If rows are staked for observation they should run crosswise of the direction the planters took, so as to sample the work of different individuals. One hundred trees is barely enough for a single homogeneous sample. Minckler (35) advocates, at least for the eastern United States, the block-line method of plantation examination in which unstaked trees on mil-acres on random lines are counted.

Amount of Mortality

It is inevitable that there will be some mortality in forest planting. Over 95 percent survival at the end of the first year is very good and unusual. Experience shows that it runs from that to a complete loss. One agency reports a 74 percent initial survival as the average of the planting of 4 years. Either something is wrong or the planter has been very unfortunate with the weather or his trees or the site is especially unfavorable if the first-year survival is not over 70 percent. Most of the mortality that normally occurs comes in the first year, but as the records of national forest plantings abundantly show losses continue for several years. Munger (39) reports for one series of plantations a 19 percent loss in 10 years which grew to a 33 percent loss in 27 years.

Causes for Mortality

The causes for mortality are many and it is not possible to determine them in many instances. Sometimes there is a combination of causes, any one of which under other conditions would not be serious--for example, rocky soil with a heavy brush cover might be unfavorable to a certain species, while rocky soil on an open area would not be so. A full discussion of the factors affecting seedling survival is not

within the scope of this paper; the subject is covered elsewhere (24) (25) (57), but a brief recital of some of the more common causes of failure may help the project superintendent to avoid making mistakes and to overcome the hazards. Some of these causes of loss are due to mistakes in the planting plan, some to error in execution, some to vagaries of the weather, some to outside agencies, such as fire and the predations of animals which are hard to control.

Poor Workmanship. The human error of the planter in not always doing a good job of setting the trees has been discussed in a previous section.

Fire is an ever present enemy, against which the planting plan should provide adequate protection, as discussed in the chapter "Care of Plantations."

Rodents, Grazing Animals, and Insects. Depredations of animals are one of the most flagrant causes of losses and should be forestalled. See chapter "Care of Plantations."

Falling Snags and Bark. Considerable mortality and mutilation may result from the bombardment of missiles from dead trees, when planting in an old burn. This is another argument for falling snags in advance of reforestation.

Vagaries of the Weather. Sometimes a high loss is experienced from an "unusual" dry spell, late spring frost, or winter kill. Often this is the inevitable consequence of conditions that are truly unusual; sometimes it is the result of poor judgment in selecting the season for planting or from getting started too late in the season; sometimes it is the consequence of planting a species or race where it should not be planted, when failure sooner or later was foreordained. At last analysis it may be due to not fitting the planting program to the soil, altitude, aspect, and vegetative cover, factors that are discussed below.

Soil. Douglas-fir is adapted to a wide variety of soils, avoiding only very heavy clays and soils poorly drained. Some of the other species are more fastidious--alder, for example, making a good saw-timber tree only on deep, well-watered, mellow soil, and the cedars in general not doing well on light or shallow soils. Failure may follow not taking account of each species' requirements.

Mortality may be due to insufficient depth of soil. Shallow soils are subject to extreme desiccation in summer and may lack good drainage in winter. Places where there is considerable outcropping of bedrock and an absence of former tree growth should be avoided as unsuitable for planting. Some soils "heave" in frosty weather and push freshly planted trees out of the ground. This is the type of injury that may be lessened by spring planting.

Rocky soils are frequently unfavorable, partly because it is difficult to set the trees correctly. A comparison of first season survival of Douglas-fir on good soil and on rocky soil for various aspects (table 16) shows that in every instance survival on rocky soil is markedly inferior.

Table 16.--Comparison of First Season Survival of Douglas-fir on Good Soil and Rocky Soil on Various Aspects

Aspect	Survival	
	Good soil Percent	Rocky soil Percent
North	89	45
East	68	42
West	65	6
Southwest	67	26
South	62	28
Average all aspects	70	29

A test of care in planting on rocky soils showed a survival the first season of 42 percent with very careful workmanship as against 27 percent with ordinary methods, but the output was more than halved as a result. The problem then resolves itself into either adopting more care in planting on rocky soil or increasing the number of trees planted so as to achieve finally the desired stocking at the minimum cost.

On heavily burned areas the soil loses some of its water-holding capacity, becomes deficient in humus and is less hospitable to planted trees. It has been found that on heavily burned spots planted trees died for several years in succession, while all around they lived, due, it was found, to temporary changes in the colloidal structure of the severely burned soil (26). Avoidance of such spots will help to lessen the mortality rate.

The pumice soil that covers parts of the Cascade region is easy to plant in, but dries out so rapidly that initial survival is rather low. Planting in machine-made furrows in pumice soil in central Oregon has given excellent results with ponderosa pine; this suggests that a similar technique may be indicated for Douglas-fir planting in these soils.

Aspect. The direction in which the planting area faces may exert a very profound influence upon the success of planting. It determines the amount of direct sunlight and heat reaching the tree, the exposure to winds of certain directions, and as a resultant, the heat and water content of the soil.

All aspects receive sufficient light for the success of coniferous plantations, but south aspects may have an amount of direct sunlight that is actually undesirable for some species in comparison to that on north exposures. Very young seedlings are killed by super-heating of the surface soil, and this type of injury is naturally connected with aspect, but it is not thought that planted trees (whose stems are hardened and covered with a cortical layer) suffer much from direct heating. The great importance of aspect is its effect on the moisture content of the soil. Table 17, taken from a study by Hofmann,¹¹ illustrates the sharp differences in the water content of the soil at the surface and at a 6-inch depth on 3 exposures, north, south, and flat, in the Wind River Valley, Washington during the growing season.

Table 17.--Monthly Average Moisture Content of the Soil at Various Depths and Total Monthly Evaporation from Free Water Surfaces Throughout the Growing Season on Three Different Aspects Within a Burned-over Area in the Wind River Valley, Washington - Measurements Taken Weekly

Character of measurement	Aspect	May	June	July	August	September
Average monthly water content of soil, percent						
At surface	North	29.8	23.2	15.3	6.5	27.4
"	South	22.7	22.2	9.9	1.0	24.8
"	Flat	29.3	35.5	15.9	2.3	31.1
At 6-inch depth	North	23.1	25.9	23.2	17.5	26.8
"	South	27.4	21.2	18.9	11.2	28.7
"	Flat	28.9	25.7	24.0	17.4	29.4
Total monthly evaporation from free water surface, inches	North	2.0	1.6	.9	1.8	.7
	South	4.2	4.9	4.4	15.1	4.0
	Flat	3.4	3.8	3.0	6.0	2.4

It will be noted that in August when drought conditions reached their peak, the moisture content at the 6-inch depth on the south slope was only two-thirds of that on the north slope; at the surface the difference was far greater. Data are not available as to the minimum amount of moisture required to support tree growth in this particular locality, but it is obvious that the critical point was more closely approached, if not actually reached, on the south aspect than elsewhere.

^{11/} Hofmann, J. V. Success and failure of Douglas fir reforestation measured by meteorological factor. 1917. Ms.

The rate of a tree's loss of moisture by transpiration through its foliage differs between aspects; when the loss is excessive the newly planted tree may have difficulty in absorbing moisture from the soil fast enough to replace it. A fair indication of the relative rate of transpiration on various aspects is the evaporation from free water surfaces; this is also shown in table 17. In August it was 8 times greater on the south slope than on the north and in every month of the season greatest on the south aspect, least on the north and intermediate on the flat.

Many instances might be cited of the effect of the rapid evaporation and low soil moisture content of the hot aspects on plantation survival. A few of them are shown in table 18 to illustrate how important it is for the planter to take cognizance of this factor in varying species, spacing, and care in planting to fit the aspect. The first 3 comparisons are on the area for which soil moisture and evaporation data are given in table 17; survival is shown to have a very close relationship with these factors. Groups A and B of the 1913 planting suffered greatly, on the south slope only, in the second season from a prolonged drought, the same drought which caused a failure of all freshly planted trees on the south slope in the 1914 group C planting.

Aspect may also have some effect on survival because of the relative susceptibility of trees on different slopes to frost. On south slopes growth starts earlier in the spring than elsewhere and thus exposes the trees to late spring frosts. Low places, where the air stagnates, are notoriously subject to frost and are thus called "frost pockets." Here frost damage and actual frost killing may be suffered with young plants, while there is no such damage on the nearby slopes.

Vegetative Cover

On most burns in the Douglas-fir region and on cut-over areas, growth of herbaceous vegetation is very rapid after the removal of the timber. Frequently, though at a slower rate, various species of shrubs take possession of the ground. In certain respects, the presence of this vegetative cover is helpful, in other ways detrimental to initial survival and growth of young trees. It assists in checking soil erosion which when excessive may either expose the roots of the newly planted trees, or bury their tops. Its shade is beneficial in reducing loss of moisture from the soil and from the trees, and in lessening temperatures; the mulch formed by decaying vegetation assists in preserving moisture and in enriching the soil. On the other hand, the plant growth competes with the tree for light, food, and moisture, harbors rodents and impedes planting. The combined effect is usually injurious to the young trees, but to a greatly varying degree, depending upon the species represented and the density of the cover. Where an area long remains bare of vegetation after the removal of the timber, or is only scantily covered, it is a rather strong indication of poor soil or severe exposure. Such situations are usually even less favorable for planting than those supporting a luxuriant vegetative cover.

Table 18.--Effect of Aspect on Survival in Several Douglas-fir Plantations

Name of plantation	Aspect	Survival end of first year <u>Percent</u>
Warren Gap, Wind River Valley, Washington Group A ^{1/} 1913	North	97
	South	65
	Flat	100
Group B ^{1/} 1913	North	100
	South	92
	Flat	100
Group C ^{1/} 1914	North	89
	South	0
	Flat	93
Cispus #6 ^{2/}	North	97
	West	82
	South	6
Cispus #8 ^{2/}	North	96
	East	94
	South	88
Cispus, spring 1923, Group A ^{3/}	Northeast	93
	Southwest	75
Group B ^{3/}	Northeast	97
	Southwest	78
Cispus, spring 1924 ^{3/}	North	94
	Northwest	90
	Flat	80
	South	72
Lookout Mt., spring 1925 ^{3/}	North	89
	Northeast	75
	Flat	83
	East	68
	South	62
	Southwest	67
	West	65

1/ The same area as that for which hydrological data are given in table 17.

2/ Small test plantings on areas similar except in aspect.

3/ Data from counts of sample staked rows in extensive plantations.

On some areas the prevailing vegetation is herbaceous, especially fireweed and bracken, where the ground has been recently or repeatedly reburned. The hindrance that this herbaceous growth exerts to the establishment of young trees is slight in comparison to that of a shrub or "brush" cover.

In this latter category come salal and Oregon grape, evergreen shrubs that form a dense cover and in good soils become 2 or 3 feet high. Where they are abundant, planting costs are high because of the necessity for scalping an opening for each tree; otherwise survival is likely to be low. Thimbleberry, often in mixture with salmonberry, makes a dense cover along creeks and planted trees have difficulty in surviving in its shade.

An important type on older burns and logged-off lands, which have not been burned lately, is a cover of a variety of deciduous shrubs and trees, such as willow, vine maple, hazel, dogwood, elder, alder, and bigleaf maple. A less common type in the Douglas-fir region but one that constitutes a still greater hindrance to cheap or successful planting is a cover of evergreen shrubs, such as various species of ceanothus and manzanita. This is found chiefly on hot south slopes and is especially prevalent in southern Oregon. It is very persistent in the face of repeated fires.

These shrubs, like an herbaceous cover, react in contradictory ways upon planted trees. The shade cast by the brush reduces the transpiration of the planted trees and retards loss of moisture from the soil, not only by its shade but also by lessening air movement and by providing a leaf mulch. However, a brush cover may have a pronounced effect on the quantity of moisture available to the tree. During the first year or two after planting the young tree is dependent upon the moisture in the upper layers of soil, which in open areas is renewed by the upward movement of water from lower levels (24), but when brush is present this moisture is intercepted by the roots of the brush so that there is less soil moisture available to planted trees in late summer in brushy areas than in open areas.

Hofmann (21) found marked difference in air and soil temperatures and in moisture content of the soil between an area heavily covered with brush and peavine and one close by that had been artificially denuded, as table 19 shows. All through the season the air and soil at all depths were cooler in the brush and the surface soil moister in the brush, but through most of the growing season the soil at the 6- and 12-inch depths was dryer in the brush than in the open. To find out whether or not in this locality at least a moderate amount of brush does more good in sheltering and cooling seedlings and soil than it does harm in drying out the soil, mortality of trees planted in the shade and in the open on the area cited in table 19 was recorded. It was found that first year mortality was somewhat heavier in the open than in the shade on north slopes and many-fold heavier on south slopes.

After 3 seasons the mortality was about the same on the north slopes in the shade and in the open, but still was considerably heavier on the south slopes in the open.

Table 19.--Air and Soil Temperatures and Soil Moisture Content on Similar Denuded and Brush Covered Areas

(Data taken weekly and averaged by months)

Period	May	June	July	August	September
<u>Air temperature^{1/}</u>					
Surface - brush	61	59	71	87	72
Surface - denuded	72	64	85	103	76
<u>Soil temperature</u>					
Surface - brush	56	56	63	73	63
Surface - denuded	75	68	93	124	89
6" depth - brush	52	55	61	68	61
6" depth - denuded	58	62	68	79	67
12" depth - brush	51	55	60	66	61
12" depth - denuded	56	62	67	74	66
<u>Soil moisture in pct.</u>					
Surface - brush	33	32	23	11	33
Surface - denuded	11	10	4	1	13
6" depth - brush	21	27	20	13	30
6" depth - denuded	27	24	23	18	24
12" depth - brush	24	21	19	15	28
12" depth - denuded	23	26	21	20	27

^{1/} Taken at crown of 1-year-old seedlings.

Another unfavorable effect of brush on planted trees is interception of light, which becomes cumulatively more serious if the young trees do not soon overtop the brush. Douglas-fir being intolerant of shade cannot stand continuous shading. Species like western red cedar, Sitka spruce, and western hemlock are tolerant of shade and are recommended for planting in brush thickets, if other conditions are favorable for them. The evergreen shrubs, like ceanothus and manzanita, give the most serious hindrance to planted trees and these occur mostly on hot slopes in the drier parts of the region where these tolerant, moisture-loving trees should not be used. Here some method of making lanes or holes in the brush patch to accommodate the trees may be necessary, as discussed in a later section.

A brush cover has the further disadvantage that it imposes a hindrance on the planting crew, resulting in reduced speed and a tendency toward inferior workmanship. The latter affects not only immediate survival but probably causes additional losses in later years and a continuing bad effect on growth.

Brush also harbors rabbits and other animals which nip off buds, leaders, tips of branches, and sometimes the whole tree. Animal cropping is by no means limited to brush areas, but studies have indicated that it is several times more severe under brush than in the open. There is a difference in rodent activity with various types of cover. There appears to be less animal cropping under salal than under bracken, for example.

The following examples indicate the comparative survival in Douglas-fir plantations in brush and in the open. They are taken from counts of staked rows in extensive plantations on the former Rainier National Forest.

<u>Project</u>	<u>Type of cover</u>	<u>Survival percent</u>		
		1st year	2nd year	3rd year
Cispus 1924	Open	80		
	Ceanothus brush	62		
	Open	86		
	Ceanothus brush, medium	66		
	" " dense	16		
	Willow-maple brush	82		
Cispus 1921	Ceanothus	50		
	Open	-	78	-
	Ceanothus brush	81	64	61
	" "	74	63	59
	" "	-	41	-

In the conduct of a planting operation there is good opportunity for the forester to use good judgment to minimize the unfavorable effects of brush and to take advantage of its favorable effects, in the following ways:

- (1) Plant between bushes (or clumps of herbs) rather than under them.
- (2) Plant on the north side of bushes to benefit by their shade.
- (3) Where the brush cover is rather continuous, use tolerant species, suitable for the site.

- (4) If the brush is too continuous and heavy for the species to be planted, open up holes or lanes in it, possibly by using powered machines.
- (5) Burning under some conditions may be employed to reduce the cover, prior to planting.
- (6) Use vigorous, large trees when planting in brush that they may quickly overtop it.

Special Planting Problems

Farm Wood Lots and Shelterbelts

An increasing amount of tree planting is being done in the region, as well as the country over, on farms to give protection to fields and buildings from wind, to check soil erosion, and to produce wood products for domestic use. Some of this is on rough land or on non-agricultural soils where the planting problem is almost identical with that on the extensive denuded logged-off lands or burns and the techniques will be about the same. Some is on agricultural land or land that has been in crop production. Here species not suitable on forest sites may be employed and special cultural practices used, such as cultivation or fencing. Since the farmer may do much of the work himself in spare hours, more care in planting may be justified than in extensive plantings. Both Oregon and Washington have issued bulletins (13) (42) on farm tree planting and the subject need not be gone into further here. Also under the leadership of the Soil Conservation Service considerable tree planting is being done in connection with Soil Conservation Districts and demonstration projects, and considerable written on the subject (49).

Farm wood lot planting has possibilities for using some of the specialty hardwoods, not considered suitable for planting on forest soils. The direct seeding of black walnut has been proposed and tried, for example. Cascara plantations have been established as a good use of idle farm acres. The growing of holly falls in the category of arboriculture rather than forestry.

Sand Dunes

Along parts of the Oregon Coast is a strip of moving sand dunes, that are both a menace to adjoining farms, forests, harbors, and transportation routes and a wastage of considerable land. The control of these dunes by afforestation is highly desirable but expensive, for it must be preceded by grass planting. The most work in this field has been by the Soil Conservation Service. The results of tests of various species and techniques have been described recently in print (34) so that this very specialized phase of planting need not be described further here.

Christmas Tree Plantations

The proposal is frequently made that Christmas trees be grown in the region as a crop as they are elsewhere, instead of following the present practice of robbing logged-off land of its natural reproduction. So far only a little planting for this purpose has been done. If and when the practice is found to be economic on a large scale the procedure should be somewhat different from that employed in planting for timber production. It is quite important to make Christmas tree plantations on land fairly free of brush and rank weeds and ferns and to keep it free so that the limbs of the prospective Christmas trees will be full foliaged and not subjected to shading or mechanical interference by competing vegetation.

The site for growing Douglas-fir Christmas trees ought to be rather poor that growth may be slow, the annual whorls of branches close together, and the tree have a "bushy" appearance. If small sized trees are to be grown a spacing less than customary for forest planting may be employed, perhaps 6 feet by 6 feet.

Brush Fields

The so-called brush fields, that are prevalent in the southern Oregon Cascade and Siskiyou Mountains, and are still more extensive in northern California, are a special problem for the forest planter. Such areas are covered by an almost continuous canopy of evergreen and often thorny bushes 4 to 6 feet high. They are both difficult for the planter to traverse and for planted trees to penetrate, unless holes or lanes in the brush cover are cut in advance. It is generally conceded that planting in these brush fields is futile without prior preparation.

A practice widely used in northern California and to a less extent in southern Oregon is to clear lanes with tractors equipped with some type of "brush-busting" device. Two types are used--those dragged behind a crawler tractor and those attached to the front of a tractor. Both types have advocates. In the former class a V-shaped plow or drag has found favor. A special type has been devised in California called the "Plumas brush stripper." This V-shaped drag, with a single ripping tooth in front, a gooseneck draw bar and cable hoist in front, and two small wheels in the rear, clears a strip 6 feet wide. The pushing type of equipment that has given satisfaction is a V-blade brush-buster unit mounted like a bulldozer on the front of a 35 or 55 h. p. tractor.

With either type of equipment it may be necessary to go over the lane a second time to prepare the strip satisfactorily for planting. These machines are said to clear 3 or 4 miles of lane per day.

Since it is necessary to leave at least 8 feet between the cleared lanes, and the lanes are 6 to 8 feet wide, the centers of the lanes are 14 to 20 feet apart. This necessitates spacing the trees

wider in one direction than ideal. Construction of planting lanes in brush fields has been done at a cost of \$9 per acre, prewar basis.

The intentional burning over of brush fields as a preliminary to planting has been employed, though this practice is attended with considerable risk even when considerable money is spent in fire-line construction and control of burning. The burning may or may not be followed by construction of lanes with brush-busting machinery.

The rodents in brush fields are an additional obstacle to successful planting and their numbers are not reduced but on the contrary may be increased by the lane construction. The execution of planting in competition with brush or other vegetation is discussed in a previous section.

The balsam firs (*Abies* spp.) make such attractive Christmas trees and are so popular that it may be more profitable to plant one of these species than Douglas-fir. If any of the balsam firs are used the site must be appropriate for it, i.e., not hot or dry. Whether or not the long winter of the mountains is necessary for successful large-scale growing of noble fir and Shasta red fir has not been proven.

Planting for Scenic Effects

Planting of forest trees is sometimes done for scenic effect, or as a phase of national defense for camouflage purposes. Trees may be planted to improve the attractiveness of campgrounds, for the naturalization of highways, to screen developments, to shade roads, or for other such purposes where scenic effect rather than timber production is the goal. This may involve using a variety of species, even exotics, and large stock. This is a specialty in itself not within the scope of this bulletin but covered in publications on landscaping, recreational forestry, and camouflage.

The planting of roadsides that traverse unsightly logged-off land is sometimes done largely for aesthetic reasons, but it also helps toward another purpose--the better control of fire; a belt of densely grown young trees will in a short time shade out the roadside weeds and brush and so lessen the hazard of fire along the highway.

Alder Firebreaks

The planting of strips of alder in coniferous plantations for fire-retardent purposes has been mentioned in an earlier section. This has been done in several cases on both national forest and private lands. The effectiveness of such strips will naturally vary with circumstances, but there is already evidence that a good strip of alder, either planted or natural, when in foliage, will slow down or stop a surface fire. Such strips should be planted where alder can be expected to make rapid growth, i.e., on deep-soiled, well-watered hillsides, on the margins of creeks, and in draws, and only at the lower altitudes in the more humid portions of the region. The spacing of the

trees should be rather close, 6 feet by 6 feet is suggested; 1-year-old stock may be used; a strip to be effective should be at least 200 feet wide. The strips should be located so as to be most helpful in partitioning off a logged and deforested area for better control of fire.

Abandoned Fields. There is likely to be little planting of abandoned fields in this region, though occasionally a piece of farm land, which is too steep or too worn out for agriculture may be so returned to forest production. Here it will usually be necessary to remove sod competition by plowing furrows in which the trees are planted or digging a good sized hole in the sod for the placement of each tree. If the field to be planted is frequented by domestic animals or deer, protection of the trees by fencing may be desirable.

Partial Coverage of Large Deforested Areas. It has sometimes been proposed that, when there are very large areas in need of reforestation (like the Yacolt burn, the Tillamook burn, or some of the great tracts of deforested logged-off land), yet funds for their complete planting are not in sight, it would be advantageous to plant only strips or groups of trees at stated intervals and at strategic places for dissemination of seed, in the expectation that the intervening areas would seed up eventually, and the planted strips would meanwhile serve as firebreaks. This may be a sound policy in places, especially where productivity is low and immediate reforestation is not important. It has been practiced on the national forests in a limited way, with about a 50 percent coverage. One objection is that the intervening areas are likely to grow up to brush and make difficult natural regeneration. Also, unless the strips are very close together the natural regeneration that filters in from the seed cast by the planted trees is likely to be widespread and uneven-aged and, therefore, make a poor quality forest. Strip planting is obviously more expensive per acre than complete coverage.

Erosion Control and Water Conservation

Planting may sometimes be done on forest lands, as well as on farms, primarily to stop or forestall erosion and to conserve the water supply. Such planting may employ species that are suitable for these purposes rather than for timber production. The planting may not be continuous but concentrated in gullies or places likely to erode. Highway cuts and embankments in mountainous country create problems of this category which call for planting of trees, shrubs, and even vines.

In places in the high mountains a protection forest rather than a timber-producing forest may be the objective, and the planting of only certain slopes indicated.

River banks subject to cutting and riparian lands subject to overflow are sometimes planted to willows, cottonwoods, or other water-tolerant trees as one means of stabilizing the land.

On the margins of reservoirs and rivers furnishing domestic water it is desirable to have conifers rather than alder or other broadleaf deciduous trees and this sometimes affords another special problem for the tree planter.

Costs and Records of Field Planting

The cost of planting in the Douglas-fir region is bound to be high in comparison to costs in regions where machine planting can be done, where the topography and cover are very favorable, or where labor is cheap. The elements of cost are several and each can vary through a considerable range. While on the basis of a 50 cents an hour wage planting is likely to cost from \$8 to \$10 per acre, it is conceivable that it could cost twice that under difficult conditions or a dollar or two less under favorable conditions. Hoffman (20) in 1941 assumes that "where nursery facilities will be operated on a basis of large-scale production at a minimum cost" the expense of planting cut-over lands with 8 x 8 foot spacing will be \$6.

The principal factors of cost are:

Cost of Stock. The big nurseries with the wage rates of recent years are able to produce 2-0 Douglas-fir trees for about \$4 per thousand. In small nurseries the actual cost is likely to be higher. The States, under the terms of the Clarke-McNary law which provides sale to farmers at cost, charge a flat \$2.50 per thousand for all forest planting stock. Transplanted stock is likely to cost a dollar more than seedlings; some species cost more than Douglas-fir.

Preliminary Examination and Site Preparation. Mapping and preparation of the planting plan costs from 5 to 20 cents per acre, depending on its intensity. Site preparation may be nothing or be very expensive. If snag falling, fire-line construction, road or trail building, or brush eradication are involved an expense of several dollars an acre might be necessary to insure a successful plantation. Some of these items might be charged against forest protection rather than the planting project. On the average project the total cost of this preliminary work is likely to be under \$1 per acre.

Transportation. Shipping trees and supplies and transporting laborers to the planting job may be quite an item in inaccessible projects, or it may be inconsequential where trucks are used and the distance is short. On some national forest projects where pack horses had to be used transportation charges were material.

Planting. If a planter can set out 350 to 900 trees per 8-hour day, at a 50 cents an hour wage, the actual labor cost of planting would be from \$11.43 to \$4.44 per thousand trees or about \$6.67 per thousand trees for a typical speed of 600 trees per man-day. At this rate the labor charge for planting an acre with 8 x 8 foot spacing would be \$4.54. Adding 10 percent for supervision and nearly as much for industrial insurance, social security, depreciation on tools and

equipment, and other incidentals, a very rough average cost for the planting process itself would be between \$5 and \$5.50 per acre. If the spacing were closer, the speed of the planters slower, or the supervision needed were more the cost might well be considerably greater.

Total First Cost. The sum of the mean of these approximations under favorable conditions and a 50 cents an hour wage rate indicates a total cost of about \$8 per acre for reforestation with 2-0 Douglas-fir where there are no expenses out of the ordinary.

This approximation for average hypothetical conditions is perhaps more informative than would be citations of costs on actual projects, where there are so many local conditions, extenuating circumstances, and bookkeeping practices that would have to be understood. For example, the reported cost of national forest projects for the 5-year period 1935-39 averaged \$8.79 per acre, but ranged from over \$20 for small experimental projects to a low of \$7.76 per acre. On some of these projects CCC labor was used which was charged up at the rate of \$1.50 per 6-hour day and board.

Replanting. The above paragraphs consider only the first cost of planting. If the planting is not successful and parts of the project have to be replanted that raises the cost per acre; the true index for fixing cost is really the acreage successfully planted. In national forest experience about 15 percent of the acreage planted is listed for replanting. It is thought safe to assume a probable need for about this much replanting, but with better forest protection, increased experience, and on sites better than the average of those on the national forests the losses may be less.

Of this loss about two-thirds have been on account of fire and the other third because of poor survival. The fact that only 15 percent of the national forest plantations are classed as in need of replanting does not imply that the remaining 85 percent are satisfactorily stocked. Intensive forest management would dictate the replanting and filling of a considerably larger acreage to attain satisfactory stocking where, on the basis of past experience, survival has been only mediocre.

Records

As in the conduct of any business enterprise it is well to keep records of what has been done, what it cost, and what are the results.

Foremen should keep each day, in addition to the usual time slip of each man's work, a record of the number of trees planted, the area planted, and the weather. These daily reports should be compiled by the project superintendent so that at the end of the season he can summarize the accomplishments in map and text form as a supplement and follow-up of the planting plan. It is suggested that the following matters should be covered:

A project map showing separately for each species class of stock, spacing, and the area planted.

A tabulation of the above data.

A description of the method of planting used, of the seed source and character of the planting stock, the class of labor, weather conditions during the job, etc.

A record of costs broken down by classes, such as cost of stock, transportation, labor for planting, supervision, site preparation, etc., to meet the accounting and record demands of the operator.

CHAPTER 5. CARE OF PLANTATIONS

It is useless to attempt reforestation by planting or sowing unless the young trees can be given the care necessary for their survival and development into a fully-stocked stand. In an earlier chapter the importance is stressed of selecting for reforestation only sites that are reasonably safe for the young trees or can be made safe. Granting that this has been done, young trees have certain enemies which thereafter must be controlled. In the Douglas-fir region the factors unfavorable to newly established plantations, other than soil and weather conditions which cannot be altered, are fire, rodents, grazing animals, diseases, insects, falling snags, and competing vegetation.

Protection From Fire

All forest lands in the region under consideration are given protection from fire by one of the forest protection agencies. Logged-off lands and burns, such as are likely to be planted, are many times more hazardous than virgin timber or well-established immature timber. They require extra intensive protection, not only because of their susceptibility to fire, but also to safeguard the investment made in their establishment. Emphasis should be on preventing fires from starting, but there must also be transportation facilities, an intensive detection and communication system, and a well equipped fire-suppression organization on hand during the whole of the dry season. It is assumed that the plantation will be so laid out that there will be natural or constructed firebreaks to help in confining a fire to a single compartment. These are especially necessary if all the snags have not been felled. The protection of the logged-off land of this region has been highly developed and so fully described by others (40) (64) (65) that it need not be discussed here in detail.

Rodents

Rodents are very serious enemies to plantations in this region. It has been truly said that without the control of rodents where they are plentiful, planting is futile. Mice destroy freshly germinated seedlings and so are enemies of direct seeding; they are not considered serious to trees 2 years or older. The archenemies of plantations in the Douglas-fir region are the brush rabbit, the snowshoe hares, and the mountain beaver, or "boomer," the last particularly in the Coast Range.

These animals bite off the twigs or main stem or both for food; if a Douglas-fir is not severed too close to the ground it may sprout other twigs and survive. Some trees are cropped repeatedly year after year, developing a stunted bushy form. Damage by rabbits is limited by the reach of the animal. If a tree succeeds in getting its terminal above this height it is safe from this enemy. Mountain beaver on the other hand climb saplings up to 10 or 12 feet high and cut off the twigs and so may kill trees of this size (plate XX).

Evidence is ample of the damage done; 40 percent of the trees were cropped in 3 weeks after planting on one Crown Willamette Paper Company plantation, 95 percent were cropped in a year on one of the Long-Bell Lumber Company plantations (36). On national forest plantations cropping of over 50 percent of the trees is not unusual, and losses from this cause of over 25 percent have been recorded.

Rodents seem to have a peculiar predilection for planted trees. When natural seedlings are present planted trees are cropped more severely for reasons that are not apparent. Port Orford white-cedar and western redcedar seem to enjoy more immunity from rodent depredations than the other species commonly planted. Where trees are set out in bare, freshly burned areas they are more subject to cropping because of the absence of other food, especially in the winter, in proportion to the rodent population. However, burning is thought to reduce temporarily the rodent population. Of course, as logged-off areas become brushier with time the rabbit population is likely to increase. Gophers and moles do some damage by uprooting planted trees in their burrowing activities. Gophers and pack rats are also among the gnawing enemies of young trees. Occasionally porcupine damage occurs, but it is not nearly as serious as in the ponderosa pine region.

Methods of Control. ^{12/} Measures for the control of rodent pests may be of 3 kinds:(1)Coating the trees to be planted (or the seed to be sown) with a poison or a deterrent, (2) spreading poisoned bait for the predators over the area prior to planting, and (3) fostering indirect means of control, such as encouraging the presence of the natural enemies of the rodents.

12/ Detailed instructions for the control of animal pests may be had from the Rodent Control Division of the Fish & Wildlife Service at Seattle, Washington or Portland, Oregon.

Coating the Trees Before Planting. Much research has been done by the Fish and Wildlife Service and many planting tests made by the Forest Service and other agencies with preparations put on the trees to deter rodents from touching them. No preparation has yet been found that is fully effective under all conditions, at all seasons, for any of these pests. Research in this field is still in progress. The most promising treatment for the control of rabbits and hares used in this region is a coating of strychnine and it is the practice of the Forest Service to use it on certain projects.

The method of application is as follows: Just before the trees are dug from the nursery beds for packing and shipment, spray them, using an ordinary paint sprayer, with a solution made up of:

7½ oz. strychnine alkaloid (by weight)
12 oz. Rezyl #53 solution (by volume)
48 oz. technical chloroform (by volume)
½ oz. flake aluminum (by weight)^{13/}

To mix these ingredients dissolve the strychnine alkaloid in the chloroform; warm and add Rezyl solution. Just before spraying add flaked aluminum and stir. The Rezyl #53 solution is made by combining 1 part by volume of Rezyl #53 with 2 parts by volume of technical chloroform. This recipe will make enough spray to coat about 13,000 seedlings. Precautions necessary in handling strychnine should be observed by all who do the spraying.

Reports of the use of this spray are conflicting and inconclusive. Its effectiveness as a poison seems to be gone by the time the new growth appears for it does not seem to deter rabbits and mountain beavers from gnawing the new growth; damage by these animals often continues for several years after planting. Painting the tree stems with an asphalt emulsion is another repellent treatment still in the experimental stage. Partly covering the freshly planted tree with a bit of dry bracken or weeds, as a means of concealing it from mountain beaver, has been suggested in a previous section.

Poisoned Baits. Much experimenting has been done with preparations to eliminate rabbits and hares, but so far none has given satisfactory results. These animals in the wild do not take baits well. Likewise, mountain beaver at some seasons do not take poisoned bait readily, but greatest success on an experimental basis has been had with sliced apples coated with strychnine powder. This must be placed in the beavers' burrows. Feeding unpoisoned apples for a few days in advance may make the animals take the poisoned bait better. The cost of the preparation is minor; the labor of seeking out all burrows may vary from a few minutes to an hour or two per acre. Ordinarily only a part of a planting project, where the mountain beaver are concentrated, requires treatment.

^{13/} As a substitute for aluminum flakes, to color the spray, benzol soluble red may be used.

Trapping and Shooting. Rodent control by trapping or shooting is too expensive to be practiced except in special cases unless the hides or meat are a compensation to hunters.

Indirect Means of Control. The inordinate abundance of small rodents is often the result of upsetting the biological balance, by exterminating the coyotes, foxes, weasels, bobcats, etc. If these latter animals are allowed to increase the rodent problem will be helped. Certainly on areas to be planted or freshly planted, there should be no encouragement to trapping or hunting these rodent predators, unless this is necessary for local economic reasons. On the other hand the taking of rabbits and hares should be encouraged.

Aldous (1) calls attention to the cycle (about 10 years) in the snowshoe hare population and recommends, for the Lake States at least, that "during periods of high hare population plantings should be confined to open sites" and that "areas in low brush cover should be planted only during the low part of the hare cycle." Planters may well appraise in advance the status of rodent activity and act accordingly.

Grazing and Other Animals

Deer, elk, and domestic animals are all rather destructive to plantations. In natural stands their depredations pass unnoticed, but in plantations where the number of trees is small the damage is concentrated; furthermore, deer, like rodents, seem to have a special fondness for planted trees. Deer and elk browse the foliage often deforming a small tree by taking the leaders; they also debark and girdle many trees by rubbing with their horns. It would, therefore, be undesirable to prohibit hunting in season of game animals on areas to be planted or recently planted, but rather to encourage it, unless closure is necessary on account of the fire hazard.

Sheep and cattle grazing are increasingly being practiced on logged-off lands of the region which are dedicated to forest production, meaning those which have not been sown with grass seed. The trampling of these animals, quite apart from their occasional browsing of planted trees is quite undesirable. Exclusion of domestic grazing stock from plantations for at least 2 years after planting is recommended, but pre-planting grazing may help to lessen the competition of brush and weeds.

The extensive plantations on Mt. Hebo, Siuslaw National Forest, suffered materially after the trees were 8 to 12 inches in diameter by having bark stripped from their bases, sometimes completely girdling the tree--probably the work of black bears (36). Grouse should also be mentioned as an enemy to plantations because of their propensity for biting off terminal buds. In British Columbia their activities have been lessened by spraying the trees before planting with a red coloring matter.

Diseases

Plantations are somewhat more susceptible to parasitic diseases of the roots, foliage, and stems than natural seedlings. This is due partly to using the progeny of seed not adapted to the locality. On the extensive Mt. Hebo (Siuslaw National Forest) plantations, as well as elsewhere, there has been at times an unwanted amount of needle blight. This is usually not fatal, but inhibits growth temporarily. There is considerable fluctuation from year to year in needle blight and endemic canker diseases, apparently associated with weather conditions. Root rots occasionally kill single trees or groups in plantations, even more than in natural stands, this damage probably being aggravated by the injury of roots in transplanting.

There are no known practicable remedies for these endemic diseases and the only preventives are to avoid using stock grown from seed from a dissimilar climate and site, to practice good hygiene in the nursery so that diseases will not become established on the planting site, and to avoid abraiding the small trees.

In reforesting with any of the 5-needle pines (a practice not recommended) care must be taken that the stock comes from a nursery that is free of white pine blister rust and that all specimens of currants and gooseberries have been eradicated from the planting site and kept eradicated.

Insects

Douglas-fir plantations have been singularly free from serious insect damage. Certain endemic insects (28) do some damage on both planted and natural stands for which, however, there seems to be no known practicable preventive. The Douglas-fir twig weevil (16) kills occasional trees, especially open-grown trees on dry sites. Cooley's gall aphid is conspicuous in different stages of its life cycle in causing severe needle cast on Douglas-fir and disfiguring galls on the twig terminals of Sitka spruce. The Sitka spruce weevil is very prevalent and damaging on open-grown Sitka spruce saplings. Since this pest is not active in dense stands, planting spruce so that it will quickly form a dense cover, as with alder, may lessen the injury. The spruce aphid has been destructive in killing both young and old trees in natural stands, but is less likely to be harmful to open-grown trees in plantations.

Falling Snags

In old burns, and to a much less extent in logged-off land, there is considerable threat to the planted trees from falling snags and from bark and limbs falling from dead trees. Many seedlings are covered up or mutilated this way. The obvious remedy is to fall snags in advance of planting or to avoid "snag patches" for this reason as well as on account of the fire hazard.

Competing Vegetation

In most parts of the Douglas-fir region a very rank growth of herbs or woody shrubs or both develops rapidly after logging or after forest fires. The necessity for taking account of this competing vegetation in selecting the planting project, in pre-planting brush eradication by machinery, possibly in burning off the accumulated vegetation before planting, and in selecting the right spots for setting the trees has been discussed in earlier sections.

Many plantations would be benefited by the removal of competing vegetation 2 or 3 years after planting, but the expense has always been a bar to so doing with economic justification, except on a few experimental plantations. Herbaceous growth, like bracken fern, fireweed, and senecio are not considered fatal to well-planted trees, though a dense mass of such weeds may inhibit growth for a few seasons. The really fatal competition of Douglas-fir plantations are the patches of woody shrubs, like hazel, vine maple, willow, thimbleberry, salmonberry, ceanothus, manzanita, and salal that quickly occupy logged-off lands and old burns and make a continuous cover several feet high. Release of planted trees from such competition by chopping down the shrubs would cost several dollars an acre but might be justified with a reasonable wage rate to save a plantation.

Planting Failed Places

Where there is an inordinate loss of planted trees the first year or two, especially if it occurs in patches so as to bring about poor distribution of the survivors, replanting of the failed places may be very desirable. A thin stand or one with poorly distributed trees is slow to make a forest cover, results in poor quality and less timber, and costs as much or more to protect and bring to maturity as a full stand. Replanting should be done with the minimum of delay and with stock which is as near the size of the already planted trees as possible. Replanting is, of course, useless if the cause of the initial loss is still present, rodents for example.

Cultural Treatment

Other than the protection and care discussed above, plantations of conifers need no cultural treatment until they are ready for pruning, a treatment that is necessary to produce high-grade lumber in a short rotation. It may be economically justified in wide-spaced plantings, when labor cost is low. This practice, which would not start ordinarily until a stand is 25 to 35 years old, is not within the scope of this bulletin.

Thinning will generally not be practiced with plantations until there is salable material like poles, piling, or pulpwood to harvest. The cutting of Christmas trees from forest plantations is not thought desirable, though plantations might be made primarily for this purpose. Where a heavy stocking follows seed spot sowing a thinning may be necessary when the trees are 3 or 4 feet high to release overcrowded clumps.

CHAPTER 6. DIRECT SEEDING

Introduction

A method of artificial reforestation which has been employed to some extent in this region and in other parts of this country and in Europe is direct seeding. By this method the seed itself is sown on the land in need of reforestation, either by broadcasting it over the entire area or by seeding portions of the area at intervals either in spots or strips prepared for the purpose. Toumey and Korstian have said: "The history of artificial regeneration shows that direct seeding is the rule and planting the exception in the early development of forestry in every country. Direct seeding finally gives way to planting" (57). This has been the history in the Pacific Northwest.

In the period 1908 to 1913 the Forest Service seeded over 12,000 acres on many different deforested areas in the Douglas-fir region¹⁴; some were extensive areas where large-scale operations could be tested; some were small experimental areas upon which contrasting methods were studied closely. Direct seeding has also been practiced in British Columbia and by a few lumber companies in western Washington and Oregon.

The results with Douglas-fir seed have on the whole been unsatisfactory. Occasionally acceptable stocking has been obtained at reasonable cost. More often a very sparse, poorly distributed stocking of seedlings has resulted and sometimes complete failure. Failures were due largely to rodent destruction of the seed and to high mortality of the very young seedlings. Many different techniques were tried in order to overcome the unfavorable factors, and discover effective and dependable procedures but without much success. Accordingly, the Forest Service abandoned direct seeding as a method of extensive reforestation in the Douglas-fir region in favor of planting, though some research has been continued in this field.

Although direct seeding is not being recommended as a generally desirable method of reforestation for this region--at least until methods are discovered for assuring adequate stocking at costs comparable to those of planting--it seems appropriate to present briefly the techniques of direct seeding and some of the results of past experience and to point out some of its advantages, disadvantages, and possibilities.

Advantages and Disadvantages of Direct Seeding

Direct seeding has certain theoretical inherent advantages and also certain disadvantages, in comparison to planting, of rather universal application, which should be mentioned.

Its advantages are:

¹⁴/ Kummel, J. F. Direct seeding of Douglas fir on the national forests in the Douglas fir region. Ms. January 17, 1930.

- (a) The young trees do not have distorted or mutilated roots as planted trees are likely to have, but start in a natural position.
- (b) There is less likelihood of attack by parasitic diseases and insects than with trees grown in mass in nurseries.
- (c) A reforestation program can be more elastic, not having to depend on the production of nursery trees that take 2 or more years to grow.
- (d) The capital investment in a nursery is avoided.
- (e) Less labor is required, and if seed is cheap, this method should be cheaper, where unfavorable factors can be controlled.

The inherent disadvantages of direct seeding are:

- (a) Mortality of unintended seedlings during the first season is very high, and sowings that result in adequate germination may be failures if the first summer is hot and dry. Where planting is practiced the nursery-grown trees are not set out until they have passed their most tender initial stage.
- (b) Seedlings from direct sowing have a 2 years' disadvantage in competing with brush and the usual rank vegetation on deforested areas in comparison to 2-year-old planted trees.
- (c) By planting 2-year-old trees, time is gained toward the final harvest in comparison to direct seeding, assuming that planted trees make as good growth as trees coming direct from seed, which, however is not assured. This probable gain in realizable growth may alone justify spending more for planting, than for seeding.
- (d) The enemies and factors unfavorable to direct seeding are more numerous, more destructive, more difficult of control, and more unpredictable than those affecting plantations; hence, the results of direct seeding are bound to be more uncertain and more erratic than the results of planting, necessitating a larger margin for safety or for replacements.
- (e) Seeding is apt to result in too dense or too thin a stand and is almost sure to give poorer distribution

and, therefore, slower complete closing of the canopy than planting; especially the bunching of seedlings following seed spotting, where several trees occupy a spot, is considered undesirable (plate XXI).

Methods of Direct Seeding

There are two distinct methods of direct seeding--broadcast sowing and partial sowing in spots, strips, or holes. The former consists of scattering the seed broadcast as the gardener sows his lawn seed. The latter involves sowing the seeds on parts of the area at selected intervals prepared for the purpose.

Broadcast Sowing. The broadcast sowing of coniferous seed may be done by hand, by the use of a hand seeding machine, or by airplane. When done by hand or with the use of a machine, the crew lines up as in a planting job and systematically gridirons the area, taking pains to make the maximum coverage without overlap or skips. A man sowing Douglas-fir seed can cover by hand a strip about 22 feet wide; with small seeded species (cedar, spruce, hemlock, and alder) a blower-type machine will sow a strip about 15 feet wide, a little more for the spruce and hemlock and a little less for the cedar; this is wider than can be done by hand.

Airplanes have been used successfully to sow grass seed on extensive areas of wild land in this region and, in a small experimental way, in the sowing of small tree seed. On large projects of suitable terrain the cost of airplane sowing is very little; were any broadcast seeding practicable this might be a good way to do the work.

In a series of broadcast sowing tests on a favorable fresh burn in the Coast Range in 1937, comparing 5 species, the following number of seedlings were alive at the end of the first season for each pound of seed sown: Sitka spruce 219, Douglas-fir 275, western hemlock 425, Port Orford white-cedar 916, and western redcedar 1,000. After 5 growing seasons very few seedlings of the first 3 species were living, but there was a satisfactory restocking of the Port Orford white-cedar and western redcedar.

The amount of seed advisable for broadcast sowing depends upon conditions on the area to be regenerated, the germination probabilities, and the cost of the seed. Obviously the cost of the seed must not exceed the cost of reforestation by other means. So much seed is consumed by birds and rodents and so much falls on stones, logs, and thickets where germination is impossible that Isaac (25) calculates that on the average there ought to be 355 naturally disseminated seeds to assure an established seedling. This would theoretically imply 8 pounds of seed per acre of Douglas-fir--more on unfavorable sites, less where conditions were advantageous. In the broadcast sowing operations on the national forests it was the practice to use from 2 to 4 pounds

of Douglas-fir seed per acre; some of these sowings were successful, most of them were not. Toumey and Korstian (57) recommend 6 to 12 pounds of Douglas-fir seed per acre, an amount that at prevailing prices would make this method economically impracticable.

In Europe, according to the above authority, where seed is cheap, very large amounts of seed are prescribed to assure success--for example, $3\frac{1}{2}$ to 13 pounds per acre of spruce, 5 to 9 pounds of Scotch pine, $4\frac{1}{2}$ to 62 pounds of silver fir.

The labor cost of broadcasting by hand or hand machine is a small item, for a man can cover an acre of ordinary hilly logged-off land or old burns in less than an hour.

In some regions broadcast sowing is preceded by machine preparation of the tract or the seed is worked into the ground by subsequent dragging the area with harrow or brush. This has been done in a small experimental way in western Oregon, but most of the lands in need of reforestation in the Douglas-fir region are not susceptible of harrowing or dragging with power machinery or the cost would be prohibitive. Where machine preparation of the land is practiced the sowing would usually be in strips thus saving in cost of labor and seed.

Using a common wage rate of 50 cents per hour and a low seed cost, \$2.25 per pound, the actual cost of broadcast sowing, exclusive of rodent control, assuming only 6 pounds of seed per acre, would be about \$14 for each acre covered. The real index of cost is the expense for each acre satisfactorily stocked. If the 6 pounds of seed do not result in adequate stocking the true cost might be much more than this.

Seed Spot Sowing. The principal method of partial sowing tried or likely to be employed in this region is seed spot sowing. This is done by a crew, lined up as in a planting project, which systematically gridiron the tract and sows a few seeds in spots at stated intervals. The usual tools are either a hazel hoe, a grub hoe, a heavy rake, or merely a well-calked boot. In most deforested areas of this region a broad-bladed hazel hoe is the preferred tool; a rake is good only where the surface is free of vegetation and debris; the foot with a heavy boot can be used with rapidity when the surface is clear and the soil loose. The purpose of making the seed spots with hazel hoe or grub hoe is to remove vegetation and litter that might interfere with the young tree seedlings.

The procedure is as follows: Select a spot reasonably free of brush, debris, and rocks and with apparently a normal soil, and with 2 or 3 strokes scalp the surface to cut off competing vegetation and remove litter, but not the humus layer. Then with another stroke or two loosen and stir up the top 3 or 4 inches of soil to make the seed bed. In some soils this may be unnecessary and actually undesirable. A measured quantity of seed, taken from a sack carried over the shoulder, is then sprinkled on the spot, covered with about one-quarter inch of soil,



PLATE XXI. Seed spot sowing done in 1910 on the Mt. Hebo project, Siuslaw National Forest, illustrating the clump-wise distribution of the trees and their small size in comparison to the single planted trees in an adjoining plantation, Plate III-B. The tree in the right foreground is of the 1912 planting.

and pressed with the foot. The spot so prepared should be, on the average, about 8 to 12 inches square. Larger spots may be unfavorable in unduly exposing the germinating seedlings to sun, while too small spots will subject the seedlings to root and top competition.

A corn planter type of hand drill has been recommended and used to some extent in the direct seeding of the larger tree seeds. It has the advantage of being a very cheap method of partial sowing. The desired number of seeds is dropped in a small hole made by the machine. Since this method provides no prepared spot or germination bed it is not desirable where this is necessary for the survival of the seedlings. The fact that the seeds are all bunched in a small hole is also disadvantageous in comparison to scattering them over a square foot of surface as with hazel hoe seed spotting.

Concerning the placement and spacing of seed spots, it was found by Schenstrom (50) in British Columbia that seed spots shaded on the north had over 4 times the number of established seedlings as those with no shade. Likewise Isaac (25) in studies of natural reproduction in Oregon and Washington has pointed out the important role of "dead shade," i.e., the shade of logs, stumps, etc. Care to place the spots where they will be shaded from the midday and afternoon sun as well as have good soil is well worth-while.

The spacing of the seed spots should usually be closer than in a planting project to get comparable quick and uniform coverage. Six by six foot spacing was used in much of the early seed spot sowing on the national forests, and is recommended as standard for the Douglas-fir region.

The number of seeds per spot must be enough to allow for the inevitable depredations by rodents and the mortality of the young seedlings, so far as these unfavorable factors can be predicted. There were tried on national forest projects all the way from 5 or 10 seeds per spot to 30 or 45; the usual quantity was 20 or 30 Douglas-fir seeds per spot with a 6 x 6 spacing or about .9 pound per acre. It was found that increasing the number of seeds per spot did not increase proportionately the number of seedlings; instead it increased the proportion of seeds eaten by predators. Increasing the number of seeds per spot threefold from 10 or 15 to 30 or 45 only increased the number of seedlings 60 percent.

In order to lessen the depredations of rodents it has sometimes been the practice to spread poisoned bait which mice would take or to coat the seed with a poison or repellent. Pre-poisoning over the area increases the chances for a catch of seedlings but adds to the cost; a coating for the seed that repels all rodents without affecting germination has not yet been found for Douglas-fir. Wire screens to protect seed spots against rodents and birds, while used in small experimental tests, are too costly for general use.

It has been surmised that the bunching of several seedlings in a single spot, following successful germination and survival, was undesirable; it might inhibit growth and might give a basal twist to the trees on the outside of the clump (plate XXI). But Garman^{15/} found that 9 years after seed spot sowing the larger the number of seedlings per spot up to 9 the taller was the best seedling of the clump. It is known, however, that an excess number of trees per acre after a certain age is undesirable and this is something that is likely to be attained by direct seeding, but not by planting.

On extensive projects on the Mt. Hood and Siuslaw National Forests in 1912 the cost per acre sown (at 6 x 6 foot spacing) was from \$4.44 to \$5.14 per acre when the seed cost was \$1.49 per pound, the common wage rate was about 30 cents per hour, and the poison cost averaged 16 cents. At a 50 cents per hour wage rate and a seed cost of \$2.25 per pound, the total expense of seed spot sowing would have been about \$7.70 per acre covered; since much of this work was unsuccessful the cost per acre stocked would be much higher.

Season for Direct Seeding

Both broadcasting and seed spotting can be done any time that ground conditions are right between the first heavy fall rains and the commencement of growth in the spring. At the higher elevations snow would, of course, prevent mid-winter sowing and might delay it until too late in the spring. The earlier the sowing is done the longer the seed lies exposed to depredations by mice that are active all winter, but the longer the time it has to be worked into close contact with the soil by the action of rain. In 4 paired tests, spots screened from animals produced several times as many seedlings when fall sown as when spring sown. A disadvantage of spring sowing Douglas-fir is that less of the seed germinates than with fall sowing. This trouble might be lessened by using pre-treated seed. The treatment might consist in stratifying the seed in moist sand at a temperature of 35-40° for 2 weeks or more, wetting it and putting it in near-freezing cold storage, or merely soaking it in cold water for a few days.

Moss^{16/} proposes in direct seeding of western white pine using vernalized seed, as is done with some agricultural crops.

Good results have obtained in an instance or two where a fall sowing was immediately covered with a snow blanket that remained until spring, a condition that is not easy to meet. There seems to be no question but that if the animal factor is controlled fall or winter are better seasons for sowing conifer seed than spring. In fall or winter sowing the seed is brought into close contact with the soil through

^{15/} Garman, E. H. Direct seeding of Douglas-fir. British Columbia Forest Branch. Ms. 1943.

^{16/} Moss, Virgil D. Preliminary report on use of germinated seed as a method of reforestation for western white pine. U. S. Bur. of Entomology & Plant Quarantine, Div. of Plant Disease Control. Mimeo. 1943. Berkeley, Cal.

action of rain and snow, has time to absorb moisture and so be ready to germinate with the first warm weather and to become established before the hot dry weather of early summer.

Results of Direct Seeding Projects Using Douglas-fir

A briefed statement of the results of the major tests of direct seeding with Douglas-fir on the national forests is presented in table 20. Data for 18 projects are given, 6 of the largest each of broadcasting, spring seed spotting, and fall seed spotting.

The significant lesson from these extensive projects as well as from the smaller experimental tests is the uncertainty of direct seeding. In some instances the amount of germination was large, in others nil. Mortality the first year was high. Generally the distribution of established seedlings was more irregular than with planted trees.

Direct Seeding with Small Seeded Species

The seed of many of the desirable native trees is many times smaller than that of Douglas-fir. This tree, on the average, has 40,000 seeds per pound; in contrast western hemlock has 300,000, western redcedar 400,000, Port Orford white-cedar 160,000, Sitka spruce 250,000, and red alder 500,000. Thinking that the seeds of these small seeded species might escape the attention of rodents and birds to a greater extent than those of Douglas-fir, experiments were made by the Pacific Northwest Forest Experiment Station from 1929 to 1933 with the sowing of seeds of several species on the west side of the Olympic National Forest. Broadcast seeding only was employed here and the tests were both on burned and unburned cut-over land and were well replicated.^{17/} Though there was a wide variation in results between areas and between years a number of the tests gave satisfactory stocking with a reasonable amount of seed. For the majority of the tests, except in 1932, there were upwards of 1,000 seedlings per pound of seed sown in the July following sowing and in some cases over 5,000 seedlings per pound of seed. Western redcedar, Sitka spruce, and red alder gave the best results, with western hemlocks showing less positive. In 4 comparative trials of Douglas-fir seed, one produced 400 seedlings per pound of seed and the others were failures. When sowing the same 1928 burn every year from 1929 to 1932 the amount of reproduction resulting from the seeding was progressively less each year due to the invasion of competing herbage and brush.

Though the mortality of the seedlings was heavy the first year after germination, especially of cedar and hemlock, there was on most plots, except for the 1931 sowing, what would be considered adequate stocking for each 2 pounds of seed sown.

^{17/} Isaac, L. A. & Dunford, E. G. Broadcast seeding with the small seeded species of the spruce-hemlock type. Ms. December 1937.

Table 20.--Summary of Results from the Six Largest Tests with Douglas-fir of Broadcast Sowing and of Spring and of Fall Seed Spot Sowing on National Forests of Western Oregon and Washington

National forest	Date sown	Aver-age	Lbs. seed per acre	Protection to seed	Results 1st fall	Number of trees per acre - remarks
<u>Broadcast Sowing</u>						
Mt. Hood	Fall 1912	119	3.3	None	1,678	2nd year 490; 6th year 210
Rainier	" "	20	3	"	800	
"	" 1910	20	2	"	0	2nd year 62
Mt. Hood	" 1912	264	3.5	Poisoned grain		In 3rd year 10% of area had over 400 trees per acre and 72% less than 100
Olympic	" 1909	20	4	Red lead	4,500	3rd year 2,500
Snoqualmie	" 1910	25	2		0	Sown on snow
<u>Spring Seed Spot Sowing</u>						
Mt. Hood	Spring 1910	600		None	Percent .4	Percent of spots with trees - remarks
"	" "	430		"	5	6th year 6%
Olympic	" "	515		"	0	3rd year 10%
Snoqualmie	" "	350		"	0	3rd year 61% on benches; none on slopes
Siuslaw	" "	1,350		Red lead	Very few	4th year 10% on lower slopes, 1% on upper
"	" "	400		" "	0	11th year very few
						7th year very irregular, possibly 5%
<u>Fall Seed Spot Sowing</u>						
Mt. Hood	Fall 1913	1,253		None	15	3rd year 3%
"	1912	1,043	.86	"	18	3rd year 13%
Olympic	" "	1,502		"	19	
Santiam	" 1913	484		"	-	2nd year .4%
Mt. Hood	" 1912	1,340		Poisoned grain	44	3rd year 35%
Siuslaw	" "	2,575	.95	" "	21	3rd year 18%

These experiments point to the conclusion that on favorable sites in the fog belt within two years after a slash burn on logged-off land, broadcast sowing of the small seeded species will give adequate stocking much of the time provided at least 1 and preferably 2 pounds of a combination of species is used. Likewise success under the same conditions would probably result from seed spot sowing, with a very much smaller amount of seed, but with considerably more labor. Experiments in Idaho, reported by McKeever^{18/}, in seed spot sowing of the small seeded species, western redcedar and Engelmann spruce, corroborate the findings reported above and give further support to the hypothesis that rodents are not such a serious menace to the small seeded species as to Douglas-fir and the pines.

Factors Affecting Success or Failure of Direct Seeding

Some analysis of the factors that cause success or failure may help to point the way to techniques of sowing that will be more successful. The consumption of seed before germination by rodents and birds is most serious. Over and over it has been proven that where seed spots were covered at the time of sowing by a tight wire screen there was many times the amount of germination as on spots open to predators. Mice, ground squirrels, chipmunks, and even shrews eat tree seed and are abundant on deforested areas. It has been found that mice quickly repopulate logged-off land after a fire. Birds also consume quantities of tree seed and flocks of juncos were seen at times to follow up the seed spot sowers and pick the seed out of each spot. In the direct seeding projects of the Forest Service in this region, now 30 years ago, various devices were used to combat the rodent menace to seed. The seed was coated with red lead, large areas were strewn with strychnine-coated grain to poison the mice before tree seed sowing, but on most areas without noticeable benefit. Krauch^{19/} writing of seed spot sowing of Douglas-fir in Arizona says: "It is evident that no success from seed spotting can be expected unless rodents are completely controlled." The Fish and Wildlife Service is continuing studies in an effort to find means of making deforested areas safe for direct seeding. Some of their findings are discussed by Moore in a recent bulletin (36).

Animal populations are known to fluctuate through wide ranges; this is particularly the case with mice. The erratic results of direct seeding may in part be due to the status of the mouse population cycle. Foresters might perhaps take advantage of this fluctuation to sow when the rodent population is at a low point. Garman in calling attention to this consideration cites Charles Elton's discussion of the practice of controlling rodent populations by infection with cultures of Salmonella.

^{18/} Northern Rocky Mountain Forest & Range Experiment Station. Research Note No. 21. 1942.

^{19/} Krauch, H. Southwestern Forest & Range Experiment Station. Research Notes No. 98. 1942.

Some recent experiments in Idaho reported by McKeever^{20/} in poisoning rodents on an area to be sown to white pine using sunflower seeds coated with thallium sulphate give some promise of controlling this menace, though there are disadvantages in the use of this powerful poison. Also, experiments with coating white pine seeds with strychnine alkaloid mixed with a tasty binder show questionable results; this technique has not been sufficiently tested with Douglas-fir.

Another cause for the low ratio of seedlings to seed following direct sowing is the failure of seed to germinate. In broadcast sowing especially, but to some extent with seed spot sowing, many of the seeds fall where they are not kept sufficiently moist, or they are not in close enough contact with good soil so that the radical can function, or they are covered too deeply to germinate. Hence, considerable good seed fails to germinate because it does not have a favorable setting.

Even though a certain proportion of the seed sown escapes rodents and birds and germinates, there is usually a very high mortality the first year, and considerable mortality thereafter. The final column of table 20 indicates this. Isaac (25) in studies of natural reproduction, which is analogous in behavior to artificially seeded reproduction, found many causes for high first-year mortality--cold, heat, drought, mice, insects, parasitic diseases, frost-heaving, burial by moving soil on sidehills, shade of competing vegetation. After the seedling has hardened down, i.e., at the end of the first season, it is less likely to succumb to any of the first 4 of these factors, but it becomes increasingly subject to excessive competition with weeds and brush and a prey of rabbits and mountain beaver, archenemies of plantations discussed elsewhere in this bulletin.

Conditions Under Which Direct Seeding is Most Likely to Succeed

In the light of experiences in this region and the well-known difficulties and uncertainties of direct seeding, it is advisable to employ it only under certain physical conditions and with certain methods, assuming, of course, that it would be used as a substitute for planting only where there is sound economic reason or expediency for doing so. The conditions and methods suggested for direct seeding are as follows:

- (1) It should be employed only on the most favorable sites; never on land too brushy for planting, nor on unstable soil, nor very wet or very dry sites, except that it may be appropriate on ground too rocky for easy planting.
- (2) When using large seeded species, like Douglas-fir, the area should be known to be reasonably free of seed-eating animals or else an effective technique of rodent control in advance of sowing or of seed protection be employed.

20/ Northern Rocky Mountain Forest & Range Experiment Station. Research Notes No. 18. 1942.

- (3) Small seeded species, like cedar, spruce, hemlock, and alder, are more likely to escape animal depredation than Douglas-fir, and on sites suitable for these species are recommended.
- (4) Seed of high germinative energy only should be employed, so that germination may be prompt and vigorous.
- (5) Areas should ordinarily be selected for direct seeding that are reasonably free of brush and rank vegetation, such as those burned-over within 2 years.
- (6) Direct seeding should be done long enough before the germination season to give the seed a chance to get well soaked and to become settled into firm contact with the soil. Fall sowing with a quick and continuous snow covering is ideal; at lower altitudes late winter sowing is suggested. Under certain conditions of spring sowing seed should be stratified or soaked in advance to hasten germination.
- (7) As between broadcast sowing and seed spotting the latter is preferred for economic reasons for large seeded species, the former for small seeded species. Broadcasting should give better distribution of trees. The amount of seed requisite for success at present prices makes the cost of broadcasting prohibitive, except perhaps for some of the small seeded species.
- (8) Seeding to be considered successful should have, after 10 or 15 years, as many and as well distributed trees per acre as would have resulted from planting, and at a cost no greater than planting.

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