FOREST REGENERATION IN THE WILLAMETTE VALLEY FOOTHILLS

by

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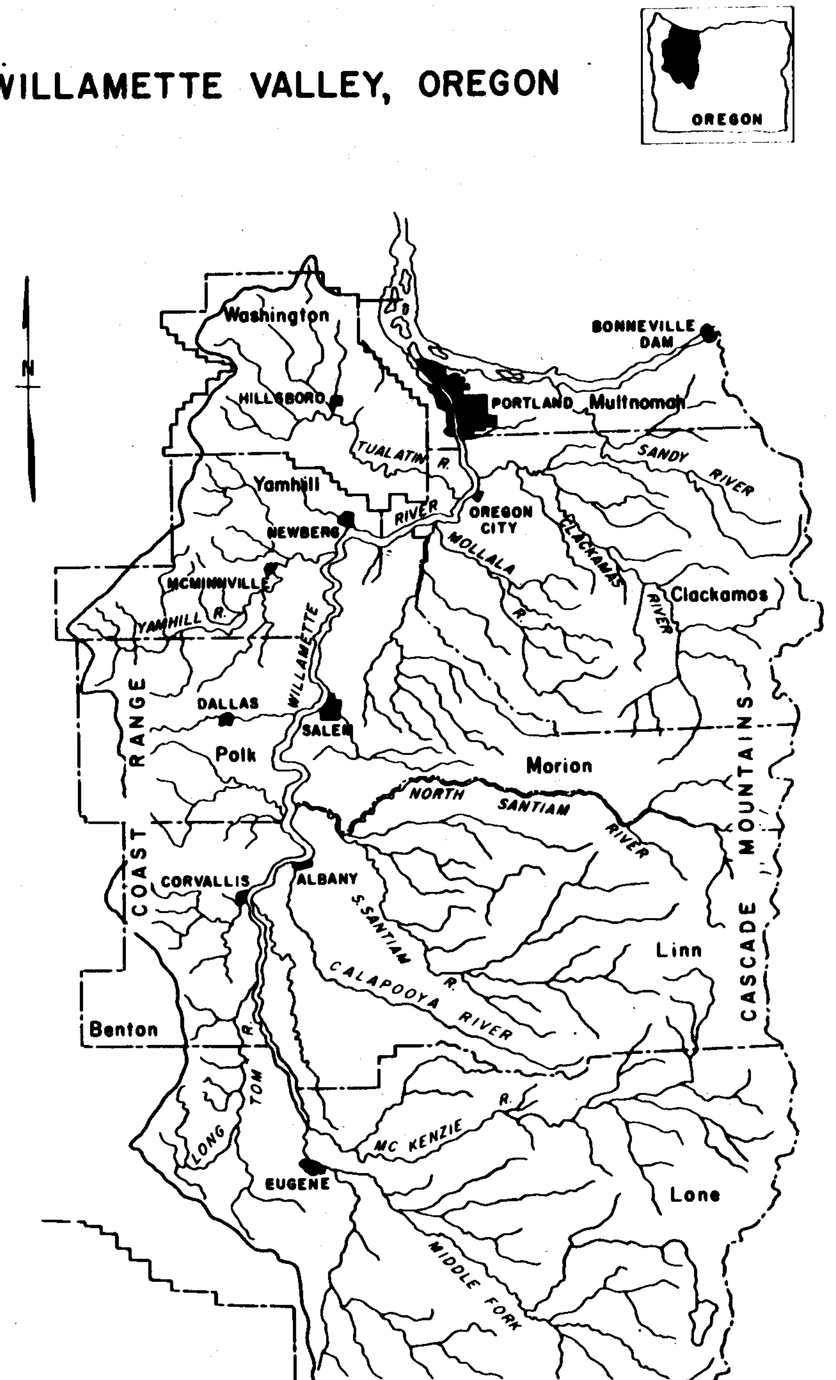

SOURCE: OREGON STATE PLANNING BOARD, WILLAMETTE VALLEY PROJECT MAP, 1935

FOREST REGENERATION IN THE WILLAMETTE VALLEY FOOTHILLS

PART I

INTRODUCTION

THE PROBLEM AND ITS IMPORTANCE

Oregon's Willamette Valley is bordered by the Coast Range, Cascade and Calapooya Mountains. After years of logging, grazing, farming and recreational use the foothills of these mountains now are covered by a patchwork pattern of grass, brush, hardwoods, second-growth fir forests and farms.

Much of the land well suited to commercial forestry in the foothills is not in forest cover at present and forestation efforts may be difficult or expensive because many factors severely inhibit forest regeneration on some sites.

As western Oregon gradually shifts to a second-growth timber economy, the demand for foothill timber increases steadily because of its proximity to wood-using industries in the Willamette Valley. Many small forest industries are already dependent on foothill timber. Forest regeneration efforts on all foothill sites suitable for commercial forestry is one step towards assuring a continuing flow of timber to dependent industries.

THE SCOPE OF THIS REPORT

The report (1) describes the silvicultural problems of establishing forests and regenerating present forests after logging, (2) evaluates techniques for overcoming many of the problems, and (3) suggests forestation procedures for foothill sites. Part II of the report contains a general discussion of regeneration problems in the foothills. The descriptions of troublesome problems in many cover types, evaluations of techniques, and forestation procedures are in Part III. Many of the procedures have been developed by direct experimental work while others are region-wide practices adaptable to foothill conditions. Part IV contains the summary and the conclusions.

Long discussions of economic considerations are not included within the scope of this report. Once the silviculturally desirable regeneration practices are known they can be modified to meet economic conditions on individual properties. Although economic factors receive little attention in the report their importance should be understood. For example, trespass and fire losses may be higher than normal on the small ownerships common in the foothills and the investment risks in forestation work may be increased as a result.

PART II

REGENERATION PROBLEMS

THE FOOTHILL SITUATION

Climatic conditions seriously affect forest regeneration in the foothills. As an example, newly germinated seedlings often are unable to survive summer drought periods. Table No. 1 below summarizes the summer precipitation at three Willamette Valley weather stations during 1951, 1952 and 1953.

TABLE NO. 1

SUMMARY OF SUMMER PRECIPITATION

Weather Station	Year	June	July	August	Monthly Extremes
		(inches of rainfall)			
Portland	1951	.03	.13	.13	High - 2.84
	1952	2.09	T	.19	
	1953	2.49	.03	2.84	Low - T
Salem	1951	.01	.17	.65	High - 2.64
	1952	2.64	.00	.03	
	1953	1.34	T	1.65	Low - 0
Eugene	1951	T	.01	.51	High - 4.76
	1952	4.76	T	.09	
	1953	1.63	T	1.09	Low - T*

*Trace

Source: U. S. Weather Bureau Local Climatological Summaries. (31, 32, 33)

Average rainfall in inches in June is 1.32; July, 0.46; August, 0.51 at the same stations. May and September averages are more favorable with 2.01 and 1.60 inches.

Annual precipitation averages about 40 inches in the valley (32, p.1) but as the table shows, only about 2.5 inches of the annual total fell during the summer periods (June, July and August for the three years). The summer rainfall did vary greatly from year to year though. Average precipitation for the three stations was only .55 inches during the dry summer of 1951 and rose to 3.69 inches during the wet summer of 1953.

Summer droughts generally are accompanied by sunny weather with intense insolation and high temperatures. Valley weather stations usually record sixty to seventy percent of possible sunshine(5, p.11) and temperatures average about 65° F. and reach normal maximums of 90° F. with infrequent maximums of over 100° F. (31,32,33) On exposed sites, soil surface temperatures can rise above the critical point for survival of young tree seedlings such as Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco.) during periods of high temperatures. (22, p.63) The effect is greatest on open southerly exposures and these slopes are often covered by grass. (34, pp.3-4)

Animals, too, influence forest regeneration. Studies have shown that heavy seed losses can be expected where rodent populations are high, (6, pp.4-8) and conditions are seemingly ideal for high rodent populations in some foothill areas. Deer and roaming bands of goats or sheep browse young trees and kill many of them.

Perhaps cover is the most important factor affecting forest regeneration in the foothills because it influences other factors and usually can be modified to encourage reproduction. A knowledge of the extent of the cover types in the foothills could give an indication of the relative importance of problems in the various cover types but no comparison is possible because the foothill areas were last mapped and inventoried during a nationwide forest inventory in the early 1940's and the cover types have been radically changed by logging and fire since then.

There are possibly some differences between site conditions in the foothills on the west side of the Willamette Valley and the hills on the east side of the valley. The eastern hills are suspected to have drier sites and somewhat less brush than those to the west. The differences have not been experimentally determined; they are merely the general observations of some silviculturists.

TREE SPECIES TO USE

Douglas-fir is excellent for forestation because of its adaptability to foothill sites, the value and extent of its potential markets and the relative ease and cheapness of its establishment on most areas. Shore pine (Pinus contorta var. contorta Dougl.) and ponderosa pine (Pinus ponderosa Laws) have survived well on some sites where Douglas-fir survival is poor but their growth characteristics and potential markets are unpredictable and they cannot be recommended without qualification. Most of the findings and studies described in this report are based on the belief that Douglas-fir is the most desirable species for forestation.

REGENERATION PRACTICES

Natural reproduction methods are satisfactory for forestation work in the Douglas-fir region except when (1) seed sources are inadequate, (2) site conditions are very severe, (3) rapid restocking is required, or (4) the value of non-salvagable trees in seed sources exceeds the cost of artificial forestation. These conditions occur so frequently in the foothills that the role of artificial regeneration may be more important than elsewhere in the region. The regeneration requirements for Douglas-fir are outlined in Chart No. 1 on page 7 as a guide for determining when Douglas-fir forests can be established by natural reproduction. The chart is an attempt to summarize the information contained in references 1, 2, 6, 7, 8, 9, 10, 13, 15, 16, 17, 22, 23, 26, 28, 29, 34, 35, 36, 37, and 38.

SEED SUPPLY

CHOICE OF SOURCES

1) Stands of mature or near-mature timber usually can restock areas up to a quarter mile within ten years if stand edges are full, site conditions satisfactory, and less than full stocking permissible. Timber should be on east side so cone-opening winds can spread seed on area.

2) Four to eight seed trees per acre with well-developed crowns can restock areas if windthrow, exposure, insect or fire losses controllable.

3) Young stands may restock nearby areas if they are of practical seed-bearing age and windfirm.

SEED YEARS AND CARRYOVER

Two or three effective seed years per decade are average in region. Almost all seed germinates, rots, or is eaten within a year after seedfall so each year's regeneration depends on preceding year's crop.

RODENTS AND INSECTS

White-footed mice and other rodents can consume almost all seed from poor or average seedfalls during winter. Seed sources are made ineffective occasionally by infestations of insects that damage cones or eat seeds.

WEATHER

GROWING SEASONS

Growing seasons in western Oregon and Washington have long droughts and high temperatures most years. Infrequent seasons are more favorable for reproduction with rains and cloudiness. Summer conditions may be very severe in foothills with prolonged droughts and very high temperatures.

DORMANT SEASONS

Winters are mild with light snowfalls, heavy rains and frequent frosts at low elevations. At higher elevations temperatures are lower and sites are covered by snow most of the winter months. Damaging frosts are confined to fall and spring months.

SITE

SIZE OF OPENINGS

Regeneration is best on open areas over one acre but very large openings may restock with light-weight seed species instead of fir.

LIGHT AND TEMPERATURE

Seedlings require half-light for survival and three-quarters to near full-light for best establishment. Full-light, although it improves vigor and growth of established seedlings, may reduce survival. Surface temperatures of 120°F. to 130°F. cause heat lesions and seedling deaths before stems become woody. Temperatures up to 150°F. can cause death through rest of first season. High temperatures also speed seedling dessication and soil drying.

SOIL AND MOISTURE

Drought deaths are common on shallow or coarse soils and may occur on some heavy soils where small amounts of available water are characteristic. Seeds germinate April through June so tree roots have only short time to penetrate to layers of permanent moistness. Root depths may average only two to seven inches the first season.

ASPECT AND SLOPE

Heat and drought deaths are common on southwest and other southerly aspects. Northeast and other northerly aspects are favorable unless competing cover is heavy. Steep slopes accentuate effects of aspect, erode easily, and shallow soils lower moisture storage capacities. Frost damage may be severe on southerly aspects.

COVER

Brush, weeds, or grass compete with seedlings for moisture, nutrients, and growing space. Heavy cover can reduce light below critical levels and germination of seedlings often commences with leaf-out and start of weed and fern growth. Seedlings almost always require mineral seedbeds and heavy layers of leaves or dead plants prevent seeds reaching seedbeds. Light cover may favor survival by shading ground and reducing air movement, especially on southerly aspects.

SLASH BURNING OR WILDFIRE

Burning of heavy slash accumulations and brush may favor restocking by increasing light, removing competition, or exposing mineral seedbeds. In other cases, fire destroys seeds and advanced reproduction, destroys beneficial shade, and blackens soil with charcoal which raises surface temperatures and speeds drying. Hard burning prevents reproduction in spots by altering soil.

PART III

REGENERATION PROBLEMS AND PRACTICES IN FOOTHILL COVER TYPES

Since many of the troublesome regeneration problems are correlated with cover conditions, Part III is divided into subsections, one for each of seven cover conditions common in the foothills.

The subsections are in this order:

Each subsection contains three divisions titled: The Situation, Experimental Work, and Recommended Regeneration Practices. Summaries of results from recent research projects by the School of Forestry, Oregon State College, are included in the divisions on experimental work. Then the experiments and results are described in detail in the Appendix.

1. GRASS

The Situation

The foothill grasslands cover large acreages on southerly aspects. The cover is composed of annual grasses, perennial grasses and forbs about a foot to a foot and a half high except on some heavily grazed areas.

General observations and historical records such as old General Land Office survey notes indicate many grasslands are replaced by forests eventually. Natural conversion is unsatisfactory for intensive forest management, however, as the rate of change is very slow and low-volume forests or low-value forest types usually result. At the same time, severe site conditions such as poor soil characteristics, high surface temperatures, inadequate soil moisture in summer, rodent losses, and competition hamper efforts in artificial forestation.

Experimental Work

Youngberg has indicated survival percentages usually will be low on some grasslands because they are underlaid by soils that contain little available moisture during long periods of growing seasons and crack severely during drought periods to expose tree roots. (38, p.9-10) Soils with these characteristics are the Cove and Climax soils. (38, p.10) Identification characteristics for the Aiken and Cove soils are given in the Benton County Soil Survey report, (3, p.1445 and 1472) and the Climax soil is described in Youngberg's report.

Owen has observed two detrimental factors (1) ground surface temperatures above critical temperatures for survival of natural seedlings of Douglas-fir during their first growing seasons (22, p.63) and, (2) soil moisture levels below critical percentages in summer drought periods. (22, p.63)

Other factors may affect regeneration seriously. Isaac has pointed out that vegetative competition for moisture, nutrients and growing space can eliminate natural seedlings and plantation trees easily. (8, p.39-44) Rodents can account for much seed loss (6, p.4-7) and conditions are seemingly ideal for high rodent populations. The author observed an experiment where Douglas-fir seed was sowed in spots. The seed disappeared from all spots not protected by rodent caps and was even taken from some protected spots by moles that tunnelled under the caps and apparently removed the seeds without disturbing the caps.

Barnes has directed several experiments on McDonald Forest near Corvallis. The forest is located in the outermost fringe of the western foothills and is owned by Oregon State College. The experiments tested artificial methods of regeneration because natural regeneration seemed impractical. In one group of experiments, native Douglas-fir was planted by various methods to determine whether or not any of the methods would assure reasonable survival. In another group, non-native races of Douglas-fir and other tree species were planted. The ultimate objective is to determine whether or not non-native trees are more adaptable to grassland conditions than native Douglas-fir. The descriptions and survival results of the two groups of experiments are on the following pages.

(a) Experiments with Planting Methods

More than a dozen planting methods or combinations of methods were tested in four experimental plantations. The planting methods attempted one or more of the following: (1) eliminate competition from other plants, (2) increase the moisture-holding capacity of the soil around the roots of the planted trees to give the trees moisture reservoirs during droughts, (3) improve soil structure around the tree roots to eliminate soil cracking and root exposure, (4) reduce insolation to minimize the effects of high temperatures and droughts. Two plantations and a supplementary planting were set out in 1952 and tree survival recorded throughout the growing season and the following spring. Other plantations were set out in 1953 and survival recorded for the first growing season.

In the 1952 experiments, one method showed more promise than the others. When trees were hole-planted and sawdust mixed with the planting soil half and half, 57 percent of the trees survived the first growing season. Survival percentages for the season were lower with other planting methods; 28 percent for trees hole-planted with sawdust, 25 percent for trees slit-planted and shaded with shingles driven into the ground on south sides of trees, and 23 percent for trees hole-planted and mulched with a thin layer of sawdust after the grass was scalped from planting spots. Survival dropped to 10 percent when trees were slit-planted without additional treatment. Many of the trees died during a prolonged drought. Less than one inch of rain fell in the valley during July and August of 1952 as shown in Table No. 1 on page 3. Most of the trees were planted in a Cove clay soil and mortality was increased by the soil's poor moisture characteristics and tendency to crack and expose tree roots when dry. All trees were native Douglas-fir from the Oregon State Forest Nursery at Corvallis. The survivals were obtained in the 1952 Planting Methods Plantations and the descriptions and survival results of the plantations are given in the appendix on pages 58 to 62.

Supplementary plantings of Douglas-fir and other species were set out next to one of the 1952 plantations. The descriptions and results of the plantings are given in the appendix on pages 63 and 64. The Douglas-fir planting is of interest here. The trees were hole-planted with a commercial soil conditioner (trade name Krilium) mixed into the planting soil and survival was 30 percent near the end of the first growing season.

A statistical analysis of mortality results showed significant differences in survival among some of the planting methods. However, many of the trees still alive at the end of the first growing season (when the analysis was made) were weakened and died during the winter. By

June of the next year survival percentages dropped and the comparative success of some planting methods had changed. Survival was still highest for trees hole-planted in sawdust-soil mixtures with 41 percent of the trees alive. Survival was second highest for trees hole-planted and mulched with 19 percent alive. Survival was 13 percent for shaded trees, 8 percent for hole-planted trees, 5 percent for trees hole-planted with Krilium, and 3 percent for the slit-planted trees. A statistical analysis was not made for these mortality results.

Some of the planting methods were tested again in 1953, such as sawdust planting in which trees were hole-planted and sawdust mixed with the planting soil half and half. Similar planting methods were also tested to determine whether or not any of them would give as high survival and yet be more practical than sawdust planting.

In one of the 1953 plantations, survival varied slightly for three hole-planting methods at the end of the first growing season; 68 percent for the sawdust planting, 63 percent when a coarse grade of vermiculite (trade name Terra-lite) was substituted for sawdust, and 63 percent when trees were hole-planted and mulched with sawdust after the planting spots were scalped. Surprisingly, survival was highest, 80 percent, for slit-planted trees. Survival was favored by an excellent growing season with about three inches of rain during the summer. The choice of planting site also favored survival as the soil was an Aiken clay loam with better characteristics than the Cove clay soil in the 1952 plantations. All trees were native Douglas-fir from the Oregon State Forest Nursery at Corvallis. A statistical analysis was not made because survival differences between planting methods obviously were less than significant between three of the planting methods and results were negative for the more elaborate methods compared to slit-planting. The survivals were obtained in the 1953 Planting Methods Plantation and the description and results are in the appendix on pages 65 and 66.

Machine aids were tested in another 1953 experiment to determine whether or not they could increase the efficiency and economy of hole-planting for practical field use without unduly reducing survival. Some trees were hole-planted in plowed furrows, other trees were hole-planted in strips cultivated with a rototiller, and others were planted in holes dug with a posthole-digging attachment on a power saw. Trees were also hole-planted after grass sod was chopped into the planting soil with shovels. Half of the trees planted by each method were fertilized. Survival percentages of the fertilized trees have been disregarded because survival was low and erratic. The surrounding grass responded to the fertilizer and apparently competed with the trees severely. 67 percent of the unfertilized trees survived when the trees were hole-planted with chopped sod. 60 percent survived when the trees were hole-planted in rototilled strips or plowed furrows, and 47 percent survived when the trees were planted in augured holes. All trees were native Douglas-fir from the Oregon State Forest Nursery at Corvallis and the survivals were obtained in the Machine Plantation. The description and results are in the appendix on pages 67 and 68.

Native Douglas-fir from the state nursery was planted with non-native trees in the second group of Barnes' plantations as check plantings. In one plantation, survival of the native trees averaged 33 percent but some of the trees were planted in winter and others in early spring and there were significant differences in mortality. Spring planting produced 39 percent survival and winter planting 28 percent. All trees were hole-planted and chopped sod mixed into the planting soil. Descriptions and results are in the appendix on pages 69 to 73. When the trees were planted in winter the ground was saturated with water. The planting soil puddled badly when worked and tree roots were immersed in soupy mud that formed hard clods around the trees as the ground dried in spring. The soil was a Cove clay, characteristically plastic and susceptible to puddling. (3, p.1472)

(b) Experiments with Non-native Trees

In Barnes' second group of experimental plantations, non-native trees from dry land locales are being tested to see if any are more adaptable to severe sites in the foothills than native Douglas-fir. The experiments are long range projects but the survivals at the end of the first growing season are of interest in this regeneration study. Several races of Douglas-fir, some pines and one hardwood species were set out in a large grassland plantation and a smaller variety of trees were included in a series of plantations on grasslands and brush-covered or bracken fern sites. All planting was done in 1953. In the grassland plantations, survival percentages were generally high for the pines and non-native races of Douglas-fir at the end of the first growing season. A hardwood species, black locust (Robinia pseudoacacia L.), also survived well but suffered from heavy deer browsing. In contrast, native Douglas-fir showed consistently low survival. The largest grassland plantation is known as the 1953 Race Plantation. The description and survival results are given in the appendix on pages 69 to 73. To summarize the pertinent information, survival was 100 percent for shore pine, 97 percent for ponderosa pine, over 70 percent for all but one non-native race of Douglas-fir (the one exception had 44 percent survival), 87 percent for lodgepole pine, and 80 percent for black locust. Survival averaged 33 percent for Douglas-fir from the Oregon State Forest Nursery at Corvallis. Results were similar in two other grassland plantations; shore pine survival averaged over 90 percent and ponderosa pine survival averaged about 90 percent. Native Douglas-fir survival was low, dropping to 26 percent in one case. The descriptions and results of the plantations are on pages 74 to 76 in the appendix. Vigor and growth of the shore pines was impressive in all plantations. Many leaders extended a foot each year during the first two growing seasons. The ponderosa pines made little apparent growth during the same time.

It should be pointed out once again that survival percentages in the 1953 plantations were probably higher than normal because of a favorable growing season. Survival was lower for some of the same species in earlier experiments. Ponderosa pine and black locust were planted near the 1952 plantations. Ponderosa pine survival was only 18 percent early in the second growing season. However, it ranked higher in survival than all but two of the Douglas-fir plantings. Black locust survival was low and the trees were heavily browsed. One other record of ponderosa pine survival is available. In a race plantation set out on the McDonald Forest in 1928, survival averaged

36 percent for all ponderosa pine races in the second year and 94 percent for pines from a Corvallis seed source. (14, pp.8-9)

<u>Recommended Regeneration Practices</u>

Natural restocking is unsatisfactory on almost all grasslands and artificial forestation often is difficult and expensive. Hole-planting may be necessary. Even then high survivals are unlikely. This is discouraging in view of the high costs of hole-planting or the modified methods that produced highest survivals in experimental plantations.

Sawdust planting in which sawdust is mixed with the planting soil probably can produce high survivals but is awkward and time-consuming for field planting. It may be usable for small projects. A simpler method of hole-planting in which grass sod is chopped into the planting soil produced fair survival in experimental plantations after a favorable growing season but lower survivals may be the general rule, and planting is slow. Auger planting in which holes are dug with a power tool may be a practical field method. Planting time was very short compared to that needed for other hole-planting methods tested in the Machine Plantation and the slightly lower survival for trees planted in auger holes instead of hand-dug holes may be apparent rather than real because only a few trees were used to compute survival percentages. A power-saw auger was used in the experiment because it was the only tool available. Two men were required for its operation and it was cumbersome. However, a one-man auger is being marketed now as an attachment for the "Little Beaver Tree Girdler" by the Haynes Manufacturing Company of Livingston, Texas. With it, one man could possibly dig holes for three or four tree planters and increase daily production per man.

Some grasslands are underlaid with heavy, plastic soils such as Climax and Cove soils. Tree survival is doubtful most years on these soils. Land uses other than forestry may be advisable. If tree planting is attempted, spring planting should be preferred to winter planting. Survival with winter planting was significantly lower than spring planting on a Cove soil (discussion on page 16). Other grasslands are underlaid by residual soils more favorable for survival.

Several non-native trees have survived well in the grassland plantations, notably shore pine from an Oregon coast seed source and ponderosa pine, although lower survivals than those recorded in the experiments would likely be the rule since survival was influenced by a favorable growing season. Before choosing a non-native tree in preference to native Douglas-fir for grassland planting, two questions should be asked: (1) Will the trees grow and develop satisfactorily on the grasslands in later years?, and (2) Will the trees be marketable? The 1953 plantations on the McDonald Forest should give answers on growth and development in the future but there is only one growth record available for study at this time. Trees in the ponderosa pine race plantation on McDonald Forest have been measured several times. A 1940 inspection showed the trees averaged 12 feet high after 12 years of growth. Growth was best for trees from El Dorado National Forest in California with an average diameter of 5.2 inches and the tallest tree growing to a height of about 26 feet. Ponderosa pine from Willamette Valley seed source showed good height growth also with the tallest tree reaching 19.4 feet. In a 1951 inspection, the El Dorado trees averaged 9.0 inches in diameter and 44 feet in height; and the valley trees averaged 5.8 inches in diameter and 33 feet in height. General vigor of trees in the entire plantation is poor now and an unknown pathological agent has partially defoliated many trees. As a general rule, native Douglas-fir should be used for crop trees on grasslands unless exceptional circumstances make the use of non-native trees mandatory or very promising.

The use of "nurse trees" for establishing commercial forests on grasslands deserves attention. It has had only casual testing so far. Owen and Sprague have noted the prevalence of Douglas-fir reproduction under scattered oaks on grasslands in separate studies, (22 and 29) and Douglas-fir has become established periodically in the ponderosa pine race plantation. The successful regeneration under "nurse trees" prompted Barnes to plant black locust in his grassland plantations. He also tested Russian olive (<u>Eleagrus angustifolium</u> L.) in a supplementary planting with the 1953 Race Plantation. Oregon white oak (<u>Quercus garryana</u> Dougl.) may be successful for "nurse trees" but it has not been tested.

Native Douglas-fir set out on grassland experiments were two year old seedlings. Older stock or transplant stock may give higher survival but has not been tested yet.

2. BRACKEN FERN

The Situation

Bracken ferns (*Pteridium aquilinum*) two to seven feet high completely cover some open areas in the foothills, and also invade grass areas or openings in brush areas. The natural regeneration of Douglas-fir is usually excellent under bracken fern cover except when the cover is very heavy (12, p.485) or when the supply of Douglas-fir seed is curtailed. Fire protection is a serious problem in regeneration on bracken fern areas because the ferns make a flashy fuel highly susceptible to fire. Although the ferns resprout shortly after burning, the fires destroy tree seeds and seedlings.

Experimental Work

McCulloch observed the effects of fern cover on the natural establishment of Douglas-fir. He found more seedlings on sites covered by bracken fern than on sites where the fern had been removed. (12, p.485)

One of Barnes' 1953 experimental plantations was on a site covered by grass and bracken fern. Native Douglas-fir had 80 percent survival in the plantation at the end of the first growing season as compared to low survival percentages of native firs in grassland plantations. Non-native trees planted at the same time also had high survival. A description of the plantation and the survival results are in the appendix on pages 77 and 78.

Recommended Regeneration Practices

Site conditions on fern sites are usually suitable for Douglas-fir regeneration, so considerable care should be taken to determine if existing seed sources are likely to reseed the areas to be regenerated. Chart No. 1 on page 7 can be used as a guide for estimating whether seed sources are adequate. If seed sources appear adequate and inspection shows the areas have not been burned and reproduction destroyed in recent years, one or both of two factors may be hindering regeneration: (1) seeds may be destroyed by agents such as rodents before germination, or (2) the fern cover may be too heavy for seedling establishment. Chart No. 1 gives the light requirements of Douglas-fir seedlings. A fern cover of less than fifty percent probably does not hinder reproduction seriously.

When either seed sources or seed supplies for germination appear inadequate, areas can be regenerated with slit-planted nursery stock. If seed sources seem adequate but seeds apparently are lost before germination, rodent control might permit natural restocking.

Forestation work is more difficult when the fern cover is too dense for seedling establishment but there are at least two possibilities. The first is to plant trees after cultural work reduces the vigor and density of the ferns. The cultural operation can be simple, such as disturbing the top soil with a bulldozer blade. Complete coverage isn't necessary as the worked strips can be spaced eight or ten feet apart and a blade eight feet wide should leave strips of disturbed soil wide enough for planting two rows of trees. A triangular spacing of six feet on the triangle legs should give satisfactory tree spacing with the rows about five feet apart and would leave one and a half feet between the trees and undisturbed ferns on the strip edges. Ripper teeth attached to the bulldozer blade can help break up fern rhizomes which grow four to eight inches below the ground surface. Some fern plants should resprout and help protect the planting sites from excessive drying or heat.

A second possibility is to regenerate areas without resorting to planting. Cultural work can strip the fern cover in late summer before the Douglas-fir seedfall and allow much of the seed to fall on mineral soil in the strips and germinate the next spring. The newly-germinated trees probably could become established under the reduced density of the fern cover on the strips. Rodent control could help prevent seed losses before germination. Baiting with poison-impregnated wheat as used by the

Oregon State Board of Forestry in aerial seeding operations should be satisfactory for control. (10,pp.16-17) Careful checks of seedfall and reproduction should show if operations are successful and tree planting should be undertaken the following planting season if reproduction is not prompt. The only unrecoverable cost would be for rodent baiting. The stripping should reduce the density of the fern cover long enough for planted trees to become established even when planting is delayed one season.

3. BRUSH

The Situation

Deciduous brush usually grows as high bushes with brambles, grass or fern covering the openings between clumps of brush. Some of the common species are willow (Salix spp.), vine maple (Acer circinatum Pursh.), elderberry (Sambucus glauca), thimbleberry (Rubus parviflorus), and poison oak (Rhus diversiloba T. and G.). Evergreen brush usually grows in low, widespread clumps that frequently exclude other ground cover. Species include salal (Gaultheria shallon), Oregon grape (Mahonia nervosa), and Scotch broom (Cytisus scoparius). Scotch broom is an escaped ornamental and is confined generally to areas where it has spread from roadsides and farmsteads. The broom's aggressive spread and strong resistance to eradication can make forestation work difficult on areas covered by it.

Brush can severely limit forest regeneration. It competes with the seedlings for moisture and nutrients and young Douglas-firs cannot withstand the deep shade under heavy brush. (9, pp.68-69) The few trees established in areas of heavy brush are usually scattered and unable to develop commercially desirable stands.

Experimental Work

The usual approach to the problems of reestablishing forests on brushlands has been the development of effective brush eradication programs. Recent work has favored spraying operations with chemical killers rather than hand or machine removal.

Several agencies have tested chemical eradicators. The results of experimental spraying operations by the U. S. Forest Service's Pacific Northwest Forest Experiment Station have not been published but some of the main difficulties encountered in an aerial spraying operation on the Cascade Head Experimental Forest were described to the author. They were: (1) expense of spraying was unjustifiably high at times, (2) uniform treatment was difficult, (3) brush regrowth sometimes started before seedlings could compete successfully. The spray operations were effective generally with only technique refinements necessary for feasible control programs. Some of the difficulties were overcome later by using ground spraying with portable pumpers. The Weyerhaeuser Timber Company experimented with aerial spraying operations in 1952. (11) A series of brush-covered plots were sprayed with various chemical eradicators and combinations of eradicators at application rates of one gallon per acre and one and a half gallons per acre. Spraying was done with an airplane.

The plots were observed in the summer of 1953 and the control results analyzed. Best control was obtained with the use of ACP977 (American Chemical Paint Company) in Helix 15 or diesel oil applied at a rate of one gallon of chemical in five gallons total solution per acre. The mixture was comparatively economical. Control of low brush such as salal and Oregon grape was generally poor except on one plot sprayed with a mixture of ACP904 and 2,4,5-T in diesel oil. Additional spray operations were carried on by the Weyerhaeuser Company in 1953. ACP977 was tested again along with other eradicators. Application rates of a half gallon of chemical per acre were tried because little difference in control was noted in the 1952 spraying operations when one gallon or one and a half gallons of ACP977 were used. A helicopter was used to obtain good spray penetration under alder and high brush such as vine maple because penetration with airplane spraying was unsatisfactory. The results have not been published as yet.

The Weyerhaeuser Company also conducted a commercial spraying operation on the company's Vail Tree Farm in western Washington in the summer of 1954. (30) A mixture of 2,4-D and 2,4,5-T with diesel oil was sprayed from a helicopter flying about twenty feet about the brush at thirty miles per hour. Control was generally effective and Douglas-fir planting was planned for the next winter. Barnes set out plantations of non-native races of Douglas-fir on a droughty site covered by light brush in conjunction with his experimental plantings on foothill grasslands. The results and descriptions of the plantations are in the appendix on pages 79 to 81. Survival results at the end of the first growing season are of interest in this study. Two non-native races of fir did well in one plantation with over 80 percent survival but the percentages for one species was lower in another plantation.

Survival was poor for native Douglas-fir in the same plantations and there was little difference in results between hole-planting and slit-planting; 65 percent of the slit-planted and 58 percent of the hole-planted trees survived in one plantation and results were reversed in another plantation with 46 percent survival for hole-planting and 41 percent for slit-planting. The first plantation with the comparatively high survival was set out on a northeasterly aspect and the other on a southwesterly aspect.

Recommended Regeneration Practices

Douglas-fir can regenerate by natural seeding on areas covered by light brush. Trees can be interplanted between brush clumps if seed sources are inadequate for prompt seeding. Seed sources should be excellent before relying on natural seeding because the brush may grow rapidly (8, p.54) and make effective regeneration impossible by either natural seeding or interplanting. Chart No. 2 on page 7 can be used for analysing seed sources. Sites covered by heavy deciduous brush or dense evergreen brush require brush eradication programs before forestation efforts can be successful. An eradicator such as the 2,4-D and 2,4,5-T mixture in diesel oil used on the Vail project, can be sprayed from a helicopter or tank truck. Some damage or killing of reproduction should be expected and Douglas-fir should be planted on the area as soon after spraying as planting conditions allow because the newly-planted trees must have an opportunity to become established and attain height before brush covers the sites again.

Scotch broom can be eradicated by spraying with chemical killers, possibly with a 2,4-D and 2,4,5-T mixture. If possible individual broom plants invading forest areas should be sprayed because broom plants spread across some cut-over areas within a few years of initial invasion and reforestation of broom-covered lands may be impossible without expensive programs. Further research on Scotch broom eradication is needed but apparently heavy spray applications are necessary. Although heavy application rates may be allowable on the few broom plants that appear first in an area, the same application rate can be prohibitively expensive for an area completely covered by broom. The author has observed an attempt to control broom by burning. Many of the broom plants lived through the fire. Research might show if a combination of burning and follow-up spraying can control broom at a reasonable cost.

4. OAK AND OTHER HARDWOODS

The Situation

Pure stands of Oregon white oak cover many of the lower foothills and the stands are often young and dense. Initial regeneration of Douglas-fir is usually good in white oak stands when seed supplies are adequate. In fact, oak cover seemingly encourages fir reproduction and many oak stands are being over-topped by firs that started under the oaks. Once the fir trees become well-established, however, oak cover is no longer advantageous because the firs grow slowly and those that eventually overtop the oaks are often scattered.

Other hardwoods, mainly red alder (Alnus rubra Bong.) and bigleaf maple (Acer maerophyllum Pursh.) occur in mixed stands or pure groves throughout the foothills. The alder stands are usually strung out along valley bottoms and small watercourses on hillsides. The trees seldom cover whole hillsides as in the coastal part of the alder range. Bigleaf maples occur in mixture with the alders, as scattered trees in Douglas-fir stands, and occasionally in small groves.

Douglas-fir regenerates poorly in the stream-bottom stands partly as a result of unsuitable moisture conditions and heavy plant cover under the stands. Young alder and maple trees are aggressive competitors of the relatively slow-growing firs on cut-over areas.

Experimental Work

Studies have been made on the "nursemaid" characteristics of white oak stands and site factors for reproduction in the stands. Examples are the studies by Sprague (29) and Walters (34). Emphasis was on the abundance of Douglas-fir reproduction observed under some oak stands compared to a near-absence of firs on adjacent sites not covered by oak.

Keniston of the School of Forestry and Hedrick of the Department of Animal Husbandry at Oregon State College are currently directing an experiment to determine which of several cultural operations or land-uses including grazing, will produce highest returns from foothill lands covered by oak. A number of adjoining plots in an oak stand have received treatments including underplanting with Douglas-fir, thinning, thinning and underplanting, clearing, clearing and planting, and clearing and seeding with grass. Portions of all plots are being used for sheep pasturage. Detailed cost records and returns will have to be analysed over a number of years before conclusive economic results are available. Survival records for plantings of Douglas-fir after two cultural operations are of interest in this study. 93 percent of the firs planted under an undisturbed oak canopy lived through the first growing season and 86 percent of the trees planted after thinning in an oak stand survived. In comparison, 72 percent of the trees planted on a clear-cut area survived. All planting was on a northerly aspect.

There has apparently been no direct experimental work on methods of encouraging Douglas-fir reproduction under mature stands of alder or maple. Brush eradication programs such as those described on pages 28 and 29 are effective on young stands of alder.

Recommended Regeneration Practices

Initial forestation work is probably unnecessary in most oak stands when seed sources are nearby. If seed sources are lacking the stands can be underplanted with Douglas-fir. Very dense stands or stands made up of veteran trees should probably not be underplanted until they are thinned. The difficult stage for the young firs is when they become well established under the oaks and are then prevented from growing at their usual rates by the oak canopy. At that time, perhaps five to ten years after regeneration or planting, the oak should be removed in a liberation cut or girdled. Girdling is not feasible in most stands because of the large numbers of stems per acre but may be satisfactory in stands of scattered veterans if younger trees have not crowded in between the older trees.

Commercial cuttings in older stands should likely be delayed if young firs are not already present until Douglas-fir can be underplanted and allowed a few years for establishment. The delay is advisable because oak stands frequently grow on areas where site conditions make regeneration very difficult without protection. In cases where cutting cannot be postponed or if clear-cutting is likely to cause serious damage to reproduction, heavy shelterwood cuts can be made and "leave" trees should give planting sites some protection. "Leave" trees can be defective or otherwise unmerchantable trees and can be girdled or poisoned after the planted trees become established.

Fortunately, forestation work may not be necessary in most alder and maple stands because it can be difficult and expensive. Three reasons why the work may not be necessary are: (1) alder and maple stands are often on very moist sites unsuitable for Douglas-fir, (2) the foot-hill stands are generally limited in extent, and (3) both alder and maple have commercial value and are likely to increase in value later on. If for some reason it is necessary to establish Douglas-fir on sites covered by alder or maple, the conversion can be made by girdling or poisoning all hardwoods and then planting Douglas-fir. Girdling or poisoning should eliminate resprouting of stumps. Brushy sites may require brush eradication programs as well. Where alder and maple stands are being harvested for present markets and Douglas-fir regeneration is wanted on the vacated sites, certain precautions should help. All trees should be cut and the stumps treated with a chemical killer to prevent sprouting and the area should be planted as soon after cutting as conditions allow. Alder and maple reproduction should be encouraged on moist sites where Douglas-fir grows poorly as the elimination of hardwood growth is likely to encourage brush instead of firs.

5. RECENTLY BURNED OR CUTOVER, NOT STOCKED

The Situation

Logging activity has increased greatly in foothill forests of second-growth fir during recent years. All trees except hardwoods and small or defective firs are usually logged when stands are mature or near-mature. Proper regeneration practices have been ignored on many cutting areas and they are being covered by grass and brush instead of fir reproduction. Slash is burned on some areas and left untouched on others. Logged areas left unburned usually have large areas covered by original forest duff and some heavy accumulations of light slash. As described in Chart No. 1 on page 7, regeneration may be difficult if the duff and slash are not removed or disturbed.

Fire is a constant threat on all burned areas and cut-over areas whether slash is burned or not. The hazardous fire period starts almost immediately on unburned areas as fresh slash dries out, and both burned and unburned areas become covered with herbaceous and brushy fuels within a few years. (9, p.54) More hazard is created on burned areas by snags and branches or trees that fall and add fresh supplies of relatively unrotted fuel over a number of years.

Other forestation problems on burned-over areas are similar to those on logged areas where the slash is burned. Seedling mortality may be high on exposed sites while prompt reproduction is needed before grass or brush have opportunity to cover suitable seedbeds.

Experimental Work

There have been many investigations on the effect of slash burning, logging without burning, or forest fires on the regeneration of Douglas-fir. Findings of Isaac's comprehensive studies (9 and others) and other silviculturists have been included in Chart No. 1.

The use of short-lived cover crops on burned sites may be valuable for encouraging the germination and survival of fir seedlings according to first year results of a cooperative research project by the Bureau of Land Management and Oregon State College. Germination and seasonal survival were significantly higher on sites sowed with India mustard (Brassica juncea (L.) Coss.) in early spring on one series of plots. The mustard plants matured early and gave ideal protection to sites without serious moisture depletion during midsummer when moisture supplies are usually critical. (24, p.1) The mustard matured later. (24, p.2) The mustard also helped prevent invasions of undesirable plants.

Recommended Regeneration Practices

Burned or cut-over areas should be adequately protected from fire before forestation by felling snags in critical areas, constructing fire breaks, and isolating or burning heavy accumulations of slash. Slash on unburned areas should be crushed near the ground during the fire-proofing operations if possible and areas of undisturbed duff should be torn up to expose mineral seedbeds. The next step is to analyze the possibilities of natural restocking. Artificial restocking should be planned if there is reasonable expectation that seed supplies are inadequate or if site conditions make natural regeneration doubtful because the sites might be taken over by problem cover types such as grass and brush. Short-lived cover crops such as mustard may be valuable for encouraging natural regeneration on some burned sites.

6. DOUGLAS-FIR, PARTIALLY CUT

The Situation

Many of the Douglas-fir stands being logged are immature and high percentages of the trees within the stands are below merchantable size. The unmerchantable trees are in groups in some stands and scattered in others. They are left as residual trees after logging and are often small and spindly with weak crowns. When the residual trees are scattered, they have little chance for survival. Many are damaged during logging, others are thrown or broken in windstorms and remaining trees are often lost to exposure or bark beetle attacks. When the residual trees are left as groups some may remain standing after wind, beetles, and exposure have taken their toll among perimeter trees.

Slash burning is seldom practiced and some logged areas are quickly covered by grass and brush.

Experimental Work

The author does not know of any direct experimental work on techniques for restoring productivity to partially cut areas. Experimental work on other cover types can be applied to the problems, however.

Recommended Regeneration Practices

Fire hazard is as high on logged areas with residual trees as on other recently cut-over areas and fire precautions are necessary before undertaking forestation work. Slash can be crushed down close to the ground when possible to speed deterioration and mineral seedbeds can be exposed in the same operation. Slash accumulations usually need not be burned because most of them are composed of small diameter slash that rots rapidly.

Some partially-cut areas can be restocked naturally by holding wind-firm, full-crowned trees as seed trees or holding groups of immature trees as seed blocks. The groups of trees can be held to maturity and logged then or logged when the new stand is harvested. On other areas where residual trees are in poor condition or sites are subjected to strong winds, all trees should be felled during fireproofing operations and other seed sources used for natural regeneration. If poor seed sources or other factors are likely to delay natural restocking, the areas should be planted without delay because the areas can become covered with grass or brush and make forestation difficult. Chart No. 1 can be used for evaluating the possibilities of natural restocking.

Many first order trees top hardwoods were harvested and fir planted only to run the gauntlet with thinning 1st generation hardwoods.

7. DOUGLAS-FIR, UNCUT

The Situation

Almost all the remaining coniferous forests in the foothills are second-growth stands of Douglas-fir. Present-day logging operations in many of these stands can create non-productive areas as described in previous sections of the report. Careless cutting practices with no regard for regeneration possibilities account for many problem areas but severe site and climatic factors make restocking unsatisfactory on some areas even when accepted regeneration techniques are followed. Some stands have been heavily thinned by fire in the past or have grown as scattered trees so that brush or grass are already established in openings throughout the stands and regeneration is hampered by the fast spread of grass and brush when these stands are logged.

The discussions in the subsections Experimental Work and Recommended Regeneration Practices are directed towards the adoption of cutting practices and silvicultural operations that will increase the possibilities of present stands regenerating promptly after they are logged instead of reverting to troublesome cover types.

Experimental Work

A number of experiments have shown the correlations between cutting practices and factors affecting Douglas-fir regeneration. Many of the correlations have been summarized in Chart No. 1 or discussed in previous sections.

Regeneration has been successful under many harvesting methods in the Douglas-fir region at one time or another. The methods include clear-cuts with seed trees, clear-cuts with seed sources nearby such as staggered setting and delayed setting systems, shelterwood cuts, and group selection cuts. In most experiments the use of large clear-cut areas generally favored natural restocking of Douglas-fir although Worthington observed that restocking was very satisfactory on six small group cuttings of 1.2 to 4.0 acres in old-growth fir in the Puget Sound area. Reproduction on a nearby clear-cut area of 130 acres was not as satisfactory except within five hundred feet of seed sources. (37, p.1) Mr. T. J. Starker, an owner of forest properties in the foothills, has secured reproduction under shelterwood cuts on sites similar to areas where restocking was generally unsatisfactory with clear-cutting.

Recommended Regeneration Practices

Group selection cuts, strip cuts, shelterwood cuts, and clear-cuts with seed trees or nearby seed sources should permit satisfactory restocking of most foothill sites. Certain factors, including slope, aspect, possibility of grass or brush invasion, wind, and seed sources, determine which methods may be most successful on individual areas. Some particular aspects of the problems in regenerating foothill forests should be noted: (1) foothill forests are almost all second-growth. Many are immature and seed-falls may not be as heavy from immature sources, (2) the summer climatic factors are severe in the foothills and increase the effects of adverse site conditions, (3) slash burning may not be essential from the protection standpoint and the slash may be valuable as shelter for reproduction on exposed sites, (4) grass can develop heavy sods on southerly aspects and effectively prevent restocking for many years.

With these considerations in mind certain cutting methods can be recommended for securing reproduction on various sites.

(1) On southerly aspects, cutting methods that protect sites should be used whenever possible, such as group selection, strip or shelterwood cuttings. The

author observed natural stands that simulated conditions after such cuttings. Restocking was often excellent in small openings, on the north sides of stands, and in scattered stands where trees were full-crowned. Two other practices may be helpful. Slash can be left unburned to give extra site protection, and felling of oaks or other unmerchantable trees can be delayed until new reproduction becomes established. All efforts should be towards securing reproduction before grass sod excludes reproduction.

(2) In stands that have been previously thinned by fire or grown as scattered trees, a seed-tree clear-cutting and extensive soil disturbance should produce reproduction in most cases by providing abundant seed supplies and suitable seed beds. Slash burning should be unnecessary but unmerchantable trees could be felled to eliminate undesirable seed sources.

(3) On northerly aspects, clear-cutting with seeding from the side should allow satisfactory restocking in most cases because site conditions are not severe. However, hardwoods such as alder and maple or brush will often encroach on logged areas. Felling of all hardwoods on logged areas and extensive soil disturbance should help in this respect. Hardwood stumps should be painted with a chemical killer to prevent sprouting. Slash

burning may be advisable if areas are very brushy.

(4) On moderate slopes, the effects of aspect are less noticeable and the choice of cutting practices can be more flexible, and with the choice dependent on logging conditions more than silvicultural requirements. Seed tree cuttings or clear-cuttings with seeding from the sides should be satisfactory and soil disturbance with felling of hardwoods and non-merchantable trees should favor Douglas-fir reproduction.

None of the alternative methods can assure satisfactory restocking and planting should not be postponed for many years if areas fail to reproduce naturally. Immediate planting may be advisable when values of residual stands or seed trees reserved from cutting in natural regeneration are high, such as on sites where quick restocking and site protection require the retention of relatively large numbers of trees. Planted trees require some protection on those same sites but it can usually be supplied by non-merchantable trees and slash. Trees should be planted when there is danger of windthrow in residual stands with poor wind firmness or located in places subjected to high winds, such as saddles along ridge lines.

PART IV

SUMMARY AND CONCLUSIONS

SUMMARY

The Willamette Valley is bordered on three sides by the foothills of the Coast Mountains, Cascade Range, and the Calapooya Mountains. Intensive and proper forestation efforts on foothill forestlands are necessary to help assure continuing supplies of timber to dependent forest industries. This report has evaluated silvicultural techniques for regenerating the forest lands and has recommended certain practices. Economic considerations have been ignored for the most part on the premise that silvicultural techniques can be modified to fit economic necessities in individual cases.

Severe site conditions in the foothills can eliminate natural regeneration and hinder artificial forestation on some sites. Douglas-fir is excellent for forestation work because of its value and adaptability to most sites. Some non-native trees such as ponderosa pine, lodgepole pine, shore pine, and dryland races of Douglas-fir survive better than the native firs on some sites but their future development and value are unpredictable. Natural restocking is often satisfactory but severe climatic and site factors make the role of artificial regeneration very important. One site factor that influences reproduction greatly is cover. It sometimes can be modified to encourage natural restocking or to make planting easier.

On grasslands, natural regeneration is unsatisfactory and expensive planting often seems necessary for successful restocking. Survival was best in one experiment when trees were hole-planted and sawdust mixed into the planting soil half-and-half but hole-planting with a machine auger may be more practical for ordinary field planting. Dryland races of fir and shore pines had excellent survival and impressive initial growth in a series of plantations. Ponderosa pine survival was also good but growth was poor.

On fern areas, restocking generally is satisfactory if seed supplies are adequate because fern cover seems to protect sites and encourage reproduction unless fern cover is very dense. Successful reproduction may be possible in heavy fern growth by thinning the fern with scarifying operations and planting afterwards. Under some conditions, fern areas may be scarified to secure natural reproduction.

On areas with light brush cover, regeneration may be satisfactory but brush grows rapidly and once areas are covered by heavy brush, expensive eradication programs and planting are necessary. Eradication with spray applications of chemicals such as 2,4-D or 2,4,5-T is promising.

Scotch broom is an introduced pest that requires control before it becomes a major problem.

Sites covered by stands of Oregon white oak are favorable for the regeneration of Douglas-fir but the trees should be removed if possible after the fir becomes established so growth will not be delayed and full stands can be formed. Underplanting can be successful in many stands if seed supplies are inadequate for natural restocking. Commercial cuttings in older stands that approach the shelterwood method may encourage restocking with firs.

Sites covered by alder or maple often are unsatisfactory as fir sites and the hardwood stands may provide returns as hardwood manufacturing increases. The hardwoods can be girdled or cut and poison applied to the stumps to prevent resprouting if Douglas-fir regeneration is desirable. Very wet sites should be left in hardwoods. Young alder encroaching on fir sites can be controlled easily by the chemical sprays used on brush.

Recently-cut areas often are left in condition unsatisfactory for reproduction and fireproofing is imperative. Additional work is necessary sometimes to prepare the sites for natural restocking or artificial forestation. Undesirable trees of inferior species can be felled to favor fir reproduction unless the trees are providing protection on severe aspects. When residual trees are left they are often spindly or weak-crowned and succumb quickly unless left in groups. Some residual groups can be utilized as seed sources.

The remaining coniferous stands are almost all second-growth forests of Douglas-fir. When logged, they should be cut in a manner to encourage rapid restocking with fir. Cutting methods such as shelterwood cuts, strip cuts, or group selection cuts should probably be used on southerly aspects to protect sites from excessive insolation and encourage reproduction. Immediate planting coupled with the retention of unmerchantable trees and slash for site protection may be advisable if seed sources cannot be left for financial reasons or there is danger of wind damage. Cutting methods probably can be more flexible on moderate slopes or northerly aspects although hardwood invasion is possible on north-facing slopes. Scattered stands usually have many grass and brush areas mixed throughout the stands and ground disturbance and relatively large seed sources are probably necessary if natural restocking is planned.

CONCLUSIONS

This report probably has created an overly-gloomy impression of regeneration possibilities in the foothills by approaching the subject from the standpoint of serious problems to be overcome. It is true that site conditions and climatic factors seriously hinder forestation work on some sites, and that mixed land uses, heavy timber drain, and patterns of small ownerships create additional problems. There are some areas where repeated planting and special techniques of planting have failed to secure reproduction.

Despite these difficulties, commercial forests can be produced by intensive silvicultural management. Many of the present-day difficulties are caused by problem cover types. Proper cutting practices or immediate planting should ordinarily prevent the formation of problem cover types, and even where such cover types exist, reproduction is often attainable as shown by the many stands of fir now rising above fern, brush, and oak covers. Forestation work on certain severe sites may be delayed prudently until new tools or new techniques lower the cost or raise survival possibilities. An excellent point to consider is that severe sites are often poor quality sites. Returns may not warrant expensive regeneration and forestation efforts may be concentrated on more favorable sites that are easier to restock and yield higher returns.

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APPENDIX

APPENDIX

DATA ON THE 1952 PLANTING METHODS TRIALS

Purpose: The testing of various planting methods to determine which methods capable of producing high survivals on a foothill grasslands area.

Location: Oak Creek drainage near sawmill in Oregon State College's McDonald Forest north of Corvallis. Number 1 plantation on west side of Oak Creek. Number 2 plantation on east side.

Planting Site: At low elevation in lower portion of valley. Number 1 plantation on easterly aspect with gentle slope on open grassland with heavy sod. Soil a Cove clay poorly drained and plastic when wet with poor moisture characteristics in summer and subject to severe cracking. Number 2 plantation on westerly aspect with gentle slope on open grassland with heavy sod. Lower portion of plantation on Cove clay soil and upper portion on shallow residual soil with some rock outcroppings.

Planting stock: All Douglas-fir (*Pseudotsuga menziesii*), two year old seedlings from Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown.

Planting date: March 24 through March 31, 1952.

Growing season: Very little rain with prolonged drought extending into early fall months and high temperatures.

Planting methods:

Slit - trees planted in wedge-type slits made with spades. Method used as control treatment.

Mulch - planting spots scalped, trees planted in holes and mulched with one half inch layers of sawdust spread over one foot radius around each tree.

Sawdust - trees hole-planted and sawdust mixed with planting soil half-and-half.

Hole - trees hole-planted without additional treatment.

Shade - trees slit-planted and shingles driven into ground at slight angle on south sides of trees.

All trees planted at six by six feet spacing.

Experimental design: Two randomized block plantations with five blocks and five treatments in each, five hundred trees total.

APPENDIX TABLE NO. 1

MORTALITY OF TREES AT GIVEN DATES BY PLANTING METHODS

Plantation	slit	mulch	sawdust	hole	shade
			Trees Dead		
	End of first growing season (November 25, 1952)				
Number 1	43	44	16	31	35
Number 2	47	33	27	44	40
Total	90	77	43	72	75
			Trees Dead		
	First part of second growing season (June 4-8, 1952)				
Number 1	50	47	33	43	44
Number 2	48	34	31	44	43
Total	98	81	64	87	87

Analysis of data: The mortality data at the end of the first growing season (Nov. 25, 1952) were analyzed by statistical procedures after angular transformations of the survival percentages. Separate analyses were made for the East and West sides, as well as a combined analysis for both sides. In the latter analysis, interaction between side and treatment proved to be just significant and therefore it seemed proper to consider the treatment effects separately by sides. An F test indicates that real differences exist among the transformed treatment means in both instances at the one percent level of significance.

The means of the transformed data are shown in Appendix Table Number 2.

APPENDIX TABLE NO. 2

MEANS OF MORTALITY DATA OF NOVEMBER 25, 1952 IN FIVE BLOCKS AFTER ANGULAR TRANSFORMATIONS

Plantation	Planting Methods				
	slit	mulch	sawdust	hole	shade
Number 1	70.7	77.3	33.6	52.7	57.7
Number 2	81.0	57.5	47.3	67.7	66.5

The least significant differences are as follows:

In Number 1 plantation at the 0.05 level - 20.13
at the 0.01 level - 23.50

In Number 2 plantation at the 0.05 level - 13.79
at the 0.01 level - 16.78

Statistical evaluation: The slit method of planting was used as the control and the other methods were compared with it. Results were:

Sawdust - significant at the 0.01 level in both plantations.

Hole - not significant in either plantation.

Shade - not significant in Number 1 plantation but significant at the 0.05 level in Number 2 plantation.

Mulch - not significant in Number 1 plantation but significant at the 0.01 level in Number 2 plantation.

An additional comparison showed that mixing sawdust with planting soil was advantageous in hole-planting. There were significant differences at the 0.05 level in Number 1 plantation and 0.01 level in Number 2 plantation between the mortality means of trees hole-planted with sawdust mixed into the planting soil and trees hole-planted without additional treatment.

No statistical analysis was made of mortality differences in June, 1953.

DATA ON SUPPLEMENTAL PLANTINGS WITH THE 1952 PLANTING METHODS PLANTATIONS

Purpose: (1) A preliminary testing of some non-native trees to observe comparable mortality with native Douglas-fir. (2) A test of a commercial soil conditioner (Krilium) to observe whether or not survival could be increased by adding it to the soil.

Location: Adjacent to former trials.

Planting site: Same as in former trials.

Growing season: Same as in former trials.

Planting stock: For purpose (1), ponderosa pine (*Pinus ponderosa* Laws) two year old seedlings from the Oregon State Forest Nursery at Corvallis, seed source unknown. Black locust (*Robinia pseudoacacia* L.) one year old stock from the state nursery, seed source unknown. For purpose (2), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from the state nursery. Seed from low elevation but source unknown.

Planting date: Very late March through April 8, 1952.

Planting methods: Pine and locust trees hole-planted without any additional treatment to planting soil. Half of the Douglas-firs hole-planted after sixteen grams of the soil conditioner (Krilium) mixed with one quart of water and poured over planting soil of each tree; the other half of firs hole-planted without additional treatment as control treatment. Trees planted at six feet by six feet spacing.

Experimental design: Two plantations of four randomized blocks numbered one and two to correspond with numbering of Planting Methods Plantations, ten trees in each plot for total of eighty trees under each treatment.

Results: Results are given in Appendix Table No. 3.

APPENDIX TABLE NO. 3

MORTALITY OF TREES AT GIVEN DATES BY SPECIES

Plantation	Species			
	ponderosa pine	black locust	Douglas-fir with Krilium	Douglas-fir control
			Trees Dead	
Near end of first growing season (Sept. 6, 1952)				
Number 1	26	29	31	32
Number 2	38	41	39	31
Total	64	70	70	63
First part of second growing season (June 9, 1953)				
Number 1	37	42	39	36
Number 2	45	43	36	37
Total	82	85	75	73

Analysis of data: No statistical analysis made. All treatments indicate some probability of inferiority to control, although the data are probably insufficient to show significant differences.

DATA ON THE 1953 PLANTING METHODS PLANTATION

Purpose: (1) The testing of promising methods of modified hole-planting once again (prior testing in the 1952 Planting Methods Trials, see page 53) and (2) observing effect of a different soil on survival with the planting methods.

Location: Oak Creek drainage in Oregon State College's McDonald Forest, in small opening just beyond the entrance on the Oak Creek road and to the right of road.

Planting site: At low elevation in bottom of valley on open grassland with westerly aspect and moderate slope. Soil is a shallow Aiken clay loam relatively fertile and well-drained, a soil type superior to that of the 1952 trials.

Planting stock: All Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown.

Planting date: March 24, 1953.

Growing season: Generally favorable with periodic rains and short droughts, few periods of high temperature.

Planting methods:

Slit - trees planted in wedge-type slits made with spades, for control treatment.

Mulch - planting spots scalped, trees slit-planted and mulched with one half inch layer of sawdust spread in one foot radius around each tree.

Sawdust - trees hole-planted and sawdust mixed with planting soil half-and-half.

Vermiculite - trees hole-planted and vermiculite mixed with planting soil half-and-half. Trees planted at six feet by six foot spacing.

Experimental design: Randomized block plantation with four blocks and four plots in each, with ten trees in each plot for total of forty trees in each treatment and one hundred sixty trees total.

Results: Given in Appendix Table No. 4.

APPENDIX TABLE NO. 4

MORTALITY OF TREES BY PLANTING METHODS

Planting Method	Blocks I	II	III	IV	All	Percent
			Trees Dead			
	After first growing season (October 14, 1953)					
slit	2	2	1	3	8	18.4
mulch	4	6	2	3	15	37.5
sawdust	1	4	3	5	13	32.5
vermiculite	4	4	3	4	15	37.5

Analysis of data: No statistical analysis was warranted because of negative results with elaborate planting methods compared to control method and relatively small differences between means of mortality with elaborate planting methods.

DATA ON THE MACHINE PLANTATION

Purpose: The testing of certain machine aids for planting trees on a grassland in the foothills.

Location: Oak Creek drainage near sawmill in Oregon State College's McDonald Forest north of Corvallis. West of Oak Creek in open grassland.

Planting site: At low elevation in lower portion of valley on easterly aspect and gentle to moderate slope on open grassland with heavy sod. Soil a Cove clay poorly drained and plastic when wet with poor moisture characteristics in summer and subject to severe cracking.

Planting stock: All Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown.

Planting date: March 14 through April 4, 1953.

Growing season: Generally favorable with periodic rains, short droughts, and few periods of high temperature.

Planting methods:

Hole - trees hole-planted and grass sod chopped into planting soil. Used as control treatment.

Rototill - strips cultivated with a rototiller and trees hole-planted in the rototilled strips.

Plow - sod turned with single mole-board plow mounted on wheeled tractor, trees planted in bottom of furrows.

Auger - trees hole-planted, holes dug with post-hole digging attachment on a five-horsepower power-saw. (McCulloch)

Fertilized trees - about four tablespoonsful of commercial fertilizer (Vigoro) mixed with planting soil for each tree. Trees planted six feet apart in rows.

Experimental design: Randomized block plantation with three blocks and four main treatment plots, each plot split for two minor treatments, ten trees in each plot for total of one hundred twenty trees.

Results: Given in Appendix Table No. 5.

APPENDIX TABLE NO. 5

MORTALITY OF TREES BY MACHINE PLANTING METHODS

Planting Method	Fertilized	Blocks I	II	III	All	Percent
		Trees Dead After first growing season (October 14, 1953)				
Dug	Yes	0	0	2	2	13
	No	0	1	4	5	33
Rototill	Yes	3	1	3	7	47
	No	1	1	4	6	40
Plow	Yes	1	5	4	10	67
	No	1	4	1	6	40
Auger	Yes	4	5	4	13	87
	No	1	4	3	8	53

Analysis of data: No statistical analysis was warranted because of low and erratic survival among trees with various treatments.

DATA ON THE 1953 RACE PLANTATION

Purpose: The testing of various non-native races of Douglas-fir from comparatively arid locales and non-native species to determine adaptability to foothill grasslands and suitability for restocking grasslands where restocking with native fir difficult. Plantation trees to be remeasured periodically to record development and growth as well as initial survival. This plantation the largest of a series on various foothill sites in McDonald Forest.

Location: Oak Creek drainage near sawmill in Oregon State College's McDonald Forest north of Corvallis. West of Oak Creek in open grassland adjacent to Plantation No. 2 of the 1952 Planting Methods Trials.

Planting site: At low elevation in lower portion of valley on easterly aspect with gentle slope on open grassland with heavy sod. Soil a Cove clay poorly drained and plastic when wet with poor moisture characteristics in summer and subject to severe cracking.

Planting stock:

Dc - Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown. Used as control treatment.

Ds - same stock as Dc given different symbol to distinguish between planting dates for the two groups of trees.

Dc trees planted in winter, Ds trees planted in spring.

Di - Douglas-fir two year old seedlings from University of Idaho, Moscow, Idaho. Seed collected from 3000 to 4000 feet elevation in the Nez Perce National Forest, Idaho in 1949.

Dm - Douglas-fir four year old transplants (2-2) from the Savenac Forest Nursery, Haugen, Montana. Seed from the Nez Perce National Forest, elevation unknown.

Dw(1) - Douglas-fir two year old seedlings from the Wind River Forest Nursery, Carson, Washington. Seed from drier sites of Gifford Pinchot National Forest, Washington, elevation 2000 feet.

Dw(2) - Douglas-fir two year old seedlings from the Wind River Forest Nursery, Carson, Washington. Seed from the Umpqua National Forest, Oregon, 3000 feet elevation.

Lc - Lodgepole pine (*Pinus contorta* var. latifolia Engelm.) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from the Deschutes National Forest, Oregon, elevation unknown.

Sb - Shore pine (*Pinus contorta* var. contorta Dougl.) two year old seedlings from the Soil Conservation Service Nursery at Bellingham, Washington. Seed from the Oregon coast at low elevation.

B - Black locust (*Robinia pseudoacacia* L.) one year old stock from the Oregon State Forest Nursery at Corvallis.

Seed purchased from dealer, source supposedly eastern United States.

R - Ponderosa pine (Pinus ponderosa Laws) two year old seedlings from the Wind River Forest Nursery, Carson, Washington. Seed from Fremont National Forest, Oregon, elevation unknown.

Planting dates: (1) January 25 through February 2, 1953. (2) One group of firs (Ds) in latter half of March, 1953.

Growing season: Generally favorable with periodic rains and short droughts with few periods of high temperatures.

Planting method: All trees hole-planted and grass sod from top of holes chopped into planting soil. All trees planted at six feet by six feet spacing.

Experimental design: Randomized block plantation with five blocks and ten treatment plots in each, fifteen trees in each plot for total of seven hundred fifty trees. One plot planted to wrong species.

Results: Given in Appendix Table No. 6.

APPENDIX TABLE NO. 6

MORTALITY OF TREES BY SPECIES OR RACES

Species or race	BLOCK I	II	III	IV	V	Total	Percent
	Trees Dead						
	End of first growing season (October 14, 1953)						
Dc	10	12	6	12	14	54	72
Di	6	1	4	3	1	15	20
Dm	7	3	3	0	2	15	20
Dw(1)	8	10	0	5	10	42	56
Ds	8	11	11	7	9	46	61
Lc	3	3	0	1	3	10	13
Sb	0	0	0	0	0	0	0
B	7	0	2	3	1	13	17
R	2	x	0	0	0	2	3
Dw(2)	7	3	0	5	2	17	23

Analysis of data: No mortality occurred in the shore pine (Sb) and hence its contribution to error in analysis of variance was zero. Ponderosa pine (R) was omitted from block II by error in planting, but the mortality in the other four blocks was very low - 2 out of 60 or 3.3 percent - and placed this species in the same category as the shore pine with respect to survival. Shore pine and ponderosa pine were therefore set aside, and an analysis of variance was conducted on the remaining eight varieties and species after angular transformations of the original survival records. An F test indicated that real differences existed among the survival means of species and races at the one percent level of significance. The means of the transformed survival data are tabulated in Appendix Table No. 7 below in order of survival success. Least significant differences are 15.9 at the five percent level and 21.4 at the one percent level.

APPENDIX TABLE NO. 7

MEANS OF SURVIVAL DATA OF OCTOBER 14, 1953 IN FIVE BLOCKS AFTER ANGULAR TRANSFORMATIONS

Trees	Sb	R	Lc	B	Dm	Dw(2)	Di	Dw(1)	Ds	Dc
Means	90.0	87.4	71.1	68.8	66.5	64.7	64.6	41.5	38.3	30.8

According to the least significant difference of 15.9 at the five percent level, the shore pine (Sb) and the ponderosa pine (R) survived better than black locust (B), Douglas-fir of Montana (Dm), Douglas-fir of the Umpqua (Dw(2), and Douglas-fir of Idaho (Di). No differences were apparent among the individuals of this second group but they all survived better than the remaining trees, Douglas-fir of the Gifford Pinchot (Dw(1), and local Douglas-fir stock (Ds) and (Dc).

Special note: Many of the shore pine had phenomenal leader growth the first and second growing seasons. Some extended a foot or more each season. Almost all trees of the species had healthy color and full foliage. In contrast, growth and vigor was poor for the ponderosa pines although survival remained high.

DATA ON OTHER RACE PLANTATIONS ON GRASSLANDS

Purpose: Additional testing of non-native species to determine their adapability to foothill grasslands and suitability for restocking grasslands where restocking with native fir difficult. Plantation trees to be remeasured periodically to record development and growth as well as initial survival.

Location: Oak Creek drainage in Oregon State College's McDonald Forest north of Corvallis. Two plantations in isolated grasslands on west side of Oak Creek upstream from large grassland containing the main 1953 Race Plantation.

Planting site: At low elevation on easterly aspect with gentle to moderate slopes on open grassland with heavy sod. Underlaid with heavy residual soils.

Planting stock:

Dc - Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown. Used as control treatment.

Sb - Shore pine (*Pinus contorta* var. contorta Dougl.) two year old seedlings from Soil Conservation Service Nursery at Bellingham, Washington. Seed from the Oregon coast at low elevation.

Pc - Ponderosa pine (*Pinus ponderosa* Laws) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from east side of Cascade Mountains, elevation unknown.

R - Ponderosa pine two year old seedlings from the Wind River Forest Nursery, Carson, Washington. Seed from Fremont National Forest, Oregon, elevation unknown.

Planting date: March 25 and 26, 1953.

Growing season: Generally favorable with periodic rains and short droughts with few periods of high temperature.

Planting method: All trees slit-planted with no additional treatment at six feet by six feet spacing.

Experimental design: No formal design for statistical analysis. Plantation No. 1, species planted in individual rows of 100 trees each. Plantation No. 2, species planted in individual rows of about sixty trees each.

Results: Given in Appendix Table No. 8.

APPENDIX TABLE NO. 8

MORTALITY OF TREES BY SPECIES

Plantation	Species or Races							
	Dc	Dc%	Sb	Sb%	Pc	Pc%	R	R%
	Trees Dead and Percentages End of first growing season (October 13, 1953)							
Number 1	74	74	2	2	9	9	none planted	
Number 2	35	60	5	8	7	12	5	8

Analysis of data: No statistical analysis made, but results confirmed the relative ratings of species and races in the main 1953 Race Plantation.

DATA ON THE FERN LAND PLANTATION

Purpose: Comparative testing of non-native species planted on a bracken fern and grasslands site.

Location: Oak Creek drainage near sawmill in Oregon State College's McDonald Forest north of Corvallis. On west side of Oak Creek just south of the 1953 Race Plantation in same open area.

Planting site: At low elevation in lower portion of valley on northerly aspect with moderate slope on area covered by light bracken fern and scattered grass. Soil clayey but more friable and deeper than the soil in the Race Plantation.

Planting stock:

Dc - Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown. Used as control treatment.

Sb - Shore pine (*Pinus contorta* var. contorta Dougl.) two year old seedlings from Soil Conservation Service Nursery at Bellingham, Washington. Seed from the Oregon coast at low elevation.

Pc - Ponderosa pine (*Pinus ponderosa* Laws) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed source from eastern Oregon, elevation unknown.

B - Black locust (<u>Robinia</u> <u>pseudoacacia</u> L.) one year old stock from the Oregon State Forest Nursery at Corvallis. Seed purchased from dealer, source supposedly eastern United States.

<u>Planting date</u>: March 20, 1953.

<u>Growing season</u>: Generally favorable with periodic rains and short droughts with few periods of high temperature.

<u>Planting method</u>: All trees slit-planted without additional treatment at six feet by six feet spacing.

<u>Experimental design</u>: No formal design for statistical analysis. Species planted in individual rows of about forty trees each.

<u>Results</u>: Given in Appendix Table No. 9.

APPENDIX TABLE NO. 9

MORTALITY OF TREES BY SPECIES

Species or Races							
Dc	Dc%	Sb	Sb%	Pc	Pc%	B	B%
Trees Dead and Percentages							
End of first growing season (October 14, 1953)							
8	20	1	2½	4	10	0	0

<u>Analysis of data</u>: No statistical analysis made, but the results confirmed the relative ratings of some species in the main 1953 Race Plantation and mortality was considerably less for some species compared to the main plantation.

DATA ON THE SOAP CREEK PLANTATIONS

Purpose: (1) The testing of various non-native races of Douglas-fir from comparatively arid localities and one hardwood species to determine their adaptability to severe foothill sites and suitability for restocking areas where restocking difficult with native trees. Plantation trees to be remeasured periodically to record development and growth as well as initial survival. (2) Testing of two planting methods (hole-planting and slit-planting) for native Douglas-fir to determine which method would produce highest survival.

Location: Two plantations in the Soap Creek drainage on Oregon State College's McDonald Forest north of Corvallis.

Planting site: At low elevation, No. 1 plantation on southwesterly aspect with moderate slope covered lightly by hardwood brush and grass and underlaid with a gravelly residual soil. No. 2 plantation on northeasterly aspect with moderate slope covered lightly by hardwood brush and grass and underlaid with gravelly residual soil. Both sites logged and burned about 1948.

Planting stock:

Dc(1) - Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) two year old seedlings from the Oregon State Forest Nursery at Corvallis. Seed from low elevation but source unknown. Numeral (1) means trees hole-planted.

Dc(2) - same stock trees slit-planted.

Dm - Douglas-fir four year old transplants (2-2) from the Savenac Forest Nursery, Haugen, Montana. Seed from the Nez Perce National Forest, elevation unknown.

Dw(1) - Douglas-fir two year old seedlings from the Wind River Forest Nursery, Carson, Washington. Seed from dry sites of the Gifford Pinchot National Forest, Washington, elevation 2000 feet.

B - Black locust (Robinia pseudoacacia L.) one year old stock from the Oregon State Forest Nursery. Seed purchased from dealer. Source supposedly eastern United States.

Planting date: February 28 through March 17, 1953.

Growing season: Generally favorable with periodic rains and short droughts with few periods of high temperature.

Planting methods: All non-native trees hole-planted and native firs either hole-planted or slit-planted.

Experimental design: No formal design, species planted in individual rows of about seventeen to one hundred trees.

Results: Given in Appendix Table No. 10.

APPENDIX TABLE NO. 10

MORTALITY OF TREES BY SPECIES AND PLANTING METHODS

Plantation	Species, Races and Planting Methods				
	Dc(1)	Dc(2)	Dm	Dw(1)	B
	Trees Dead or Missing and Percentages End of first growing season 10/20/53-11/3/53				
1					
Trees Planted	57	51	19	66	19
Dead & Missing	31	30	2	10	1
Percent	54.4	58.8	10.5	15.1	5.3
2					
Trees Planted	94	100	none	38	24
Dead & Missing	39	35	--	11	1
Percent	41.5	35.0	--	28.0	4.2

Analysis of data: No statistical analysis made, but in general results agree with those in Race Plantation and permit extension of the conclusion that drought resistant races of Douglas-fir are better survivors than the local races on severe logged and burned foothill sites. Much of black locust mortality resulted from heavy deer browsing.