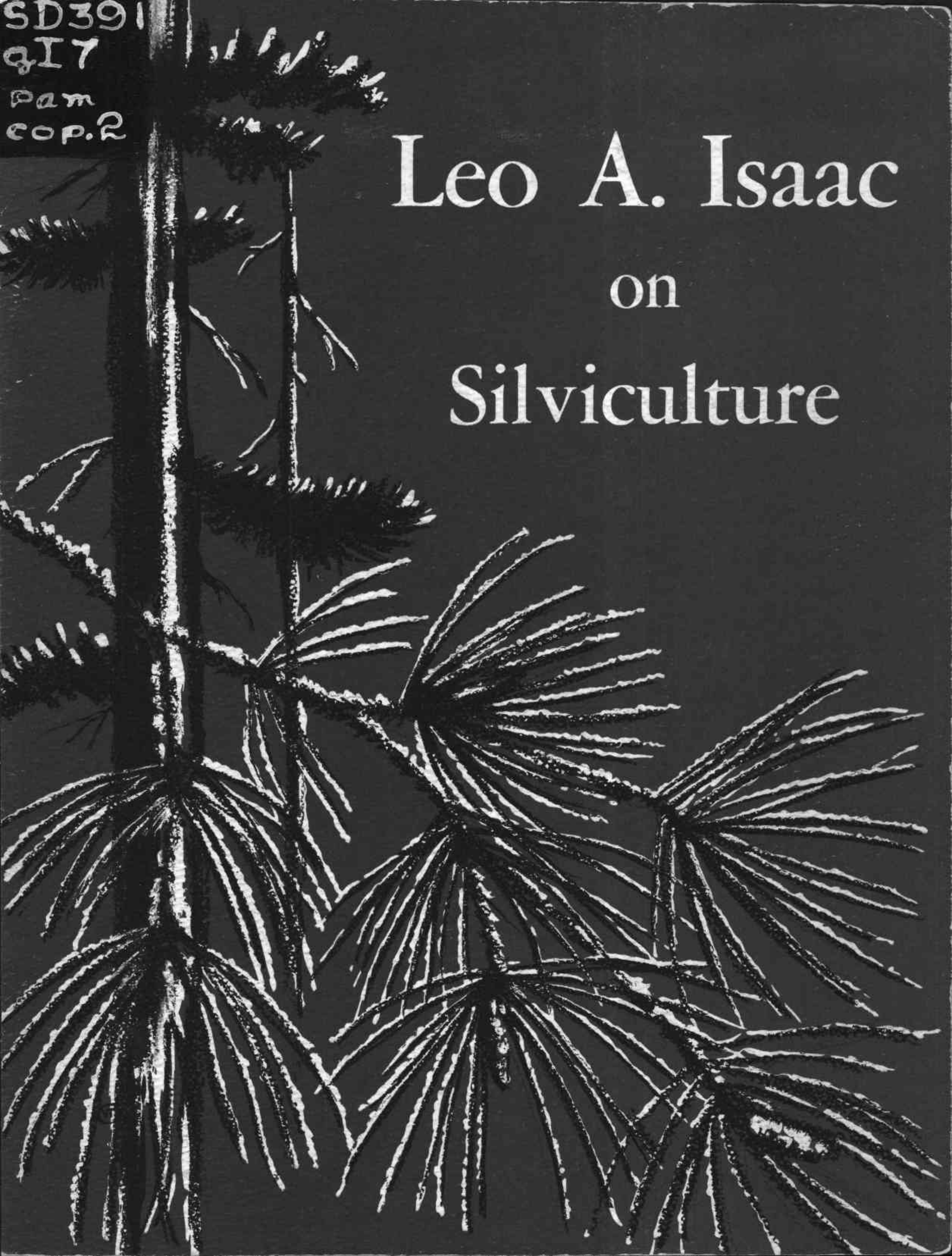
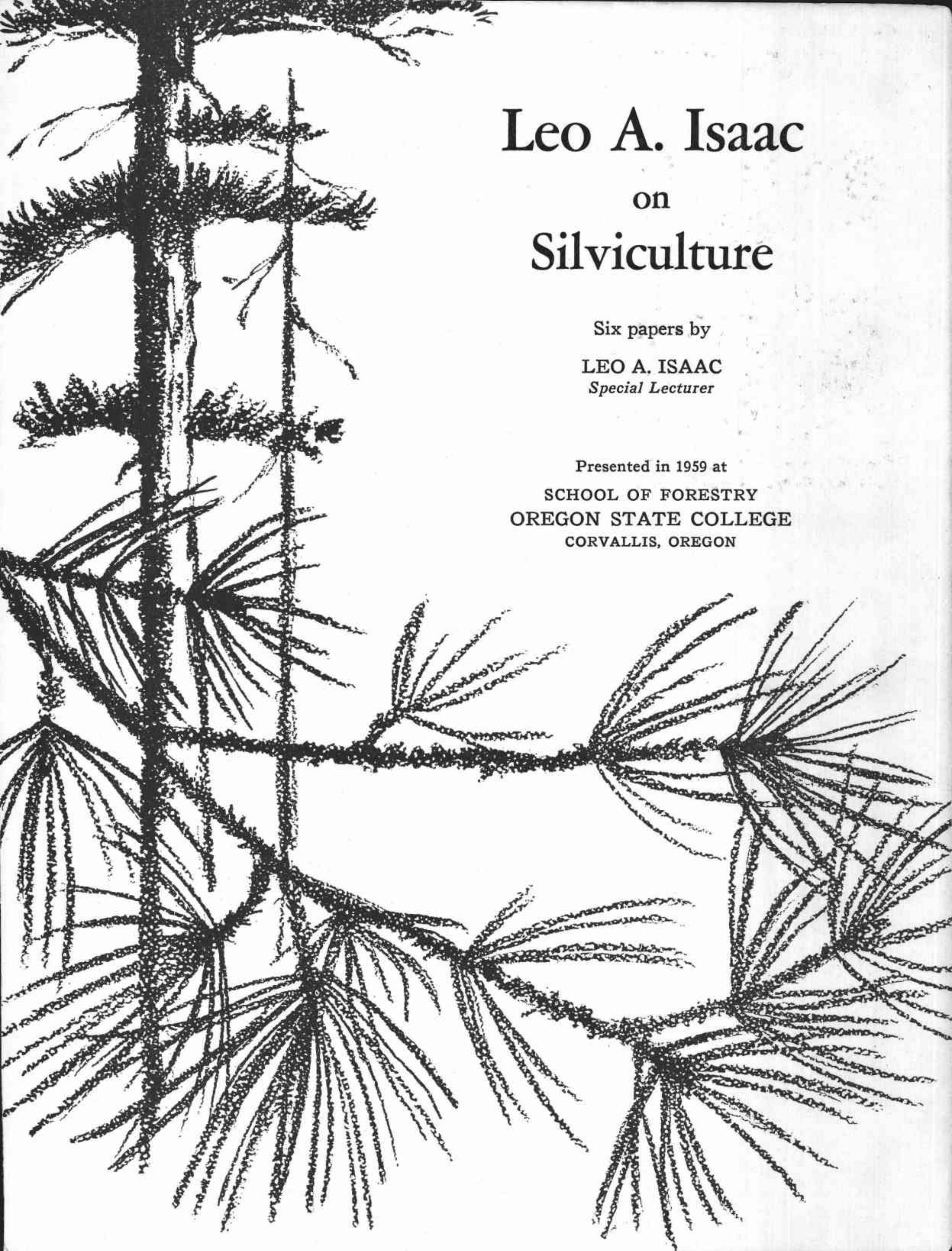
Leo A. Isaac on Silviculture





Leo A. Isaac
on
Silviculture

Six papers by

LEO A. ISAAC
Special Lecturer

Presented in 1959 at

SCHOOL OF FORESTRY
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Preface

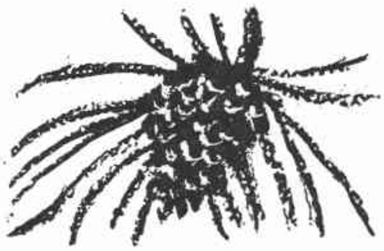
These silvicultural essays by Leo A. Isaac are a further contribution to forestry from the Louis W. and Maud Hill Family Foundation. Through the good offices of the Foundation, the School of Forestry at Oregon State College was privileged to have Mr. Isaac as visiting professor in the spring of 1959. In these talks he made a special effort to bring to the students field information that normally would not be found in textbooks. The lectures which Leo gave are reproduced here for wider circulation. The School is greatly indebted to the Foundation for making these lectures possible, and wishes to express its high appreciation of this support.

In forestry circles Leo enjoys an international reputation, and stands in no need of introduction. However, it is only fair to cite here some of his honors and his works. He has been awarded the highest recognition bestowed by the Oregon Academy of Science, the Society of American Foresters, the University of Minnesota (his Alma Mater), the United States Department of Agriculture, and the Western Forestry and Conservation Association. In acknowledgment of his lifelong research in regeneration, the West German government invited him to Europe as its guest; and he served the United Nations for over two years as a forestry adviser to Turkey. This latter assignment followed his retirement after nearly 40 years with the U. S. Forest Service.

Among his best known publications are "Reproductive Habits of Douglas-fir," "Factors Affecting the Establishment of Douglas-fir Seedlings," "Partial Cutting in Old-Growth Douglas-fir," and "Better Douglas-fir Forests from Better Seed." This last was written while at the University of Washington under a special grant from its College of Forestry.

This collection is an interesting cross-section of Leo's ideas on a variety of subjects. His many friends, starting with the School of Forestry, will welcome them as an addition to the legend that is Leo Isaac.

—W. F. McCulloch
Dean, School of Forestry
Oregon State College.



1. *Notes on Silviculture and Ecology of Douglas-fir*

THE FORMER scientific name of Douglas-fir, *Pseudotsuga taxifolia,* means false hemlock with yew-like leaves. Yet the tree itself is very different from either hemlock or yew, both in nature and habit of growth. It is called a fir, yet does not belong to the true fir genus (Abies), instead belongs to a separate genus that contains four well recognized species: they are *Pseudotsuga japonica* of Japan, *Pseudotsuga sinensis* of China, *Pseudotsuga macrocarpa* of California and *Pseudotsuga menziesii* our own common Douglas-fir here in the Northwest. Two strains of this species are recognized in the U. S. Forest Service Check List of Native and Naturalized Trees (1953) based mostly on foliage color and cone scale variation. They are: the *glauca* (or blue form) from the Rocky Mountain and southern part of the range; and *menziesii* (or green form) from the Pacific Coast. The latter strain is by far the most important commercially.

Douglas-fir is a magnificent tree, surpassed in size only by the redwoods. There are several living trees in Washington and Oregon that are over 15 feet in diameter and many that are over 300 feet in height. Remnants of stands between 600 and 700 years of age are not uncommon and many trees have been cut that were over 1,000 years old. Under virgin conditions it has produced the finest timber stands in America, if not in the world. Maximum volume measured on a single acre in a 375 year old stand is 390,000 board feet.

The question is often asked, "Why haven't we introduced better trees from other countries?" The simple answer is that we have not been able to find a better forest tree than Douglas-fir. At the Wind River Arboretum and elsewhere more than 150 different species of conifers have been tested in competition and Douglas-fir has made better growth and development than any of the other species.

Although this tree makes its best development in the humid climate west of the Cascade Summit here in Washington and Oregon, it does grow under an extremely wide variety of climatic conditions. It grows from the cold, moist coast of British Columbia south to the warm, moist region of the redwoods where it is seldom exposed to frost. Inland and eastward it goes up to timber line in the mountains and south to New Mexico and Arizona where there is considerable summer rainfall. Its eastern limits are the Piney Hills in northeast Montana, where the annual rainfall is only 12 inches and the minimum temperature goes down to 56° below zero Farenheit. Yet this tree, that covers such a wide range of conditions, is highly sensitive to change and is subject to frost damage, and needle blights, and other diseases, if moved to a climate different from the natural environment of a particular strain. Good growing strains, moved to a similar environment as far away as western Europe, have made spectacular growth, surpassing by far, in both volume and quality of material, the other important trees used in European plantations. In other instances, seed taken from the wrong environment planted side by side with the successful plantations have made very poor growth and in many cases have gone to pieces before they reached commercial size.

As well as a rather wide climatic range, Douglas-fir has a wide tolerance for soil types. Given an abundance of moisture and adequate light, it will grow on any soil from coarse gravel to heavy clay. However, its most magnificent development, its most rapid growth and its longest life occurs on deep, well drained loam soils.

Douglas-fir usually grows in extensive pure stands, although it may occur in mixture with hemlock, true firs and the cedars. It is interesting to note as one moves from pure stands of Douglas-fir in the hills and interior valleys toward the coast in Washington and Oregon, Douglas-fir first gives way to western hemlock, Sitka spruce and cedar on the moist stream bottoms, then on the moist and northerly hillsides. Close to the coast it is found only on the well drained, warm southerly hillsides and ridges. There are intrusions of alder, cottonwood, bigleaf maple and a large number of brush species but Douglas-fir is not known to require or to grow in a true mixture with broadleaf species.

Douglas-fir is classed as an intolerant tree and therefore will not reproduce in the dense shade of the forests west of the Cascade Mountains where it makes its best growth. The dense virgin forests that man first found when he came to the northwest country consisted mostly of even-aged stands. These even-aged forests followed the complete or almost complete removal of the old-growth forests by fire, windfall, insects or disease, or a combination of these. Occasionally a partial burn would result in a two or three-age class forest, but this was the exception rather than the rule. The Douglas-fir stand, except in the dry fringe types, is therefore a subclimax type of forest that would disappear entirely if it were kept indefinitely protected from fire, disease or cutting. As a normal even-aged stand grows and becomes mature, the weaker individuals of Douglas-fir are crowded out by suppression or killed by some other agency and fall out of the stand *one by one*. In the absence of fire, these trees are replaced, not by Douglas-fir, but by its tolerant associates that can reproduce in the shade, such as yew, hemlock, cedar and the true firs, grand fir at lower elevations and silver and noble fir higher up.

Since this tree requires almost complete removal of the stand in order to reproduce, naturally it does not lend itself to selection cutting except in the driest part of the range. But it is possible to substitute clear-cutting and harvest, for nature's method of removal (insects and fire) in order to adapt this tree and this stand to a managed forest. This substitution of cutting for nature's method of removal must be done with extreme care in order to secure natural regeneration. Nature is never in a hurry, and if we want prompt and full restocking it may be necessary at times to resort to planting or seeding to prevent other species or brush from replacing the Douglas-fir.

Douglas-fir is better than an average seeder. Both male (staminate) and female (pistillate) flowers occur on the same tree and even on the same twig near the tips of the branches, but there is evidence of a provision in nature that prevents this tree from self-pollinization and inbreeding. Some observers claim that the male and female flowers on the same tree seldom open at the same time. Others hold that the tree is self-sterile, the pistillate flowers from one tree must obtain their pollen from another tree if they are to produce cones and fertile seed in appreciable amounts. Either or both claims must be true as isolated trees never produce heavy crops of viable seed.

An interesting story came back to us from Europe. There are two trees in Edinburgh, Scotland raised from the first seed sent to England by David Douglas in 1827 from McLoughlin's Hudson's Bay post at Vancouver, Washington. Both trees started producing flowers rather profusely about 1850 but only one of them has produced good seed crops at rather frequent intervals since. Very evidently the second tree is pollinated by the first, but the reverse is never true. This seed has been carefully gathered, and today there are hundreds of acres of very fine plantations from the seed of this one tree in the British Isles and in western European countries. The interesting point is that both trees flower profusely, but only one of them produces seed.

The specific source of the original seed brought over by David Douglas has been a complete mystery in Europe until very recently. The seed was shipped with other seeds from San Francisco, and for nearly a hundred years, Europeans have been searching without success in the vicinity of that city for a similar strain of Douglas-fir. Recent studies of the records of the Hudson's Bay Company and David Douglas' diary indicate that the seed was probably collected on the plains outside of Vancouver, Washington.

Douglas-fir growth among young trees varies greatly because the seed from a given tree carries the genes from two parents and these parents in turn carry a variety of genes from many generations of parents that have gone before them. However, it is a safe assumption that seeds from a fine parent tree, pollinated by an equally fine specimen are more likely to produce seedlings that are above average. It is also quite certain that in their offspring, there will also be some seedlings that will be below average as well as those that are average or above average.

Records from test plantations now 40 years old show that superior strains have developed under natural conditions and that their offspring retains these characteristics. Natural stands have been found that are making better than expected growth for a given soil or elevation. Superior stands are being used more and more to provide the seed from which seedling stock is derived for reforestation.

For the current seed crop in Douglas-fir, tiny flower buds develop in the fall of the year under a small bud scale and remain fairly inconspicuous for awhile. By mid-winter, however, the female flower bud will have grown to a much larger size ($\frac{1}{2}$ inch) than the male flower bud or the vegetative bud. The female flower usually occurs just back of the terminal bud near the tip of the branch. Cones begin to take form in the spring of the year about the time growth buds burst. They open and remain in an upright position for awhile to receive pollen from another tree. After pollination the cones quickly close and turn down, following which both cone and the seeds grow to maturity.

Pollination period varies with altitude, and latitude, but under average conditions takes place over a 2 to 3 week period in April—for the individual tree the period is approximately a week. The pollen sacs in the male flowers burst and the orange colored, dust-like pollen is spread by the wind. The pattern of distribution of pollen is not greatly different from that of Douglas-fir seed, although in some instances the pollen may travel much farther. Pollen flight from open growth or free crown trees is certain to be far greater than that from trees in a closed stand. Silen, working in the Willamette Valley found pollen in abundance for a distance of six times parent tree height, and small amounts of pollen everywhere in the valley during the shedding season. Pollen released in a normal stand has been observed to quickly settle into the crowns of adjoining trees and flight under such circumstances is not likely to extend more than a few hundred feet unless associated with upward air currents or great turbulence. Although pollination takes place in April, the actual fertilization of the individual egg cell or seed may not take place for 6 weeks. That portion of the seeds that are not successfully fertilized may continue to develop into hollow or sterile seeds or they may wither as the cone develops. Once fertilized, the embryo continues to develop into a viable seed and the process of regeneration is again on its way.

An abundant flower crop is the first indication of a favorable seed crop, but it is by no means positive assurance. Pistillate flowers may be injured by severe late frosts or pollination may be thwarted by continuous rainy weather. Cones frequently have insect infestations which greatly reduce the seed crop. Strangely enough, insect infestations appear to be heaviest when the cone crop is light.

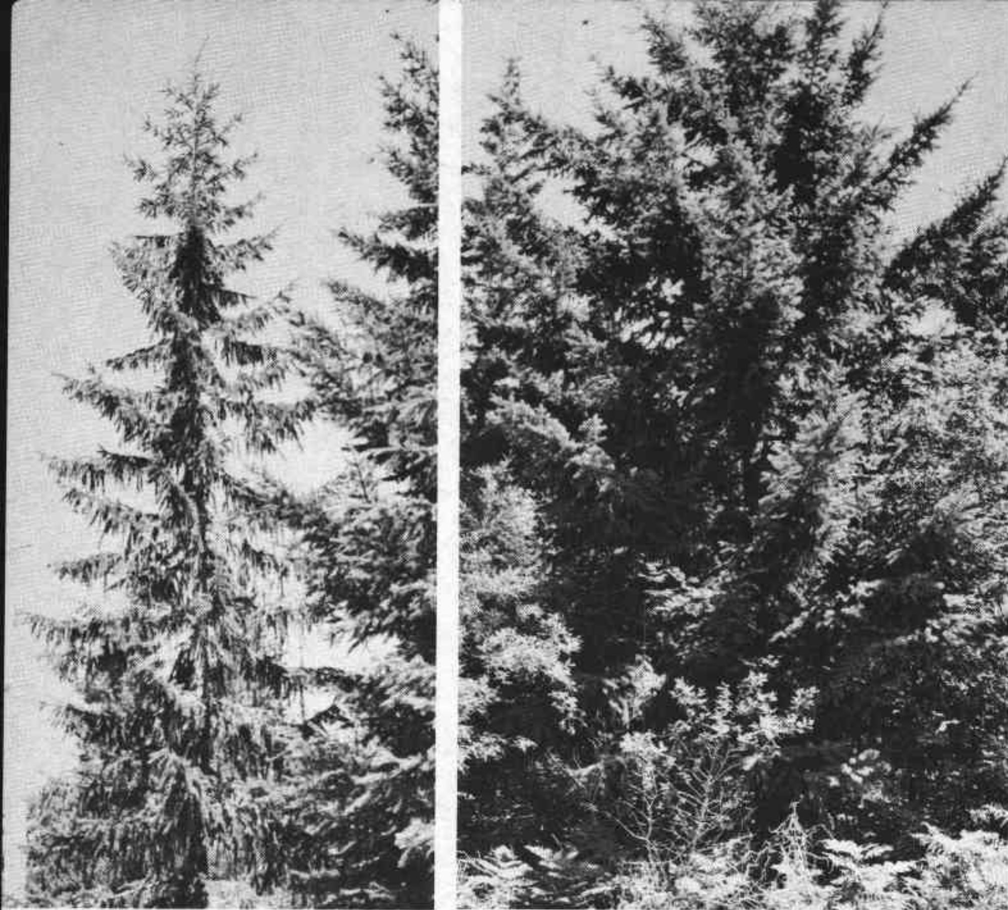
Douglas-fir cones normally ripen in August and normally start shedding seed at least by the first of September. Regardless of degree of ripeness, the cones remain closed in damp or rainy weather; therefore, the season of dissemination may vary from year to year. This matter of ripeness is important; cones cut by squirrels or picked before seeds are well filled out and ripened, produce seed that may germinate but will not have vigor enough to produce a seedling that will live. Normally about three-fourths of the seed has fallen by the end of October, but a small amount may remain in the cones and fall from time to time until the following spring. Many of the empty cones hang on the trees through the second season, which may cause errors in surveys of the current crop of new cones.

The winged seed of Douglas-fir when released from the cone falls with a spinning motion at a rate of about 3 miles an hour. It is scattered by the wind with a diminishing density for a considerable distance. Under favorable conditions a cut-over area is expected to receive adequate amounts of seed for distances up to six times tree heights from a timber edge. But air movement, with its turbulence and rising currents, is so extremely variable that wide variation from average seed flight frequently occurs.

There is still considerable difference of opinion as to the amount of seed or number of seed trees required to reseed cut-over areas, but some rather convincing records are available. During the past 32 years, there have been six abundant seed crops and 10 failures. The other 16 were an irregular mixture of light and medium crops. A failure or light seed crop usually comes both before and after a heavy crop. Not all trees produce cones, and most trees left after logging have small crowns. A good seed producer, in a good year, will probably produce a pound of seed. If the good producers survived, two such trees would adequately reseed an acre providing the seed-eating rodent population was very low and conditions for germination and survival were favorable. Seldom do all of these favorable conditions occur on a single acre, much less on a large continuous area. It is my considered judgment, substantiated by many field records, that the equivalent of several seed trees per acre is necessary to reseed a cut-over area before competition and other factors make it impossible.

Life of Douglas-fir seed on the forest floor, once thought to extend over a span of years, is really very short—a single season. Actual tests

1. Staggered settings in old-growth Douglas-fir stands on western slopes of Cascade Mountains.
Western Ways Inc. photo.



2. Desirable (left) and undesirable form (right) for lumber production. Horizontal branching habit with relatively thin branches (left) reduces the knot surface in the final product and a high percentage of the wood produced is formed in the bole as opposed to the tree on the right. Both trees are growing within 100 yards of each other under similar conditions.

3. Mature Ponderosa pine stand.
U. S. Forest Service photo.

substantiated by the occurrence of seedlings in the field have shown that practically all seed not eaten by birds and rodents germinates or decays within the growing season following its fall. Some of the seed sown late in the spring in nursery beds or in the field will hold over and germinate the following spring. The same is true of seed that by chance is held in the cone until late in the following spring.

In the original scheme of things Douglas-fir came in after fires (set by lightning or Indians). Seed for the most part germinated on bare mineral soil from which surface duff and raw humus had been burned away. The same holds true after logging but it germinates even better on a disturbed mineral soil surface that contains a moderate amount of humus in the upper layers to hold moisture.

Once germinated the Douglas-fir seedling has a host of hazards that limit its chances for ultimate survival. Its habitat for the most part is one of hot, dry summer days and cool nights. Frost is the first enemy that may take the toll of tender, young seedlings. The seedling may be torn from the soil by "frost heaving" or the tender stem destroyed just above the soil surface.

After germination the seedling normally requires some shade to survive. Shade of living vegetation or "dead" shade from debris protects the seedling from both cold at night and excessive heat in the daytime. Tissue of seedling stems may be injured by temperatures of 123° F. or higher depending on seedling age. On hot, southwest exposures and flat areas having air temperatures of 85° to 90°, the author has recorded surface soil temperatures of over 130° on unburned sites. Black burned surfaces had temperatures 10° to 15° hotter. Under complete insolation such temperatures cook the cambium of the young seedling at the ground surface and the seedling dies and topples over. The highest soil temperature recorded on a black charred surface was 166° F.

Late summer drought is perhaps the most consistent cause of seedling loss. This loss appears to be equally heavy or even heavier on good soils than on the more gravelly or stony soils. The seedling on the rich soil develops a large lush top and a shallow spreading root system, and when the hot summer drought period strikes, the surface soil dries from the top down faster than the roots can penetrate. On the poorer soil, crown growth is less and the roots penetrate deeper in search of plant food and moisture. With a small crown to support the more extensive root system enables the seedlings to survive when the drought period hits.

Shade has been mentioned in connection with early seedling survival of Douglas-fir but it has far deeper significance. First it is a matter of protection, later a matter of tolerance. On the drier, warmer part of its range the seedling normally requires some shade to survive. But once established regeneration thrives best in full top light and the growing tree becomes fairly intolerant of shade. "Dead" shade of dry weeds and slash is more favorable than shade from living vegetation because it does not compete with the seedling for moisture and plant food. Also there is a delicate balance between the point where living shade is beneficial and where it becomes harmful competition, like weeds in a garden. In the most simple terms, anything more than light shade of grass, weeds or brush becomes progressively more detrimental to seedling establishment and early growth, and anywhere above 75% of total shade may become a limiting factor to natural restocking. In a controlled test, seedlings quickly died under virgin timber where the light intensity was 1% or less even though there was no root competition from over-wood. Identical seedlings in 25% of full sunlight and without root competition made better survival and growth than seedlings on the open cutover for the first two years. The vigor of these seedlings gradually declined until by the tenth year growth had practically stopped and the seedlings died one by one. In the drier part of its range where the stands are shorter and less dense, and the crowns let in more light, some seedlings manage to survive under timber. In some such instances, they may develop into an all-aged forest, but this is certainly not the case in the dense stands west of the Cascade Range in Washington and Oregon.

Good natural stands normally start with anywhere from 1,000 to 10,000 seedlings per acre. Once the canopy is closed, the more vigorous individuals gradually assert their dominance and the weaker trees are crowded out by suppression. By age 40, the number will be reduced to about 500 trees or less per acre. In the absence of cutting, natural causes will reduce the number of stems and gradually open up the dense even-aged stands. A root fungus, *Armillaria mellea,* that attacks the young tree at the root collar, is usually the first to show up. *Poria weirii,* another root rot, may occur about the same time or later, and has been more prevalent in young stands in recent years. These diseases may kill a single tree or a large group in an infection center causing serious losses as the crowns are opened up and the stand develops. Bark beetles and other insect pests often play a similar part in opening up young even-aged forests. But poor tree distribution or over-stocking may reduce growth and vigor of stands, therefore in over-crowded stands we may substitute a partial harvest or thinning for these natural methods of opening up dense stands as they approach maturity. It is true that if a Douglas-fir stand is not destroyed by fire, tempest, or other enemies, its tolerant, associates, cedar, hemlock and the true firs, will develop as an understory in the dense shade and eventually take over, as the even-aged Douglas-firs mature and *die out one by one*. We have many examples of this climax forest in different stages of that transition. However, this new climax forest of tolerant trees is inferior to the old even-aged subclimax of Douglas-fir. Furthermore, there is one other important point to remember, all of these tolerant associates make their most superior development, not in the all-aged climax forest, but only when they occur as even-aged stands associated with Douglas-fir or with each other.

It is therefore, a lucky circumstance that here in the Douglas-fir region man need only to substitute cutting and harvest for nature's methods of complete forest removal, in order to prepare an area for renewal of the best type of forest that it can produce, and at the same time preserve other forest values. But substituting cutting and harvest for nature's method of removal is not an overly simple procedure. Nature in the process of renewal was never in a hurry, neither did she demand prompt and full stocking of commercially important species on every acre. In her scheme of things, recreation pressure was not great, subsurface runoff was ample even after fires and there was plenty of time for wild life to build up on a burned area. Under her methods of removal, soil was never torn up and it was seldom denuded to the extent that it would be highly subject to erosion or leaching.

Since man, for his greater comfort and leisure, is demanding prompt and full timber crops and at the same time wishes to maintain recreation values, wild life, streamflow, and other uses, he must aid nature in her processes to speed up restocking. Progressive thinning is the first logical step in the harvesting of young Douglas-fir stands. As the stands grow older and thinning has progressed to a point where there are not sufficient stems to utilize the site, then patchwise clear cuttings should follow. If carefully done this procedure provides walls of green timber to aid in fire protection, an adequate seed supply for natural regeneration and the most satisfactory habitat conditions for watershed protection, wild life and recreation.

2. *Silvicultural Aspects of Species Growing With Douglas-fir*

THE SPECIES that commonly grow in association with Douglas-fir in approximately the order of abundance or frequency in Washington and Oregon are: western hemlock, *Tsuga heterophylla;* western redcedar, *Thuja plicata;* grand fir, *Abies grandis;* Pacific silver fir, *Abies amabilis;* noble fir, *Abies procera;* Sitka spruce, *Picea sitchensis;* Port-Orford-cedar, *Chamaecyparis lawsoniana;* lodgepole pine, *Pinus contorta;* sugar pine, *Pinus lambertiana;* and ponderosa pine, *Pinus ponderosa.*

The silvicultural aspects of a mixed stand have far greater significance than most foresters suspect, and on a site where one or more trees occur readily in a stand, and make good growth, they should not be ignored in regeneration and management plans. For the purpose of comparison I will cite advantages of both pure and mixed stands.

Advantages of a Pure Stand in the Douglas-fir Type

1. In most forest localities one particular tree species is superior for the site from the standpoint of vigor, growth rate, form and quality of material.

2. A specific type of material is often wanted in a particular locality; it may be pulp-wood, construction material, furniture wood, fuel, etc. In such instances the demand is best filled by pure stands of the best species for the purpose.

3. Severe sites or severely deteriorated sites are often difficult to reforest and one particular species will survive when others will not. In such instances a pure stand is necessary at least for the first rotation.

4. With pure stands it is necessary to develop procedures and markets for only one class of material.

Advantages of a Mixed Stand in the Douglas-fir Type

1. Medium and heavy seed crops of Douglas-fir and its associates occur at irregular intervals but with a mixed stand there is usually a medium or heavy crop of at least one species every year. That results in more prompt and adequate natural reseeding.

2. Shade tolerance and seedbed requirements differ for seedling establishment for different species, therefore the species most suited to a particular spot or part of an area will predominate. The higher seedling survival will result in more prompt and adequate restocking.

3. The different species that grow in mixture with Douglas-fir vary in their demand for sunlight, soil moisture, growing space, and plant nutrients. Each species takes something from the site not needed by the other species present; therefore a mixed stand is more apt to more fully utilize the site than a pure stand.

4. Forest insects and diseases often attack a single species or genus and a mixed stand not only provides assurance against complete loss of a stand, but also forms a barrier to the spread of disease from one tree to another within a stand. Example: White pine made up 15% of young virgin stands in Western Washington and Oregon. It was wiped out by blister rust but the rest of the stand and the final yield was not hurt.

5. The annual fall of needles, cones and twigs forms the natural fertilizer for the forest, and the amount of plant nutrients so furnished by each tree species varies a great deal. For example the western redcedar that occurs in light mixture in our Douglas-fir stands has been more or less ignored or neglected in our plans for reforestation, yet it has been found to be the highest contributor of plant nutrients among our northwest conifers. Its needle fall provides about twice as much calcium and 10 times as much nitrogen as the needle fall of lodgepole pine, and it approaches alder as a soil conditioner.

6. Most associates of Douglas-fir are more tolerant of shade than Douglas-fir and over a great part of the region they do not grow quite as well as Douglas-fir; therefore, these species automatically occupy a secondary position in the forest crown and allow a given acre to support more stems than a pure stand of Douglas-fir or any other intolerant tree. The heaviest volumes in young stands on the better sites in the Douglas-fir type occur, not in the pure stands, but in the mixed stands containing a considerable amount of western hemlock and some cedar. Toward the coast some Sitka spruce may also occur in the mixture.

7. In many localities there is a demand for material other than Douglas-fir such as hemlock or true firs for pulp or cedar for poles or posts. With more than one species present it is possible to vary the cut in accordance with fluctuations in the current demand.

From the foregoing lists of advantages of pure and mixed stands it is quite evident that mixed stands are advantageous wherever more than one species will make good growth on the site when grown in mixture.

With the exception of noble fir all of the associate species are equally or more tolerant of shade than Douglas-fir. For that reason they may occur along with Douglas-fir natural reproduction and come in as an even-aged stand, or they may develop late as an understory as Douglas-fir matures and begins to open up from one cause or another. It is the more tolerant associates that usually form the climax forest in the Douglas-fir type.

Although the associates are tolerant trees and will grow in an all-aged forest, it is an established fact that they reach their maximum development and produce the highest yield when they constitute a considerable portion of an even-aged mixed stand. This is particularly true of hemlock; when this tree develops in the understory it has a broad, thin crown and the limbs hang on all the way to the ground and continue to grow. Some of these limbs persist until the tree approaches old age and the tree has a stunted growth rate and appearance, and often has a defective bole. On the other hand, when hemlock occurs as a mixture in a dense even-aged stand its lower limbs die and fall off early and it develops a clean bole long before the Douglas-fir, grand fir, or Sitka spruce that may be growing in the mixture with it. The most beautiful young forest that I have seen in this region is a mixed forest of this nature on the Cascade Head Experimental Forest at Otis, Oregon. In all of the mixtures that occur each of the species has some special features that are worthy of separate short discussion.

Western hemlock is the most common associate and occurs throughout the Douglas-fir region in Washington and Oregon on all except the driest sites. On the more moist, cool sites it may equal or exceed Douglas-fir in growth rate and may predominate in the stand. It usually occupies a somewhat secondary position in the crown canopy and allows more stems to be present in the stand than pure Douglas-fir. This mixture with more stems to the acre on the better sites, produces the heaviest yields in the Douglas-fir type. Hemlock may also come in as an understory and become one of the important trees in the climax forest, but under this form of development it does not produce a high quality forest or a high yield.

Hemlock is not a more frequent seeder than Douglas-fir but the seeds are so small that a light crop of cones may produce a larger number of seeds than a heavy crop of Douglas-fir; they often run over 300,000 to the pound as compared to 35,000 for Douglas-fir. The small hemlock seed has a larger wing proportionally than its associates and is carried farther by the wind than any other northwest conifer.

As a result of the large number of seeds produced, and the long distances carried by the wind, cutover areas are well seeded to hemlock; nevertheless, seedlings are so sensitive to complete exposure and drought, and seedling mortality is so high that all seedlings may die on clean burns and exposed sites, and the tougher seedlings such as Douglas-fir, Sitka spruce and cedar may survive and take over. On the other hand, where shade and other conditions are favorable, seedlings occur in such numbers as to be harmful to stand development. I have actually made counts where seedlings totaled over 5 million to the acre. Of course, in such dense stands only dominants survive for a period of 7 to 10 years, but if even 2 to 3 thousand of these survive they will seriously handicap stand development. The stands tend to stagnate, growth is retarded, and such tall, slender stems are developed that serious loss often results from snow damage and wind. Hemlock requires a moist site and an acid soil; it thrives in pH values from 3.0 to 6.0. It will survive on mineral soil but thrives better on soils high in organic content. It has one growth habit not common to other conifers of the region. Decaying stumps and logs are favorite seedbeds and when a seedling occurs on a rotten stump or log it will send enough roots out over the side to eventually anchor the tree, but, for some as yet undetermined reason, it will also send roots parallel to each other for the length of the log until bundles of roots have been developed in the rotten wood. Because of its tolerance vast numbers of seedlings occur under normal forest cover, and it is not uncommon to see a carpet of hemlock seedlings on the forest floor. If these are not too completely destroyed by a clearcut logging operation and the area is not burned the remaining seedlings quickly accelerate in growth and develop into a new stand.

Hemlock is slightly more difficult to handle in the nursery than Douglas-fir, but if the organic content of the soil is kept high, the soil kept acid, and the seedlings given some shade very good 2-0 or 3-0 planting stock can be produced.

Grand fir is perhaps the second most important associate of Douglas-fir. In Washington and Oregon it most commonly occurs in a light mixture along stream courses or on moist sites. Under virgin stand conditions it is not known to occur as a pure stand or even to predominate in a stand over an extensive area. Grand fir is one of the most tolerant among the associates of Douglas-fir listed in this paper and is commonly found as understory reproduction in virgin Douglas-fir stands. Under this condition it grows very slowly and may be only 2 or 3 feet tall at a hundred years of age. But if the stand is opened up by cutting, windfall, mortality, or some other cause, this tree has the faculty of rapid and complete recovery and will quickly make a normal growth rate.

Seed crops are perhaps more frequent than Douglas-fir but the seeds are larger and the cones and trees are less numerous. As previously stated, reproduction may develop as an understory and grand fir may become part of an all-age climax forest. But it may also come in as a light mixture with even-aged Douglas-fir regeneration. It is in this form that it makes its best growth and development. Although seedlings are usually less numerous, survival is similar to Douglas-fir on open cutover areas. Under brush cover survival is better than that of Douglas-fir but such Douglas-fir as does survive usually makes more rapid growth and gets above the brush more quickly.

Grand fir grows more slowly during the first year or two in the nursery and requires some shade during the first year, but is otherwise not more difficult to handle than Douglas-fir.

Grand fir, as stated above is not known to occur in natural pure stands, yet it is being planted in pure stands in Western Europe with apparent success. A short distance west of Dublin, Ireland, I was shown a 50-year-old plantation of pure even-aged grand fir that had already been thinned several times. The crowns were well closed, lower limbs were dead and fallen off and boles were clear and straight. Practically all vegetation on the forest floor was crowded out and it was without doubt the most beautiful plantation I have ever seen.

Pacific silver fir derives its name from the silvery color of its foliage and almost white bark in early age. It occurs in mixture with Douglas-fir in a patchwise pattern at the higher elevations in western Oregon and Washington, but on the northwest side of the Olympic Mountains and north along the coast of British Columbia to Alaska it comes down almost to sea level. It is a tolerant tree about on a par with grand fir and will come in either as an understory and form a component in an all-age climax forest, or it will come in as an even-aged stand of reproduction in mixture with other species. At the lower elevations (under 1,500 feet) in Washington and Oregon it appears to be a short lived tree and seldom makes good development but in the virgin stands at higher elevations individual trees often attain a height of 200 feet and a diameter of 6 feet, and are over 300 years old. It will grow slowly and continue to live in an understory for a long period of years like grand fir, but upon release makes a quick recovery and rapid growth.

Silver fir is perhaps a more frequent seeder than Douglas-fir but the cones are clustered near the tip of the tree and since the seeds are large it probably does not produce as many seeds as Douglas-fir. Like other *Abies,* in seedling establishment it is similar to Douglas-fir. It handles well in the nursery but growth is very slow during the first 2 years.

The significance of silver fir in the Douglas-fir mixture is that it appears to reproduce readily and makes equal or better development than Douglas-fir on many of the sites at higher elevations in Washington and Oregon.

Noble fir is the largest and perhaps the best of the *Abies* to occur in mixture with Douglas-fir. It is even less tolerant than Douglas-fir, therefore it would fall in the sub-climax forest type along with Douglas-fir. Where it is found in virgin stands it is always in the dominant or codominant crown class, therefore it must have come in following more or less complete removal (or at least killing) of an existing stand. Reproduction of noble fir comes in only in mixture with other species as even-aged stands of regeneration or in openings at higher elevations where competing vegetation is not heavy.

Like other *Abies* it grows slowly in the nursery during the first two years but it is not difficult to handle in the nursery or to field plant.

The significance of noble fir in mixture with Douglas-fir is that it produces a fine quality of wood and is superior in form and development to Douglas-fir at the middle and higher elevations in the type. At elevations where Douglas-fir begins to drop out of the stand noble fir can survive the storms, the cold and deep snows of winter and produce good timber trees at that elevation.

Sitka spruce occurs in mixture with Douglas-fir throughout its range from north to south along the Pacific Coast. It is a moisture-loving tree and occurs only in the so-called fog-belt or superhumid zone not characterized by the long, hot, dry summers that are common to most of the Douglas-fir type. As the type extends from the valleys out toward the coast, spruce and hemlock first occur along the stream courses, then on the cool, moist slopes. Spruce gradually comes in as firs drop out until it predominates or occurs in pure stands over considerable areas. It, along with redwood are the only trees in the mixture that rival Douglas-fir in size and age.

Spruce is slightly more tolerant than Douglas-fir but it is not as tolerant as either hemlock or cedar. It will reproduce in the largest openings of an all-aged climax forest along the coast but more often occurs with Douglas-fir as an even-aged sub-climax forest that follows the complete removal of the old stand.

Sitka spruce, like hemlock and cedar, is a more prolific seeder than Douglas-fir and has a small seed (225,000 per lb.). But seedling mortality is higher than that of Douglas-fir and its early growth is slightly slower; for that reason it does not readily and completely predominate in Douglas-fir stands. It is the largest of the spruces and large old trees produce a clear wood of very fine quality. But limb shedding in young stands is extremely variable. Often live and dead limbs are retained on the tree until it is quite old, over a hundred years, but frequently one finds in a stand two trees standing side by side, one with limbs all the way to the ground and the other with a clear bole. It is possible that limbyness is a genetic characteristic and can be eliminated by selection.

One other characteristic of spruce should be mentioned. If the lower limbs of a stand have died and the stand is then opened up by a partial cut and the sunlight let in, adventitious buds will develop on most trees and the boles will put on a new set of limbs. For that reason the stand does not lend itself readily for partial cuts or very heavy thinnings.

Sitka spruce is very fine pulpwood and it is used for interior finish, and general construction, boat building or wherever light weight and strength are requirements. It is not highly resistant to decay.

Western Redcedar is perhaps the most tolerant of the timber trees that grow in mixture with Douglas-fir. It is a moisture-loving tree and usually occurs along stream courses and on cool, moist slopes, but will occur in less thrifty form even in the drier parts of the Douglas-fir type. It usually occurs as single trees or in clusters on moist spots. In northwest Washington and the British Columbia Coast it sometimes occurs in amounts such as to predominate in the stand over considerable areas. Although it is given little consideration in either artificial or natural regeneration it continues to occur in young growth stands in about the same proportion as it occurred in the virgin forests. This comes about because cedar is a somewhat more prolific seed producer than

Douglas-fir or its other associates and the seed is carried comparable distances by the wind.

Although it is becoming scarce, the clear wood of large old trees is still highly prized for shingles, house siding, and various finishing purposes. Trees of smaller sizes are valued for poles for telephone and electric lines and for fence posts.

Aside from the value of the wood the tree has other significance in the stand. It is not subject to the same insect and disease attacks as other conifers, and its annual needle fall is known to be higher in plant nutrient content than any other associated northwest conifer. In a nitrogen or calcium deficient soil a mixture of cedar may play an important part in improving the thrift of the stand.

Port-Orford-cedar grows in a true mixture with Douglas-fir over a limited range on the southern Oregon and northern California Coast. It often forms a considerable portion of the stand and in some instances predominates. Like western red cedar it is more tolerant and grows a little slower than Douglas-fir and when starting as an even-aged stand it soon occupies a secondary position in the crown canopy.

In reforestation procedures this tree handles more easily than most conifers. But in recent years planted trees have been so severely attacked by a root fungus that its use is questionable for the present, at least. Although it occurs only on a limited area in southern Oregon and northern California, planted trees have done very well for several hundred miles north of its natural range along the coast and in European countries.

Lodgepole pine cannot be said to grow in true mixture with Douglas-fir but it is important as it takes over and replaces Douglas-fir as soils become excessively dry, sandy or gravelly. Also it replaces Douglas-fir where there are impervious layers of hard-pan and drainage is poor.

This tree reproduces readily and makes rapid growth in early life, but it is a short lived species.

Its wood is valuable for poles, boxwood, inside construction and pulpwood.

3. *Notes on Ecology and Silviculture of Ponderosa Pine*

THIS DISCUSSION will cover the general features of ponderosa pine (*Pinus ponderosa,* Law.) silviculture, but rather than dwell on all details a special effort will be made to discuss additional findings and features for this species not normally covered in the standard silviculture text books.

General features will cover the entire range of the species but the detailed discussions will deal primarily with ponderosa pine growing in Oregon and Washington.

Ponderosa pine is the most widely distributed species of this genus in North America. It extends from the upper Fraser River in British Columbia on the north to Durango, Mexico in the south, and from east central Nebraska on the east practically to the Pacific Ocean in the west. It occurs from near sea level in the State of Washington to elevations of 9,000 feet in the southern part of its range.

The U. S. Forest Service "Checklist of Native and Naturalized Trees of the United States" (1953) recognized two varieties of the species. *Pinus ponderosa* var. *ponderosa* and *Pinus ponderosa* var. *arizonica,* Shaw, and in addition several geographic races of ponderosa. Some authors call all of it occurring east of the Continental Divide and the Central Plateau of western Colorado, *Pinus ponderosa* var. *scopulorum.*

Although classed as a hard pine its wood is soft. It is commercially more important than the soft pine group and is surpassed in size within the genus only by the sugar pine (*Pinus lambertiana,* Dougl.). The wood is comparable to the true soft pines and is much sought after for home building, other construction and even such uses as furniture and pattern making.

Climate

Most of the ponderosa pine type occurs in a semi-arid region characterized by hot, dry summers although there are exceptions, on limited areas, such as north-central California, and western Oregon and Washington where the annual rainfall will range from 40 to 70 inches. Normally it will not occur where the annual precipitation is under 10 inches but in Arizona and other places in the southern part of its range, where most of the rainfall is in the early summer growing season it is known to survive in an annual rainfall of under 8 inches. Average annual temperatures are between 41.8° and 49.8° F. and annual extremes at recorded weather stations are —37° and

+107° F.; but ponderosa pine is known to survive well at lower minimum and higher maximum temperatures.

Soil

Ponderosa pine grows on soils of practically all origins, types, and textural classes but makes its best growth and development on well-drained, deep loams. It normally does not thrive on a poorly drained soil with an impervious layer close to the surface or in the soil zone usually occupied by the roots. The tree thrives best in a soil with a pH value of 6.0 to 7.0 (slightly acid to neutral) but survives in pH values from 5.0 to 9.0.

Botanical Characteristics

Normally ponderosa pine supports a dense crown of needles up to 4 inches long in tufts, with three or less needles per fascicle. The *scopulorum* variety east of the Continental Divide in Montana and the Dakotas often has a predominance of needles with two attached at the base while on the rest of the range three needles attached at the base predominate. The bark of the mature tree usually varies from an orange to yellow, and for that reason, the tree was originally called yellow pine. The bark on young trees is usually a dark gray, and west of the Cascade Range and on other good sites this dark color persists, at least until early maturity. This is particularly true in the Willamette Valley. The bark of the young tree is smooth but bark scales and furrows increase with age until the bark consists completely of furrows and elongated plates.

The Stand

Virgin stands of ponderosa pine in the true type of the semi-arid region were for the most part all-aged forests and are in general considered climax forests. It is not a great deal more tolerant than Douglas-fir, yet in the less dense stands of the semi-arid region, it manages to reproduce in the openings as mature trees fall out or are removed by fire or some other cause.

It grows in pure stands or in mixture with other conifers and occasionally may be found mixed with madrone and black oak on upper slopes or with aspen, cottonwood, and other hardwoods along stream courses, and on subirrigated slopes. The conifers that occur in mixture with it in Washington and Oregon about in order of abundance are: Douglas-fir, *Pseudotsuga menziesii;* (Mirb.) Franco; lodgepole pine, *Pinus contorta* Dougl.; grand fir, *Abies grandis* Lindl.; white fir, *Abies concolor* Lindl.; sugar pine, *Pinus lambertiana* Dougl.; western white pine, *Pinus monticola* Dougl.; western larch, *Larix occidentalis* Nutt.; and western juniper, *Juniperus occidentalis,* Hook. The lodgepole pine takes over and ponderosa drops out as sites become poorly drained or air temperatures become too low. The juniper grows in mixture on the drier sites and often replaces the pine entirely as desert conditions are approached.

Following large fires or complete destruction by cutting, insects or disease, ponderosa pine may develop as an even-aged stand and continue to develop in that manner until a measure of stagnation exists with considerable retardation of growth. As stagnation is broken under natural conditions by drought, an attack of insects or disease or a ground fire (or a combination of these) the uneven-aged characters of the stand will again develop. In other instances grass and brush may follow complete removal and restocking of pine may be so slow and scattered that an uneven-aged condition will start from the beginning.

Flowering and Seeding Habits

Flowering of ponderosa pine varies with seasons and localities but in Washington and Oregon usually starts in early May. Male and female flowers occur on the same tree. From mid-May to early June the female conelets reach full development and pollination takes place, but the actual fertilization does not take place until about a year later when the seed is practically full grown. Like other pines, ponderosa cones require two seasons to mature and the seed is usually ripe about mid-August of the second year. In a large general locality flowering and seed production is later and becomes less profuse at the higher elevations.

In Washington and Oregon seed dissemination usually starts in late August and is pretty well over by the end of November. In some localities a part of the seed is known to remain in the cones until the following spring.

No dependable periodicity of cone crops of ponderosa pine has been determined. Heavy crops may occur from 6 to 10 years apart; during this period of time there is likely to be from two to three each of medium and light crops and complete failures. Like other conifers, open grown trees produce heavier crops than trees in more dense or closed stands.

Cone insects, *Conophthorus ponderosae* and *Megastigmus albifrons,* attack cones and seed during the formation stage and the attack is usually heaviest when the crop is light.

Once the seed is ripe, birds, squirrels, chipmunks and mice consume considerable quantities of it, and along with that destroyed by insects, may take all the seed during years of light crop. On the other hand during the years of heavy crops when there is a surplus of seed, rodents often store seed in the soil that is not found, and it later germinates and produces seedlings.

Seed is normally disseminated by the wind, but the distance of dissemination for ponderosa pine is not as great as that of other western conifers. It seldom seeds adequately for a distance of more than four to five times tree height from a timber edge. However, because winds are phenomenally variable, seeding distances may on occasion be equally variable.

Natural Regeneration

A study of natural regeneration in virgin stands of ponderosa pine will disclose that it occurs in an even-aged, patchwise pattern with 5 to perhaps 25 years between the age classes in the different patches. The seedlings are more resistant than most other conifers but site conditions are so severe over most of the area that seedling mortality is very heavy. A medium or heavy seed crop followed by a favorable season for survival and associated with favorable shade conditions on the ground are required for a reasonable amount of survival of natural regeneration. This combination of conditions seldom occurs in nature and during most years practically all natural regeneration dies. It may die from direct heat injury, drought, or competition or a combination of these causes. Seedlings may also be killed by frost, cutworms, birds, rodents, or deer. As previously stated they are more drought and cold resistant than most of their associates, which accounts for the approach to pure stands on southerly exposures and other severe sites. The only known methods to aid natural regeneration are rodent poisoning and soil scarification to provide a better seedbed and reduce competition following medium or heavy seed crops.

Under a selection system of cutting there is an adequate seed supply, openings, shade and time to wait for the establishment of natural reproduction. Since ponderosa pine will reproduce in small openings and under light shelterwood stands this probably accounts for the fact that selection cutting has been almost universally adopted for this type. It is no doubt the best procedure in all except the best sites where there is considerable evidence that better yields and a more profitable forest can be grown in even-aged stands with successive thinnings.

Competing Vegetation

In addition to the associated tree species mentioned, several species of brush and grass grow in competition with ponderosa pine throughout its range, sometimes to the exclusion of pine itself. They prevent seedling establishment and retard growth of established trees. The most common species in Washington and Oregon are ceanothus, bitterbrush, manzanita, mountain mahogany, rabbit brush, sage brush, pine grass and bunch grass. Anything that can be done in connection with a logging operation or otherwise to reduce cover in areas of limited precipitation, will proportionally increase seedling establishment and later growth.

Races and Strains of Ponderosa Pine

Within the varieties of ponderosa pine mentioned earlier in this report there are many races and strains. These exhibit special fixed characteristics that are of special significance in artificial reforestation. Although the species occurs over a wide geographic range and an equally wide climatic range and variation in soil types, strains from one locality may not make satisfactory growth in another locality unless site conditions and climate are similar. On a Douglas-fir cutover area in the Wind River Valley ponderosa pines brought in from other parts of the range of this species were quickly choked out by Douglas-fir natural regeneration, while scattered ponderosa pines from some local unknown seed source have been competing successfully with the Douglas-fir natural regeneration for the past 35 years. Tests of seed from the complete range of the species have been made in plantations on uniform sites over a period of 30 to 40 years and a report of results is now about to be published by Silen and Squillace. One of these plantations is located here near Corvallis on the McDonald Forest. These plantations show that many growth habits are hereditary and will show up wherever they are planted. A Steilacoom Plains strain with big limbs, bushy crowns and rough boles had a similar development on all plantations, while a strain from the Willamette Valley growing equally fast beside it has straight clean boles and small limbs and crowns. Some fast growing strains make similar good growth in all plantations; other strains were fast growing in some plantations but not in others; certain strains are more subject to frost damage than others; and an astonishing fact shown was that two out of 13 strains were much more highly subject to animal (deer and rabbit) damage than the other strains.

Seeding and Planting of Ponderosa Pine

Natural seedlings often do not survive the first season in a major portion of the ponderosa pine type. As explained in previous pages, a good seed crop, a favorable season for survival and favorable ground conditions are necessary for survival of appreciable numbers of seedlings. For that reason broadcast seeding, even with ground scarification and rodent control, is likely to result in frequent failures. Spot seeding is not likely to produce much better results even though special care can be exercised in the placement of the seed. The direct seeding is therefore not recommended until special aids and better procedures have been worked out.

Nursery practice for ponderosa pine has been worked out and almost any type of seedling can be produced at a reasonable cost if the field planting needs are made known. Field survival in plantations now varies all the way from practically zero to 100%. The problem confronting the forester today is (first) to determine the type of stock needed for each particular area and (second) to determine the planting procedure that will allow the seedlings to grow. Transplanting or field planting is a great shock to a tree and it increases with size and age particularly after the first or second year. Some trees never recover from the shock of transplanting within a rotation age. On the more favorable sites, well-developed, root-pruned 2-0 seedling stock is likely to make the most rapid recovery. But on more severe sites where seedlings must be larger and hardened by transplanting, recovery may not be as rapid and complete, but survival will be better with transplants. The greatest benefit will come from extreme care in the lifting, packing, transport and planting procedure. As many as possible of the fine roots and root hairs should be retained so as not to destroy the feeders and soil micro-flora that have developed on the roots. For that reason I would advise carrying seedlings in wet moss instead of a bucket of water. Of course, seedling roots should never be exposed to the sun or allowed to dry out or heat in the bale. In planting it is always better to find the best spot to plant rather than to locate the correct spacing, and extreme care should be taken to pack the soil tightly on the bottom as well as on the top of the roots. On our more severe sites it may be necessary to resort to preparing transplants in square roofing-paper pots and field plant them without disturbing the roots as is being done in the Southwest at the present time.

Ponderosa pine reproduction is often patchwise and overdense and stagnation of stands often takes place. All age stands respond to release, and thinning is recommended particularly in average or better sites.

Clear pine is a valuable and much sought after wood and the pruning of final crop trees to produce clear wood on average and better sites is certain to pay good dividends. Experiments have shown that the lower quarter or third of the crown can usually be removed without retarding growth or permitting the entrance of decay. The lower limbs that are beginning to dry up are the ones that can be pruned off with safety.

Cutting Methods in Ponderosa Pine

When cutting operations first started in ponderosa pine foresters were confronted with a vast area of overmature timber all very much in need of cutting. Clear-cutting was neither desirable nor did it cover the area rapidly enough for this overmature all-aged forest. The ordinary selection cutting was not satisfactory either.

At first, heavy selection cuts were made in order to make cutting operations pay. Then as insect and other losses became widespread, lighter cuts and more rapid moving operations were developed. To aid the lighter cuts tree classifications were developed based on tree vigor—"Dunning's Tree Classification" and "Keen's Tree Classification." Later as insect damage accelerated, Salman and Bongberg developed a (mortality) risk rating. From this evolved a "Sanitation Salvage" method of cutting that permits moving quickly over large areas removing only the trees that are most likely to die before another cut can be made.

The latest development in cutting methods now being tested is known as "Unit Area Control." This presupposes that patches of different sizes within a pine stand are uniform in composition. Each patch is considered as a separate unit and a treatment is prescribed.

Eventually we will arrive at a point in ponderosa pine cutting methods where each marketable tree will be considered in relation to its vigor and susceptibility to attack, and also in relation to immediate neighboring trees and the general condition of the stand. We will then be practicing real silviculture in ponderosa pine.

4. *Tree Improvement in Forestry*

I WAS OBLIGED to add the term "Forestry" to this title because trees for all other purposes have already been improved. Fruit and nut trees, shade and ornamental trees, all have been improved under managed use, just as grain, grass, vegetables, berries, livestock and poultry have been improved under use. Forest trees and fish are two items that civilized man continues to use extensively in their native wild state. Tree improvement is under way both in Europe and in this country, as will be noted later, but few of the results have yet had much impact upon forest practices (very little of it has as yet gotten into general field use).

The reason for the delay in forest tree improvement is not apathy on the part of the forester, but first because the tree is a longtime crop rather than a yearly crop, and second because, up to the present time, there has been a super-abundance of wild virgin forests ready for exploitation (to be used up and gotten out of the way). Today, with a few minor exceptions, the end of virgin forests is in sight throughout the world. Another generation and there will be very little wild unmanaged forest left and trees will have to be raised as a longtime crop. As this day gradually comes to us we must be ready with better trees for the forests of tomorrow if forestry is to compete with other land uses.

Two questions are constantly being asked: (1) can forest trees be improved, and (2) will tree improvement pay under management? Geneticists and foresters throughout the country have already demonstrated that forest trees can be improved, and the economics of the procedure are as simple as this: An acre of Site II Douglas-fir 50-years-old should support a normal stand of at least 25 M. bd. ft. per acre. At $20.00 per M., stumpage thus would be worth $500.00 per acre. Cost of land, planting costs, and carrying charges should not be more than a maximum of $455.00 an acre for the 50 year period, and it may not be more than half that much. That would leave a final net profit of approximately ($45.00) 10% of the total cost in addition to the interest on initial outlay which is included in the total cost of establishment.

Now if it is possible to increase the yield 10% by the use of improved trees (and it is) the net profit would automatically be doubled, because it costs approximately the same per acre to raise a good forest as a poor one; any increase in yield per acre that results from improved trees is, therefore, clear net profit.

Forest crops differ from other crops because the improvement must come in the very beginning. If you plant the wrong variety of wheat you can get better variety a year later, or if you start with the wrong chickens, you can feed the wheat to them and chop their heads off and get new ones, and in either case you have not lost much. But if you plant poor forest trees, you may not discover your error for 10 or 15 years and you are stuck for a lifetime with a poor forest and an unprofitable crop.

How can forests be genetically improved? Forests can be improved by the introduction of better trees from foreign lands, or by improving species now on the ground.

The nature and amount of tree improvement that can be accomplished with an existing stand will first depend upon whether a forest operation will rely on *natural regeneration* or will employ *artificial regeneration.*

Forest Improvement Through the Introduction of New Species

The greatest forest improvement in many parts of the world was done, not through the improvement of a particular tree species or the development of hybrids by breeding, but through the introduction of better tree species from foreign lands. The outstanding example of this is the introduction of Monterey pine, ponderosa pine and Douglas-fir to Australia, New Zealand, South Africa and South America. Everywhere in Europe except in the northern part of Scandinavian countries our northwest tree species are making better growth than their native Scotch pine, Norway spruce, European larch and silver fir.

But the opportunity to improve the forests of northwestern United States through the introduction of new species has not been possible to date simply because we have not been able to find trees that will do better than our own native species. At the Wind River Arboretum over 150 species of conifers from other parts of the world have been tested in comparison with Douglas-fir and other northwest species and to date none of the introduced species have equaled our own trees. Smaller tests in other localities have given similar results. Therefore, the chance for forest improvement through introductions does not appear promising here in the Northwest. The same is true with the southern pines in the southern part of the United States.

Forest Tree Improvement With Natural Regeneration

With natural regeneration the forester is, under proper management, assured of a stand at least as good as the old forest being removed. But there is some chance for improvement. The first step that can be taken is to leave better than average trees for a seed source (very often only scrub trees are left to produce seed after a cutting operation). A second improvement in natural young stands can be made by thinnings. If the best trees are saved as final crop trees and the poorly formed, slow-growing and diseased trees are taken out in successive thinning operations, the stand will consist of the best trees for the entire length of the rotation and the very finest trees can be left as seed source for the next crop—exactly the reverse would be true if the good trees were cut first and the scrub trees retained. Many excellent stands have been developed in Western Europe by careful thinnings for several tree generations. A few areas have been treated in a reverse manner, taking good trees out first and leaving the poor ones—these are a sorry sight. I was shown a 275-year-old beech stand in Holland that had been hi-graded for 250 years as a "people's" forest. Today it looks like an over-grown stand of vine maple on the Oregon Coast. Less than a quarter mile away on a similar site a good stand of beech is being grown from a good (young) strain of trees. So it is possible to build up or degrade a forest with successive thinning operations after natural regeneration. Good thinnings not only improve the current forest crop but provide better parent trees for future natural regeneration.

Tree Improvement Through Artificial Regeneration

The greatest opportunity for forest or tree improvement is, however, associated with artificial regeneration. As a matter of fact, most tree improvement programs take artificial regeneration for granted at least for the first generation or two of improved trees. Artificial regeneration permits two broad fields of tree improvement. The first, is tree improvement through selection and natural crossing of the best natural wild strains or individual trees to produce better seed for immediate use; the second is tree improvement through cross-breeding artificially or otherwise between genus, strains or superior trees with the hope of capturing in a single stem the favorable qualities of both parent trees. The latter process will require a long period of years.

There are two urgent needs that will employ both of the above procedures in the tree improvement program: the first is natural selection to provide better seed and better planting stock for the planting program of the immediate future, the second is cross breeding over a period of years to produce still better trees for the future.

Better Seed and Better Trees for Immediate Use Through Selection

The development of better trees or better strains or new species through cross breeding is at best a long time process, although it promises the greatest returns eventually. But while the program is going on, our most urgent need is for better seed and planting stock for immediate use during the next 10 to 15 years. This can best be accomplished through selection from our own natural stands. The first step is to select the best native stands in each general locality and improve them as seed collection areas. The second step is to select from these best stands the very finest individual trees (plus trees), and from these trees, develop seed orchards through vegetative propagation.

Selection and Improvement of Natural Seed Collection Areas

There is no fixed measure or yardstick for selecting a superior stand in a locality. The best that can be done is to select a stand that is as good or better than a qualified man would expect to find on a given site or at a given elevation. The stand should be at or approaching a seed bearing age; it should be large enough to permit the judging of growth rate, form, and branch arrangement. The next step is to improve this stand by cutting out all inferior trees. This would leave only the best trees to pollinate each other. Seed from such an improved area should produce a new stand that is somewhat better than the original forest, but too much improvement should not be expected because individual tree growth is affected both by heredity and the environment in which it is growing.

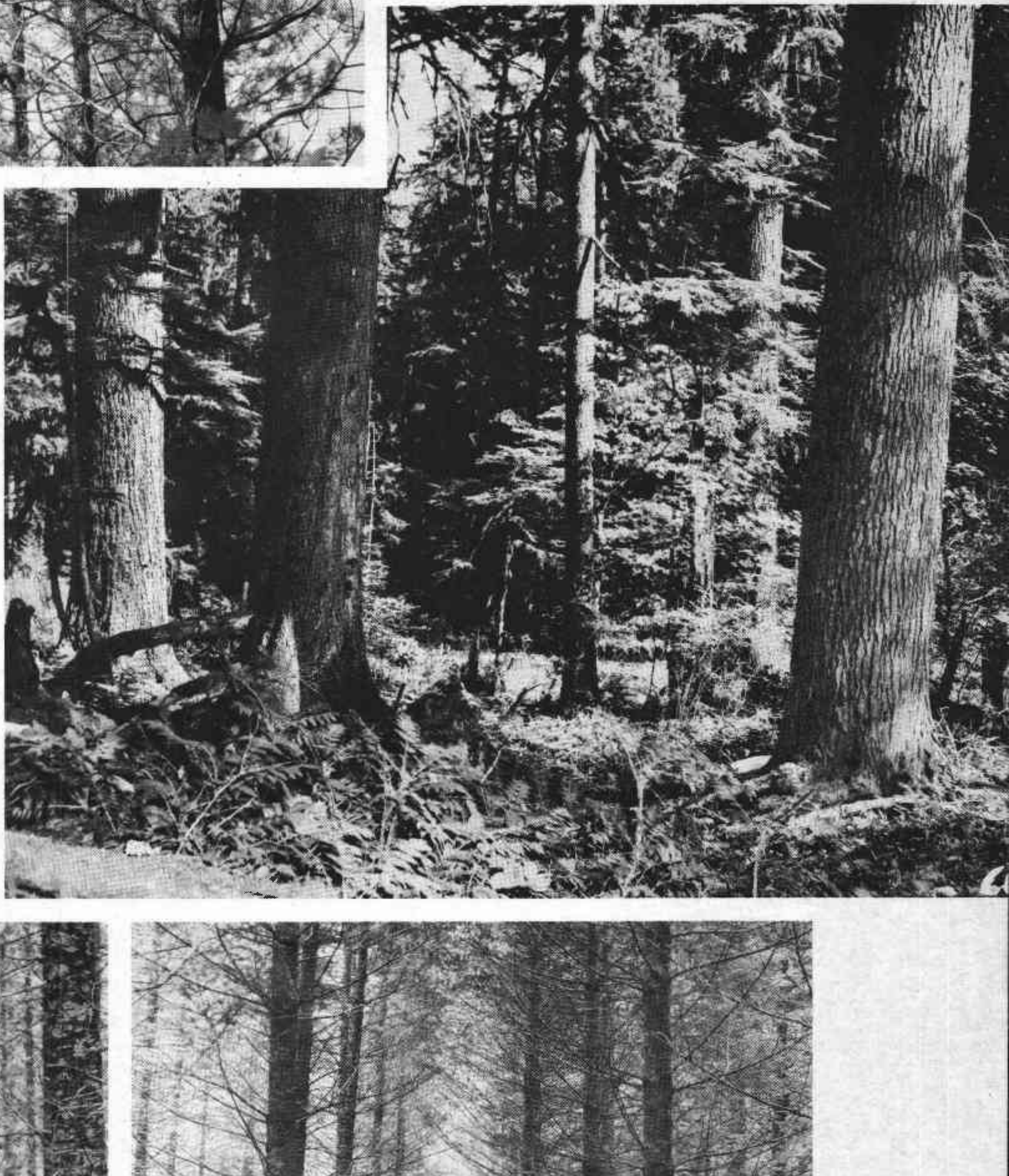
The size of such seed areas will vary with species and localities and in an isolated locality might be quite small. In an extensive young growth stand it has been estimated that these areas should be at least 10 acres in size to prevent excessive pollen contamination from the sides. It would be well to have an area large enough so that seed collections could be made some distance in from the outer edge—therefore the larger the area the better.

The removal of inferior trees from a seed collection area, and the branch mulch resulting from this thinning should result in some increased cone production. Recent tests have also shown that seed production can be increased by fertilization. But neither of these practices of course, improves the genetic quality of the seed.

4. Repeated burning is the greatest single enemy of reforestation in coniferous forest areas. Center of photo marks the boundary of the second burn. Area to the left was reburned and has no seedlings; area to the right was burned once by a light fire and is now well stocked with regeneration.

5. Old-growth Douglas-fir stand.
Booth-Kelly photo.

6. Disease resistance is a promising field for tree improvement. The tree on left is heavily infected with western crown gall fungus. Row of trees on the right is uninfected and apparently resistant.
U. S. Forest Service photo.



7. Mature Western hemlock stand.
Booth-Kelly photo.

8. Thirty-two year spacing test plantation demonstrates that overstocking is as harmful as understocking. It retards both height and diameter growth and promotes snow break and storm damage in young stands. Left: 4′ x 4′ spacing, average diameter at breast height 4.1 inches, average height 38 feet, cubic volume 703 feet. Right: 12′x12′ spacing, diameter 8.4 inches, height 58 feet, cubic volume 2508 feet.

The number of natural seed collection areas needed will vary with amount of seed needed and with the climatic variation in the total area to be planted.

The seed collection area should be in the same general climatic belt as the planting area. The average annual temperature of a planting site should not be more than 1° to 2° F. higher or lower, and the absolute minimum should not be more than 5° F. lower than the seed area. Seed from a dry zone will not produce a good stand in a moist zone even though it may be not many miles away or at a greatly different elevation. Summer rainfall should also be similar on both areas.

These improved natural seed collection areas should provide seed for immediate use and bridge the gap between now and the time when still better seed and planting stock will be made available through artificially developed "seed orchards" and through breeding.

Superior Strains, Plus Trees, and Seed Orchards

We will move gradually from the simple to the more technical methods of tree improvement. Along with the establishment of the improved natural seed collection areas mentioned above, should go the development of "seed orchards" from the superior trees in our natural stands.

Next to the improved natural seed area the "seed orchard" offers most promise for producing better tree seed on a large scale. It is well known that inferior, average, and superior strains have developed in our natural wild stands. The superior stands are better than neighboring stands in both form and growth rate, and perhaps other characteristics. Within these stands occasionally is found an unusually fine tree. Foresters and geneticists have called such trees *"plus trees."* It may be better due to environment or it may be genetically superior to its neighbors. Under the present program these trees are being sought out and registered in a "plus tree register" just as the Agricultural College might register a jersey bull or any other blooded animal. Preliminary instructions have been prepared for the selection of plus trees for the plus tree register and copies are available upon request. Early instructions which I prepared have been improved and perfected by John Duffield, Roy Silen, and other geneticists and foresters. There are now about 250 trees recorded in the plus tree register for the northwest and many more have been located but not recorded.

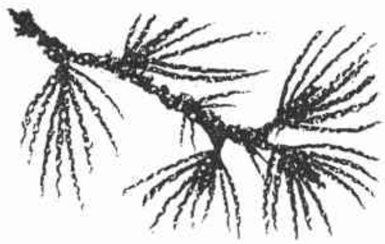
The conventional method of establishing a seed orchard is to take scions from 20 or more plus trees in a given locality. These scions are grafted onto sturdy seedlings two or more years old, and when the graft is well enough established the stock is outplanted in a seed orchard in some isolated location. Sometimes the seedlings are outplanted first and the scions grafted onto them after they are established in the seed orchard. In any event the seed orchard must be reasonably isolated from outside sources of pollen.

The selection of plus trees varies somewhat with species and purpose; in addition to the standard characteristics of growth rate, form, branch habit, and wood quality, they may also be selected for resistance to drought, animal damage, insects, and disease. Once established, a seed orchard can be stimulated to earlier and more prolific seed production by cultivation, thinning, and fertilization; some additional stimulants are still in the experimental stage. Ultimately the seed orchard will produce seeds which are from the very finest individual trees from the best strains. The next step is to progeny test the stock from the selected trees to determine if they are genetically superior or if their superiority in the stand was the result of some unknown factor in early life. In other words, will the seedlings be as good as the parent tree? Once a tree has been progeny tested and found genetically good, it becomes a certified (or elite) tree and can be used indefinitely for propagation purposes. On the other hand if a tree is not found to be genetically good, all the grafted plants from such a tree can be eliminated from the seed orchard.

The Place of Breeding in Forest Tree Improvement

The forester or geneticist may make considerable progress by selection in natural stands alone, but the greatest and most permanent gain will probably be made by breeding. Seldom if ever would a *plus tree* be found in natural stands, that was superior in *all* of the most desirable tree characteristics. One tree may be *outstanding* in growth rate and form, another, *average* in growth and form, but outstanding in wood quality. The geneticist may cross the fast growing tree with the tree of superior wood quality, hoping to select a limited number of the progeny that will have the good qualities of both parent trees. These in turn will be recrossed until the gain becomes a fixed hereditary characteristic. The tree may then be crossed with a more disease resistant tree to develop a strain that is not only disease resistant but is superior in growth rate, form and wood quality as well. And so the forest geneticist moves on, his work more time consuming and technical, his results less certain, but his promise of ultimate gain greater than those who work with other forms of tree improvement.

It is because of the long time nature of tree improvement by seed orchards and cross breeding that it has been recommended, that both be carried on simultaneously with the selection and improvement of seed collection areas in natural stands. The natural stands will provide better seed for the immediate period and as time passes the genetic program should provide still greater improvement for the trees of the future.



5. *European Forestry*

To discuss European Forestry one should first have a general picture of the relation of forestry to the current economy of a country or group of countries. I will attempt to do this by broad groups or general regions.

Western European countries have varying amounts of public and private forest ownership. All recognize the value of forests, and some governments go so far as to pay a considerable part of plantation establishment. Germany and Austria have close to 40% of their land in forests, Finland and Sweden have more than 50% of their lands in forest. Norway and the other countries of western Europe have 25% or less.

The Scandinavian countries are natural forest areas that have maintained their forest cover down through the ages. The forest resource provides one of their greatest industries. They are exporters of forest products, therefore, they must not only keep their forest lands productive but must keep their production costs down. They seek natural regeneration whenever possible and plant or seed only when absolutely necessary.

The Middle-European countries have made a real effort to maintain their forests, but because of expanding populations they still are obliged to import some forest products. Because forest land is scarce and forest products expensive, foresters do not wait long for natural regeneration but often replant before the old forest is completely cut away.

Denmark, Holland and Belgium have long appreciated their needs for timber and have considerable areas of man-made forests. Their man-made forests are some of the best managed forests in Europe. However, all of these countries must import forest products.

The British Isles, once quite depleted of forests have made great progress in reforestation since World War I. Most of their forest products needs up to now have been imported from countries of the British Commonwealth, although Scandinavian countries and Russia have supplied substantial amounts.

Spain, Italy and Greece have sadly depleted their forest resources and have vast areas of worn-out, overgrazed and eroded land. Most wood products must be imported. Spain and Italy are making rapid progress in their reforestation programs.

Tree Species to Work With

When the polar ice cap retreated it left Europe deficient of good tree species. Instead of having hundreds of good timber trees to work with as is the case in the United States, there are less than a dozen good forest tree species. They include: Scotch pine, Norway spruce, European larch, silver fir, beech, birch, oak, maple, sycamore and poplar. In recent years they have introduced many foreign species with good success. Most important of these are: eucalyptus, Japanese larch, Douglas-fir, grand-fir, Sitka spruce, western hemlock, noble fir, Pacific silver fir, lodgepole pine, red oak, yellow poplar, and cottonwood. A test of seven strains of Douglas-fir near Munich, Germany, showed that one of them originating from central Washington at an elevation of about 700 feet made about a third better growth than Site I Norway spruce, the best local tree in the vicinity. Other strains were approaching this growth rate also. Somewhat similar success is being obtained with other American tree species.

Forest Fire Control

Although they occasionally have large, destructive forest fires in Europe, fire does not appear to be the problem, nor to receive the attention that it does in this country. There are many reasons for the situation: (1) fire hazard is low because forests are cleaned up for fuel or other purposes, (2) there is usually rain in midsummer and fire danger comes only in spring and fall when the leaves are dry, (3) the forest stands are very accessible by roads and trails, (4) and people live in the forests and have become fire conscious.

Grazing and Other Animal Damage

Domestic grazing animals are kept out of the forest to the extent that they do very little damage except in Spain, Italy and Greece. Large wild game animals are troublesome and do damage at times but they are considered a product of the forest and their annoyance is tolerated. Rabbits are a serious menace to plantation establishment in many parts of the country where they are numerous. In Germany, Ireland and elsewhere it is often necessary to fence against them until the plantation trees have grown tall enough to be out of danger from rabbit damage. In Spain, Italy and Greece, goats and other grazing animals have destroyed the young forests on vast areas and are preventing new forests from becoming established except in the rare cases where special protective measures are being taken.

Natural Regeneration Planting and Cutting Methods in Europe

In the heavily forested Scandinavian countries where forest products are export items and production costs must be kept down, more attention is given to natural regeneration than in other countries. Growth rates are slow and forest owners are willing to wait longer for reproduction to become established. When natural regeneration fails they plant, but special attention is given to getting the very best seed for a given site.

All through central Europe where forest products are import items they are expensive. Labor is somewhat plentiful and not expensive, but time and growing space are limited. Under such conditions they do not wait long for natural reproduction but plant promptly after cutting, in fact they often pre-plant under a shelterwood and allow the new forest to become established before the final cut of overwood is made. The more tolerant the tree species the more readily they will lend themselves to this type of cutting. Once the new forest is established the overwood is promptly removed because even the most tolerant species make their best development and produce the highest yields when grown in an even-aged stand with successive thinnings.

Forest Nurseries

The forest nurseries of Europe are of many sizes, forms, and descriptions, and follow no specified pattern. They may vary in size from a small nursery developed right on the planting site to the largest commercial forest nursery in the world. The Pein & Pein Nursery at Helsenbek, Germany is said to produce 300 million trees a year, and they market a great number more that are grown for this company under contract.

The nurseries of Europe produce larger and older field planting stock than is generally used in America, and a high percentage of the stock consists of transplants. Labor is not expensive and they do not hesitate to spend considerable time and money to establish plantations, and give them care after planting. Foresters claim that the larger stock is needed to compete with the dense grass, weeds and low brush. In Holland they were turning over circles of sod in the fall to allow the sod to rot until spring before the tree was to be planted. In the southern countries (Spain, Italy and Greece) on the more severe sites foresters are sometimes forced to resort to potted trees in order to get them to survive.

Cutting Methods

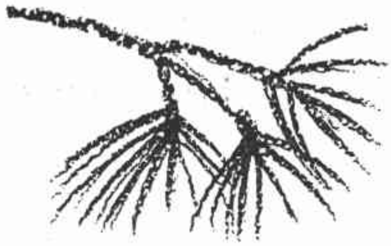
Methods of cutting vary a great deal in European forests. Where tolerant species like beech or silver fir are grown attempts are made to maintain all-aged forests. In other instances a forest may start as an even-aged stand of intolerant species like Scotch pine and as cutting progresses tolerant species are underplanted or allowed to come in to prolong the rotation. The most common cutting procedure is to start with an even-aged stand and make successive thinnings until rotation age is reached. At that stage a shelterwood or other type regeneration cut is made. Under-planting of the stand may be accomplished before a final cut is made.

Stand density or degree of thinning in Europe varies even more than methods of cutting. Craibs planting in South Africa, and cricket bat planting in England use extremely wide spacing, not allowing trees to compete at all. Another school of thought in England advocates planting in dense clusters or clumps, leaving spots or strips of the soil unoccupied. The common practice in the rest of Europe is to plant too densely for maximum production of good quality material at the lowest cost in the shortest time. In France, Germany and Austria it is not uncommon to find them planting 5,000 to 10,000 trees per hectare. This amounts to 2,000 to 4,000 trees per acre which is far more than will live until they can be harvested even for fuel. Foresters advocating dense planting claim greater height growth, more clear lumber and many other benefits that are completely imaginary and false. This overstocking of plantations is the most costly single error in all European Forestry.

Stand Improvement and Tree Improvement in Europe

During the past half century Europe has made great advances in stand and individual tree improvement for forest purposes. By successive thinnings, removing all inferior trees for several tree generations, beautiful stands have developed for the production of better seed and the production of better quality material. This is particularly true in Germany and Austria. Sweden, Norway and Denmark have classified their forests for seed collection purposes. They've gone further to select the very finest individual tree specimens, and from these are developing even finer trees through cross breeding and the establishment of seed orchards for the production of better seed.

Forestry in Europe, as well as in this country, has finally "come of age" and is in the process of improving the wild forest tree for human use, just as has been done with livestock, fruits, grains, and all other growing things for better living.



6. *Turkey--Its Forests and People*

TURKEY is a romantic country that dates back to the dawn of civilization and the beginning of recorded history. Everywhere ruins remain as grim reminders of ancient glory.

It has an area of about twice the size of Oregon, circled on the north, west and south sides by low coast range mountains and crossed in the east by the high Tarus Range. The entire central part of the country is a high, semiarid plateau called the Anatolian Highlands.

Once the center of world civilization and development, this vast country is now cluttered with an impoverished people trying to make a living on worn out, eroded, and overgrazed land. The population of 23 million live mostly on the land and from their flocks. It is estimated that there is a goat for every man, woman, and child in Turkey, a similar number of sheep and lesser number of cattle, horses, donkeys, water buffalo, and camels. Many of the people drift with their flocks to the highlands in the summer and back to the coast or villages in the winter. Their chief foods are meat, dairy products, wheat, rice, fruit, and vegetables. Over 80% of the people live in the country or in small villages. Their crude homes, usually one or two rooms, are made of rough timbers, stone, or mud bricks or a combination of these.

Since foreign aid (mostly American) became available, a widely spaced system of truck roads have been developed and are being extended into forest areas. A mainline railroad with several short branches (built by Germany) crosses the country from west to east; and coast towns on the north, west and south have a low grade freight and passenger boat service.

Turkey was once a well-forested country, but hundreds or even thousands of years of over-cutting and over-grazing have reduced the commercial forest area to less than 15% of the land surface, and a third of this is held to a brush stage by overgrazing. The national government claims ownership of practically all forest land and employs 9,000 guards to police it. But the people, through an age-old custom, claim the right to forest use and as a result all forest area is overgrazed. In spite of the guards, approximately half of cutting is done in trespass. Cutting is done for all domestic purposes, such as housing, fuel and stock food.

Turkey has had an organized forest service for over 100 years, with a headquarters at Ankara and branch offices in all parts of the country. For many years they have had a well equipped, government supported forestry college, and the forest service employs between

700 and 800 graduate foresters. A Forest Research Institute sponsored by the United Nations has been established at Ankara.

Most forest headquarters are now supplied with Willy's jeeps, station wagons, or trucks (again from American Aid) to get around their districts. The government does its own logging, and owns most logging installations and sawmills. A few small sawmills are privately owned. The government has three short narrow-gauge logging railroads and one overhead cable logging system (taken from a Belgian company about 25 years ago). Most highway log hauling is done with trucks, and trucking is on the increase, but practically all logs are still brought out of the forest on wagons or crude two-wheel carts drawn by water buffalo, cows or horses. All skidding is done by these animals. Poles and fuel wood are often handled by hand or brought out on small donkeys.

Turkey has about a dozen important timber trees. They are Scotch pine, *Pinus sylvestris* L, Austrian pine, *Pinus nigra* Arnold, Aleppo or red pine, *Pinus halepensis* var. *brutia* (Ten.) Henry, Italian stone pine, *Pinus pinea* L.,Turkish fir, *Abies bornmuelleriana* Mattf., Oriental spruce, *Picea orientalis* L. Link., Cedar of Lebanon, *Cedrus libani* Loud., black poplar, *Populus nigra* L., Oriental beech, *Fagus orientalis* Lipsky., and oak, *Quercus* spp. The forests occur in a patchwise pattern on the slopes of the coast range mountains that circle the country on the south, west and north sides. The latter includes the Black Sea slopes which support the best stands and constitute an excellent forest growing site like the west slope of the Cascade Range in Oregon.

Because of population pressure and the age-old demand from the people for land for cultivation and grazing use, no system of sustained yield cutting has been worked out. Each year many more hectares of productive forest land are destroyed by fire, grazing and cultivation, than are restocked by planting or natural regeneration. In the more open pine forests of the semi-arid interior and southern coast mountain slopes overgrazing keeps down the natural regeneration, while in the dense stands of the Black Sea slopes cutting is so light (1 cubic meter per hectare) that the single tree openings are becoming occupied with broadleafs, and the more valuable conifers are gradually being eliminated. In a desperate effort to save their remaining forests the Turks are making this light cut to avoid the encroachment of cultivation, and of grazing, but they do not seem to realize that they are slowly eliminating their valuable conifers.

The forested areas on the slopes of the coast mountains of west and south Turkey are poorly stocked with a low grade forest of pine —*P. brutia* at the lower elevations and *P. nigra* above the 800 foot level, and limited areas *P. pinea* on the west coast and *Cedrus libani* in the Tarus Mountains. The entire area of *P. brutia* at the lower elevations has the general appearance of having been high graded for the past 2,000 years, and leaving the scrub trees to reproduce the stand for one generation after another. Stands are poorly stocked and trees are of poor form and scrubby in appearance, except in some remote and inaccessible areas where trees are good form and fast growing.

Considerable use is made of foreign tree species, particularly with broadleafs in farm and village plantings. They use black locust, (*Robinia pseudoacacia* L.), boxelder (*Acer negundo* L.), poplars (*Populus* spp.), willows (*Salix* spp.) and eucalyptus (*Eucalyptus* spp.). Disease infested coastal swamp areas of south Turkey have been reclaimed by eucalyptus and good wood crops are being harvested at 10 to 20 year rotations. Douglas-fir and other American species and Norway spruce and other European conifers are being tried on an experimental scale and show great promise. Douglas-fir on the Black Sea slope is showing much better growth and development than native species. But foreign tree species have, as yet, not become a part of the general reforestation program.

This is where my assignment comes in. I was asked by the United Nations to assist the Turkish Government in selecting species and areas for reforestation, and to aid in reforestation technique.

Reforestation in Turkey started about 1930, shortly after Ataturk, the great Turkish patriot and dictator, took over the army and the country and drove out the Greeks. He set up a republic and attempted to westernize the country, and reforestation was part of his plan. About 1950, young Turkish foresters were sent to this country under the American Aid program. They studied for one-to-two-year periods in American forestry colleges, and worked in American forest nurseries and on reforestation projects. Some of these men returned to their country and were able to put into effect what they had learned. When I arrived in Turkey in October, 1956, I was surprized to find (at Dursunbey) a forest nursery that would be acceptable most anywhere in this country. They were raising good 2-0 root-pruned pine planting stock at a very low cost. But there were about two dozen additional nurseries that were progressively poorer, many producing low grade transplants at a very high cost. The task before us was to bring these nurseries up to standard.

The 5-year reforestation plan, started in 1955, calls for the planting of a total of about 90 million trees a year. Perhaps not more than half of that goal has been reached to date. Most planting is done with a home-made grub-hoe type of tool using either the center-hole or side-hole method. But over a great part of the country site preparation is necessary. In western Turkey a non-sprouting brush (*Cistus* sp.) follows forest fires, and strips must be cut through it before trees can be planted. On the moist Black Sea slopes the eradication of scrub oak, rhododendron and other brush is so difficult and costly that it is almost prohibitive, and accounts for the fact that little planting has been done there. On the hot, dry slopes of south Turkey sites are often so severe that it is necessary to use potted stock, or to terrace the hillsides, in order to get trees to grow.

Both in the forest nursery and field planting operations, the women of Turkey do a considerable portion of the work. For this they are paid from 3 to 5 Lira a day which is equivalent of 30 to 50 cents in U. S. money.

Throughout the country the pressure of grazing and cultivation is so great that it is necessary to put a guard on a plantation area before a tree is planted. And the guard must remain there day and night until the planted trees are above the reach of grazing animals.

Areas destroyed by grazing, cutting and fire are still greater each year than the area reforested, but Turkey is making real progress both in the rate of restocking and in technique. Except for Israel, Turkey is far ahead of all other Mediterranean countries in a reforestation program.

In addition to "on the ground" assistance in nursery practice and field planting in all parts of Turkey, during my two year assignment I managed to prepare for the Turkish Forest Service field manuals on seed collection, nursery practice, and field planting for Turkey. These were processed by the United Nations and placed immediately in the hands of English speaking foresters and are now being translated into Turkish for general use.