An Abstract of the Thesis of

Thomas Buckeridge Burns, Jr. for the degree of Master of Arts

in the Department of Geography to be taken December, 1971

Title: Sequoiadendron Giganteum in the Willamette Valley of Oregon

Approved: Carl L. Johannessen

The giant sequoia (Sequoiadendron giganteum (Lindl.) Buchh.) of California is native to a small area of the western Sierra. In recent geologic history it has failed to enlarge this range. In addition, the tree evidences an inability, under current protective management, to sustain a reproductive rate necessary to maintain the size and density of the present range, although the living specimens have a low incidence of disease and an extremely low mortality rate.

In spite of this apparent inability to maintain or extend its range naturally, the sequoia has been highly successful in adapting to other situations, notably the Willamette Valley of Oregon. Approximately twenty years after its initial discovery in 1852, sequoia seeds were planted in a nursery near Portland, Oregon, at the northern end of the valley. Seedlings from this germination were subsequently planted in a variety of locations throughout the Portland area. These first trees, which have not yet, after a century, acquired the growth characteristics of maturity (i.e., rounded crown, self-pruned trunk, pronounced enlargement and thinning of the lower lateral branches), have achieved heights and diameters surpassing all native species in this area. In addition,

they have produced viable seeds which have germinated under both natural and artificial conditions.

The tree demonstrates a high natural resistance to such hazards as insect infestation, rot, disease, and fire. Poor drainage inhibits their growth, but normally soil conditions, slope, aspect and relative humidity appear to be non-crucial to growth performance of the sequoia. The Willamette Valley habitat compares favorably in both temperature and precipitation extremes to the natural range in the California Sierra. Under ordinary (uncultivated) Willamette Valley conditions the sequoia averages nearly an inch growth per hear d.b.h. for the first 50 years of growth, slowing slightly thereafter.

Tests for strength and fiber characteristics have only recently been undertaken, but current testing at the University of California at Berkeley indicates characteristics equivalent to western red cedar. Resistance characteristics pertain to lumber products of sequoia as well as to the standing trees, giving the lumber an added advantage in the commercial market.

On the basis of inadequate test plantings, the sequoia has long been assumed by foresters to be unsuitable as a potential forest tree in Oregon. However, practical unofficial experience indicates the tree has adapted extraordinarily well throughout the Willamette Valley, and well up into the Douglas fir regions on the bordering slopes. Its demonstrated rapid growth rate and low mortality rate in parts of Oregon, its ability to reporduce, coupled with its apparent ability to meet an increasing demand for wood fiber, recommend the sequoia as an addition to the forest trees of Oregon.

SEQUOIADENDRON GIGANTEUM IN OREGON:

ITS HISTORY AND POTENTIAL

by

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A THESIS

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The investigation which led to this master's thesis began with an undergraduate paper on distribution of sequoias in the Eugene area. Through the encouragement and perception of Dr. Carl L. Johannessen, the subject developed into a consuming master's research.

Critical illness, and finally death on October 23, 1970, prevented Tom from completing the written account of his research. The Department of Geography, and Dr. Johannessen, undertook to sponsor the completion of the thesis, other requirements for the master's degree having been met. I was permitted the honor of the final writing, and assume responsibility for phrasing and terminology.

I am indebted to the University on Tom's behalf for this opportunity to have his work recognized. I am most grateful to Dr. Johannessen for constant encouragement, guidance, and patience; to Dr. Clyde Patton for editing; to Dr. William Loy for assistance in developing some of the graphic materials included, and to the Department of Geography. Dr. Herbert Sampert of the University of California at Berkeley deserves special recognition, as do Drs. Harold Biswell and R.A. Cockrell of Berkeley, Dr. Richard Hartesveldt of San Jose State College, and Floyd Otter of Sacramento, all of whom provided support and invaluable background.

Private citizens have long appreciated the qualities of the sequoia. Tom hoped, with this work, to focus the attention of Oregon's timber resources management on the potential of that magnificent immigrant from the California Sierra, *Sequoiadendron giganteum*.

Martha F. Burns

(Mrs. Thomas Buckeridge Burns, Jr.)

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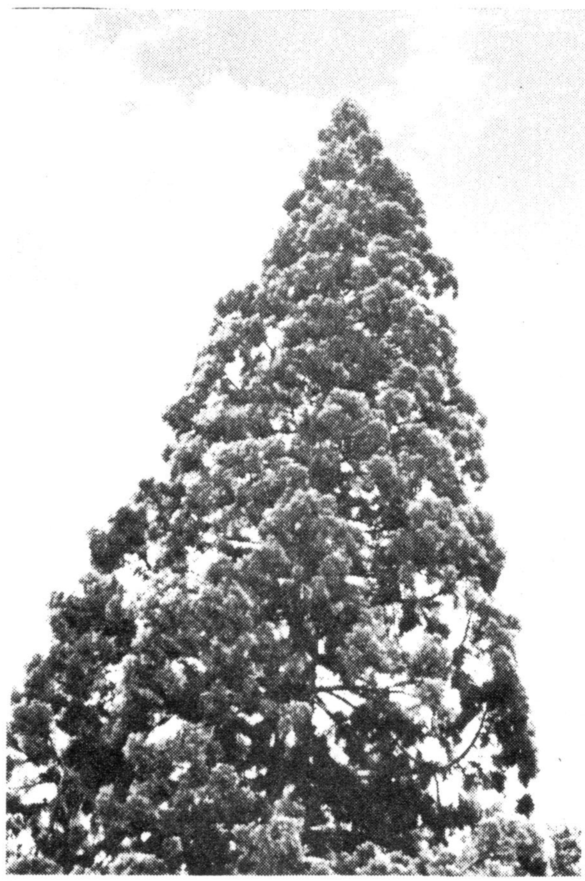


SEQUOIADENDRON GIGANTEUM IN OREGON:
ITS HISTORY AND POTENTIAL

INTRODUCTION

The Problem

Sequoiadendron giganteum (Lindl.) Buchh. is growing rapidly in Oregon and its distribution is increasing with time. It is a unique species indigenous only to an extremely small natural range on the western slope of the California Sierra Nevada. Since it does exceedingly well in the Willamette Valley of Western Oregon, the giant tree apparently has had its distributional range greatly increased due to the aegis of man.

World Distribution

Following an expedition into the Tuolumne and Merced Groves with the Joseph R. Walker exploration party in 1833, Zenas Leonard (1904:180) recorded the first known description of the giant sequoias. The information, however, was not publicized at that time (Stagner, 1952:2).

A. T. Dowd first carried word of these remarkable plants from their natural range to the outside world. A paid hunter for a flourishing gold camp, he wandered by chance into a high grove in Calaveras County, California, in 1852 (Johnston, 1966:14, 15), and enticed others from his camp into the area by his stories.

The coastal redwood, discovered nearly a century earlier growing throughout the foggy, north coastal California, had recently been classified botanically (Sequoia sempervirens [D.Don] Endl.) at the time the giant tree was discovered. General interest in the new species lagged however, until timber was needed for gold camps. The discovery of gold created and sustained an atmosphere of excitement, adventure and exploitation, as well as a need for wood. The new discovery of the high mountain giants created a sensation.

In England, a controversy raged briefly about naming the tree after the Duke of Wellington (Farquhar, 1966:87). It was first assumed to be a close relative of S. sempervirens (coast redwood); it is now thought by many to be a separate genus. The proper scientific name of the species, and its generic designation, are still controversial (Stark, 1968:267). However, Nellie Beetham Stark, Richard Hartesveldt, Harold Biswell, and Herbert Sampert, all specialists on the sequoia, prefer Sequoiadendron giganteum (Lindl.) Buchh., (giant, or big tree, or sequoia), and this scientific name is becoming widely accepted (Farquhar, 1966:87).

The present natural range of giant sequoia extends from Placer County to Tulare County, California (Fig. 3). The area of the isolated groves totals about 50,000 acres in a narrow discontinuous belt on the western slope of the Sierra Nevada (Biswell, Buchanan and Gibbens, 1966:630). The size of this range appears to be static and quite possibly diminishing (Sampert, 1968: pers. comm.; Stark, 1968a: 267). The zone of groves is the last remnant of a once much more extensive distribution in geological time.

Fig. 1. Oregon's first sequoias. John Ramsey Porter's double row of sequoias during early years. Undated photograph from family records was taken from opposite end of land from Fig. 2.

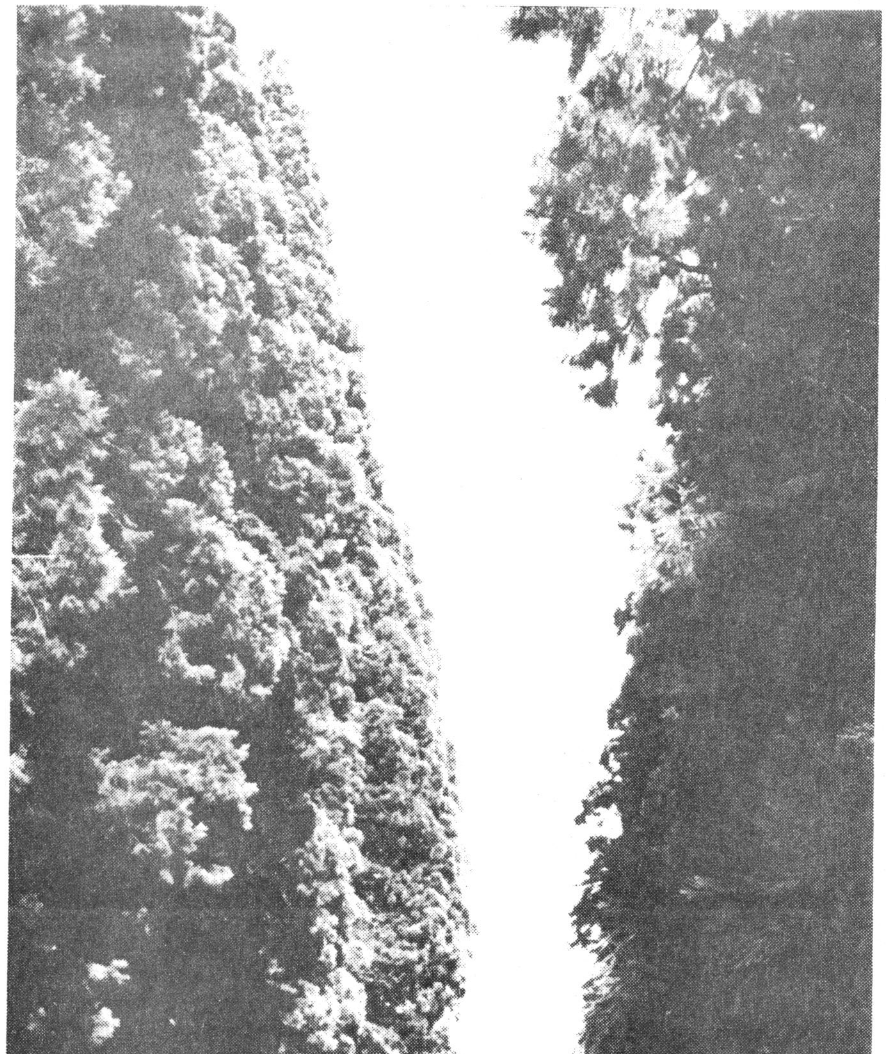


Fig. 2. Porter's home grove of sequoias a century after planting near Forest Grove, Oregon.

However, in just over a century, seed of sequoias has been transported and has prospered from England, Switzerland and Hungary to New Zealand (Farquhar, 1966:88). Stanford (1958) and Stark (1968b: 84) claim the seed has been successfully introduced to at least fourteen countries and various states in the United States. Emanuel Fritz (1967: pers. comm.) cites a sequoia in Spain with a d.b.h. of 7 feet, 5 inches, a considerable size for a century's growth.

History of Development in Oregon

The giant tree was introduced to Oregon in the late 1860's. The history of the tree in Oregon begins with John Ramsey Porter who was born in 1827 and arrived in Oregon in 1848. He went to California in 1849, apparently to take part in the gold rush, and came back to Oregon about three years later to settle a donation land claim a mile northeast of the present town of Forest Grove, on Christmas Day, 1852 (Van Dyke, 1967: pers. comm.). Family records show he must have gone back to California because he was living in Oakland in 1856 and did not return to Oregon until the early 1860's to settle his land claim permanently and to start a nursery, primarily of fruit trees. He brought sequoia seed (rather than seedlings or cones) at this time from the California groves. The dates on the family records indicate germination of the seeds in Oregon to be no earlier than 1868.

His trees are the first known in the state, and were planted in two rows of eighteen trees each bordering a lane to his house (Fig. 1). There are now thirty-one trees standing, (Fig. 2), and four stumps of trees blown down in an unprecedented near-hurricane in 1962, known in Oregon as the "Columbus Day storm." One gap in the rows is unaccounted for. The stumps provide a comparative check of ring count against the recorded planting date. The stump ring count gives a maximum age of ninety-five years in 1970 if we include a generous decade for growth to height of stump. Therefore it is apparent that the trees cannot be more than one hundred years old.

As a local nurseryman, and the only one of the time known to stock sequoias, Porter was likely responsible for all the earliest sequoias in the Hillsboro-Forest Grove area, and for others in Portland that date from the 1880's. The Willamette Valley now contains thousands of sequoia trees.

From the beginning, in Oregon as elsewhere, the tree was admired for its aesthetic qualities. There is evidence of its early association with churches and public buildings, and later, as easily distinguishable section or boundary markers. Sequoias were valued for their visual uniqueness. No evidence exists that any plantings were made in anticipation of an eventual timber crop.

The sequoia has shown a remarkably good response to the Willamette Valley habitat. The valley's more northerly latitude (44°-46°N) in comparison to its range in the Sierra is offset by lower elevations (50 to 500 feet above sea level). Its wet-winter/dry-summer climate approximates conditions in the California natural range. The tree not only thrives, with an extremely low mortality rate, but has begun to reproduce naturally, indicating potential as a permanent member of the Willamette Valley biota.

This study emphasizes sequoia development prior to the time when they became easily and generally available in nurseries, that is, from 1868 to 1940. The plantings from this period are of sufficient age to allow documentation of adaptability, survival and possible reproduction.

METHODOLOGY

Literature Review

Few publications deal in detail with the distribution and the ecology of the giant sequoia. Of those that do, nearly all treat the tree in its native habitat. Several studies of an observational nature were published from the late 1950's to the early 1960's, all based on investigations within the natural range. Many of these have concentrated on the Whitaker's Forest tract under the supervision of the University of California at Berkeley, California.

Early in this century naturalist George Sudworth (1908) included the giant sequoia in his Forest Trees of the Pacific Slope. Prior to that, John Muir (1877; 1878; 1888; 1911) had written several accounts, also from a naturalist's viewpoint, of the habitat and idiosyncracies of sequoia, noting in carefully descriptive terms, many observations about characteristics and conditions that serve now as reference points for researchers.

However, from Sudworth in 1908 until Schubert's (1957; 1962) compilation in 1957, nothing of a scientific nature was published concerning sequoias. Nellie Beetham (Stark) (1961; 1968a; 1968b) undertook probably the most comprehensive botanical studies of the sequoia. A group of specialists from the University of California at Berkeley and from San Jose State College have begun to fill in the gaps of knowledge about the sequoia, and include Herbert Sampert, Richard Hartesveldt, and Harold Biswell. In addition authors such as

Hank Johnston (1966) and Floyd Otter (1963) have written accurate narratives of the history of man's interest in the tree.

Only two studies have been published concerning the sequoia in the Pacific Northwest, one dealing with the trees at Wind River in the Washington Cascades and the other with Cascade Head on the Oregon Coast. These are meager in scope and offer little useful information on the growth history of the tree. A study of the possible use of sequoia for wood fiber products is currently being undertaken in Hungary (Hartesveldt, 1968: pers. comm.).

No quantitative studies have been undertaken concerning reproduction, growth rate, resistance characteristics, mortality, or wood fiber analysis of S. giganteum in the United States. R. A. Cockrell of the University of California at Berkeley has just completed a limited study of mechanical properties of the wood. It is understandable since it is a protected species in California, that the sequoia would not be taken seriously as a candidate for commercial study (in spite of visual evidence that it thrives in other localities than the protected native range as parks and forests), but it is difficult to fathom the total lack of interest in its performance for maximum knowledge of the species by those agencies charged with its preservation.

Field Research

Previous publication on the sequoia in Oregon being effectively non-existent, information concerning sequoias in the Willamette Valley was obtained almost entirely from field research. The field work includes correspondence or interviews with present owners and descendents of original owners, visits to sites of older trees, mapping and ecological analysis of sites, tree size measurements, tree ring analysis and, in many cases, recording by photographs. Information was sought regarding both cultivated and non-cultivated sequoia trees and groves.

Scope

Groves in the California Sierra were visited for purposes of visual comparison. The University of California School of Forestry Library at Berkeley was visited and faculty researchers interviewed in person. Groves and many individual trees in Oregon and southern Washington, outside the Willamette Valley, were located, visited and recorded for ecological detail. Within the Willamette Valley, groves and individual trees were located, visited and mapped. Where available, the history of the trees in the valley and their present condition were recorded.

Method

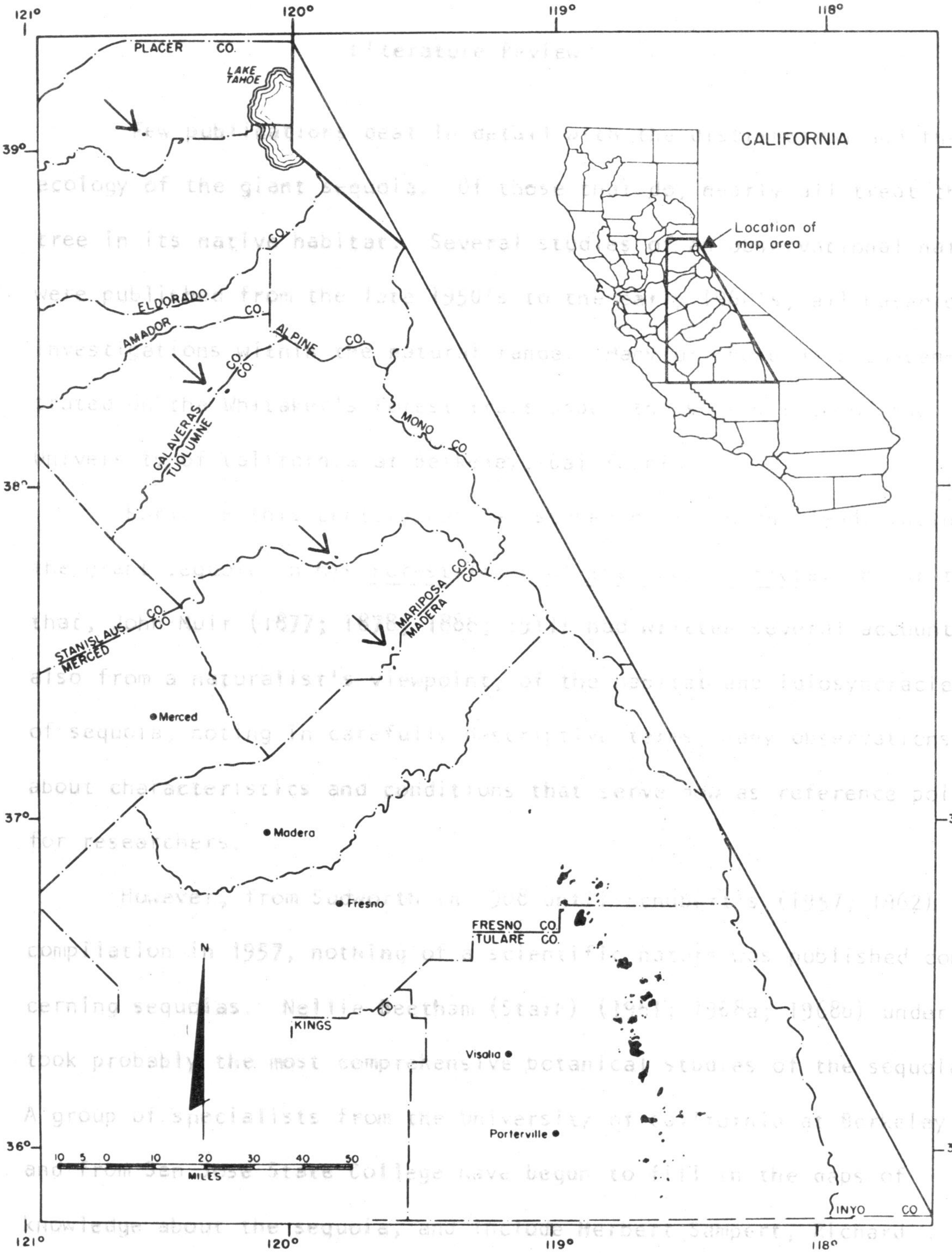
Correspondence was initiated with past and present owners of older sequoias in the Willamette Valley. Correspondence also includes communications from persons having information about early plantings, such as T. J. Starker of Corvallis, and the Oregon State University Archivist, as well as those responsible for current planting practices in the Willamette Valley, and researchers conducting current studies in California.

A historical record of the first trees was developed primarily through conversation with Mrs. Joseph Van Dyke, a descendent of the Porter family, who provided definite dates from early family records. Other sources served to corroborate her information. The Oregon Historical Society was able to provide some early photographs. Information on the 1890's planting still is nebulous. The 1935 plantings were from seed from California, and were spread through the efforts of the School of Forestry of the Oregon State Agricultural College in Corvallis, now Oregon State University. Many of the persons directly involved in these plantings were contacted.

Many older trees (those planted prior to 1940) were located and visited, and measured for diameter breast high (d.b.h., about 4 feet, 6 inches from ground level). Increment bores were taken where permission was granted, for analysis both of age of tree and of growth development. Photographic records were made of many individual trees including those showing poor growth, normal growth, and extraordinary growth.

Site analysis of slope and aspect, evidence of ground water, and plant associations was made at each location. Peculiarities of site or growth pattern were noted, as well as evidence of mortality or disease. Basic soil information was obtained from U. S. Geologic Survey Maps and Soil Conservation Service offices. Evidence of cone production was noted. Climatological information relating to individual sites was obtained from U. S. Weather Bureau compilations.

Fig. 3. The range of giant sequoia in California.



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The range of giant sequoia. Adapted from a map by the California Department of Natural Resources.

RESULTS

Natural Range in California

Distributional Limits of Maximum Range in Modern Times

Over eighty groves of *Sequoiadendron giganteum* are located on the west slope of the central Sierra Nevada of California at elevations of about 7500 feet in the south to about 4500 feet in the north. A few trees grow naturally beyond these limits (Grater, 1968: pers. comm.). The distribution of the groves extends for a distance of 250 miles from Deer Creek in Tulare County north to the middle fork of the American River in Placer County (Stark, 1968a: 267). The groves are larger, have more sequoia trees per acre, and individual trees are more "exuberant" (Muir, 1877:247) near the southern limits of the range (Fig. 3).

When John Muir toured the sequoia range in 1875, he noted that the range of the trees was related directly to the ancient glacial coverage in the Sierra. The groves developed on those areas unchilled by cold air drainage from glaciers upstream and unscoured by glacial ice (Muir, 1877:250). He observed, "The wider the ancient glacier, the wider the corresponding gap in the sequoia belt." He also felt the species was distributed from the south, accounting in part for its northern sparseness. He found no single trees growing more than a mile from the main body, and these were usually young (Muir, 1877:244, 251).

The closest fossil relative of the big tree is the late Tertiary Sequoia cheneyi (Hartesveldt, 1964:12). This ancient species has been found in the paleontological record in west central Nevada, east of Reno.

Ancestors of the sequoia date from the late Jurassic, and later apparently radiated from their probable original home in the Arctic archipelago, southward to western Europe, North and South America and along the eastern coast of Asia (Berry, 1920:153-155). Of this vast ancient family, only three descendents survive: S. sempervirens, S. giganteum, and Metasequoia glyptostroboides (dawn redwood), each now indigenous to one limited natural range in the world. Although little is known of the dawn redwood, now native to China, the range of the giant sequoia is probably the most restricted.

Characteristics of Sequoia Groves

The groves range in size from more than 6,000 trees in Giant Forest in the southernmost part of Sequoia National Park (elevation 6,000 feet) to a total of only six trees ten feet in diameter and over, in the northernmost grove (elevation 4,500 feet) (Schubert, 1957:3).

The sequoia grows in association with other species, rarely occurring in unmixed groves. Isolated single trees are seldom observed in the Sierra range (Stark, 1968a:275), and never more than one mile from the nearest grove (Muir, 1877:244). The sequoias' flat, broad, greatly interwoven root mat provides a highly stabilizing base for the great trees (Crippen, 1968: pers. comm.), as well as serving as a sponge to trap sufficient ground water to sustain them during periods of drought (Muir, 1877:248, 249).

Environmental Conditions in California

Autecology of Giant Sequoia

> Summers in the natural range of the species are warm and dry with almost no precipitation except for occasional light thunderstorms. Most of the annual precipitation (ranging between 24.8 and 35.8 inches) falls as snow beginning in October or November and continuing through April or May. Annual snow accumulation varies from 45-185 inches.
>
> The warmest month of the year is August when daily air temperatures may rise to 40°C, but often drop to 2°C at night. Intense summer solar radiation on exposed sites may heat the soil surface to 65°C while temperatures on shaded sites may be as much as 16°C lower.
>
> The winters are cold; air temperatures seldom exceed 10°C during the day and sometimes drop to minus 23°C at night. The average annual frost free period is 124 days. (Stark, 1968:267)

Stark's average annual precipitation readings for the range differ markedly from weather station readings within the area (Fig. 4); the recorded averages being much higher, particularly for stations in the lower range of elevation of the trees. Other compilations show slight variation in precipitation over differing periods of time for these same weather stations, but such differences can probably be disregarded.

Fig. 4. Climatic Data for the Natural Range of <u>Sequoiadendron giganteum</u>[1]

STATIONS	Elevation	TEMPERATURE (F.)					PRECIPITATION (inches)	
		Average Annual	Average January	Average July	Extremes*		Average Annual	June-August
					High	Low		
Calaveras	4,696	50.1	36.9	68.7	107	-4	53.56	.70
Yosemite	3,970	53.4	36.3	72.0	110	-6	36.51	.86
South Entrance	5,120	49.4	39.1	69.9	102	-3	46.00	.20
Huntington Lake	7,020	42.3	30.2	61.0	89	-18	32.00	--
Grant Grove	6,600	46.2	36.9	66.2	90	-6	45.00	.63
Giant Forest	6,412	46.6	32.0	64.0	94	-5	45.00	.66
Averages of Stations Listed	5,636	48.0	35.2	66.9	98.6	-7	43.01	.61

1 Table adapted from <u>Climatological Data: California Annual Summary, 1967</u>, Vol. 71(13), U.S. Department of Commerce, ESSA. Normals based on period 1931-1960.

* Source: <u>The Distribution of Sequoiadendron giganteum</u>, unpublished ms. Donald E. Graham, University of Oregon, 1959.

More significance attaches to extremes of temperature and precipitation. *Sequoiadendron giganteum* will be shown to demonstrate a tolerance of a wide range of average annual temperatures, and to a lesser extent, of average annual precipitations. Precipitations range from twenty-five inches (Stark) to over fifty-three inches (Fig. 4) annually within the area of the groves. Most of this falls as snow during the winter months in the higher elevations, although lower elevations experience considerable fall and spring rain as well. In addition to the June through August dry period, March and October are likely to be dry. November and December may also record little precipitation but normally either April or September, or sometimes both months, record more than 2.5 inches. Failure of precipitation in both of these months can extend the drought period to ten months as it did in 1959 in Grant Grove (listed in Fig. 4) (U.S. Weather Bureau, 1944-1967). If it is soil moisture that limits the sequoia's establishment and growth, it is most likely that this length of drought and its associated relationship to available ground water makes the critical difference for the plant.

Temperatures occasionally fall well below freezing, (note -18°F at Huntington Lake), and rise to over 100°F at times in some locations. Conditions in Oregon (as will be shown in the next section) are well within these climatic extremes.

A growing season length of 124 days is given by Schubert and Beetham (1962:658) as an average for the natural range. This length varies widely from station to station, however.

Data are not available from the Sierra to establish tolerances of the sequoia, although some situations in Oregon and Washington indicate that extremes of excessive precipitation may limit growth.

Muir found the stands to be located on non-glaciated bedrock but noted that they have sometimes developed on moraines (Muir, 1877: 251). On these non-glacial islands soils are generally developed from granitic, dioritic or andesitic rocks. The most common soil series are Holland, Olympic and Sierra (Schubert, 1953:3). Schubert quotes Nellie Beetham (Stark):

> Giant sequoia grows on a wide variety of soils from shallow rocky to deep sandy loams. Although it develops on shallow, moderately dry soils, the tree grows best on moist, deep, well drained soils slightly to moderately acid in reaction. The best growth of seedlings has been observed in soils of pH 6; poorer growth was found at pH 5 and 7. Seedlings planted in wet soil do not survive because of low aeration. (Schubert, 1957:1)

Stark states "*S. giganteum* can develop a two-storied root system well suited to summer drought." (1968a:94). Nearness to ground water assists the trees through the dry summer, although it has been found by nearly all students of the trees that standing water or saturated soils are detrimental to the growth rate.

> Many seedlings die in areas where the soil is too wet or too dry. When the soil moisture at 6 inches' depth exceeds 18 to 20 percent or falls below 5.5 percent in sandly loam, conditions do not suit seedling survival. Short periods of excessive soil moisture do little damage, but aeration becomes inadequate during long periods of floods. Severe root competition for the limited soil moisture supply reduces the chance of seedling establishment in old stands. (Schubert, 1957:8, 9)

According to Yosemite Park Naturalist, Robert Crippen (1968: pers. comm.), longer growing season and regular supply of moving ground water noticeably increase the growth rate of the tree.

As with other conifers, younger trees show a faster growth rate than mature trees, and mature trees continue to show a consistent although greatly slowed growth rate. It should be kept in mind that as the tree increases in height and diameter, the same amount of wood fiber production must be distributed over a greatly increased circumference. Young trees develop a conical symmetry that begins to "crown out" into a rounded top some time after one hundred years. Older trees lose their branches below about one hundred feet and upper branches tend to become very thick, often long, and no longer retain the characteristic symmetry of younger trees (Sudworth, 1908:140).

Cones mature during the second summer of their development, attain a length of two to three and a half inches and produce about 230 seeds. Full production of cones occurs from the age of 150 years on in the forest, although younger trees, growing in open situations, will bear cone crops (Sudworth, 1908:145; Schubert, 1962:668). Seed dealers generally agree that viable seeds come from older trees (Adams, 1968: pers. comm), but I have found seedlings from trees no more than sixty years old, some possibly younger. Sequoia seeds are very light and readily wind-borne for short distances, but are too insubstantial to be of major interest to rodents or birds

(Schubert, 1962:660), although squirrels store cones for winter (Sudworth, 1908:140; Otter, 1969: pers. comm.) and Otter (1963:9) reports seed loss to deer mice at Mountain Home. Seeds require sunlight, moisture and mineral soil to germinate, although parent trees normally accumulate a dense smothering litterfall to the drip line which impedes the growth of any vegetation. Once under way, seedlings are normally hardy. Present reproduction rates are considered insufficient to maintain the stands at their present size (Stark, 1968a:275).

Synecology

The groves differ greatly not only in size, but also in plant associations, although most groves contain these main species in addition to the sequoia:

> Abies concolor (Gord. & Glend.) Lindl., Libocedrus decurrens Torr., Pinus jeffreyi Grev. & Balf., P. lambertiana Dougl., P. murrayana Grev. & Balf., P. ponderosa Laws., Sequoiadendron giganteum (Lindl.) Buchh., and Taxus brevifolia Nutt.
>
> Ferns, mosses, herbs, grasses, and brush are common in some groves. Continuous mats of herbaceous and low shrubby vegetation once grew in most groves, but heavy recreational use of some areas has severely reduced the ground cover. (Stark, 1968a:268)

Since sequoia seedlings need both sunlight and mineral soil to grow, the popularly initiated current protective policies have allowed more shade-tolerant species, mostly white fir, to overtop the small sequoias with the result that the proportion of white fir in stands is increasing and regeneration of sequoias is decreasing.

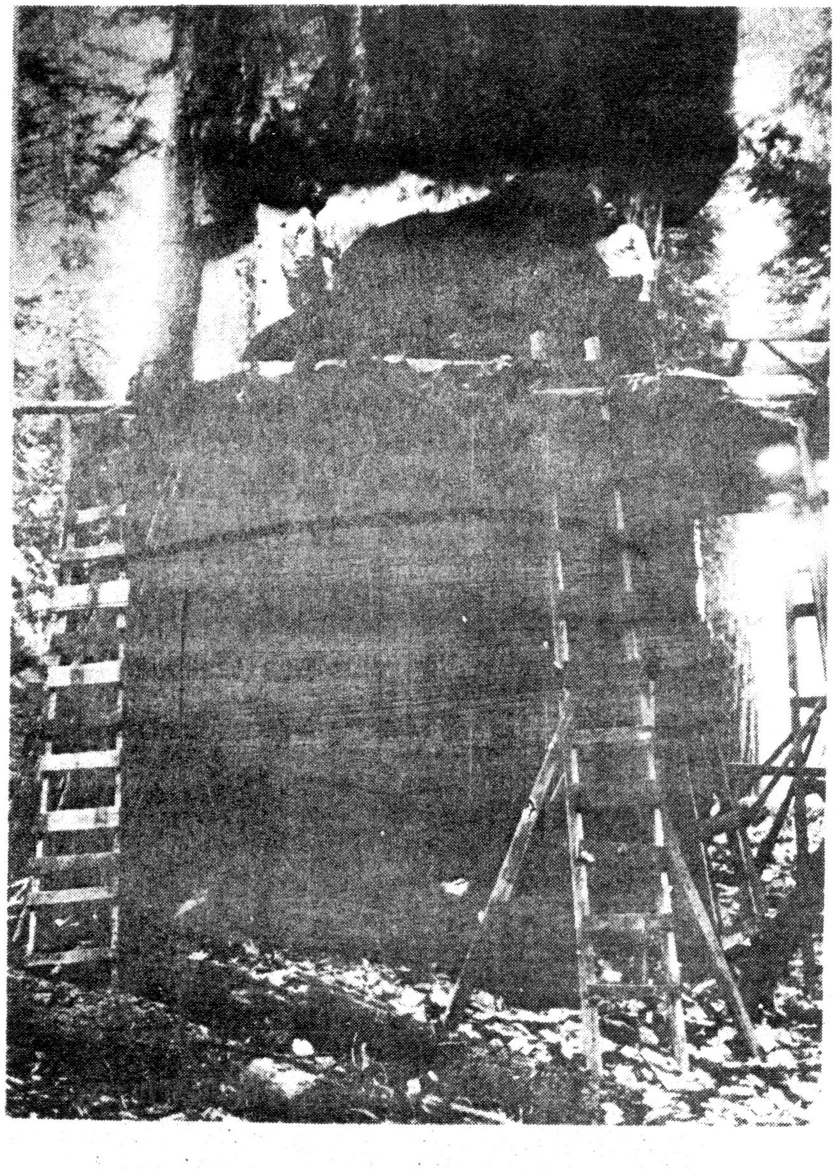
An apparent "fire ecology" pertains to the sequoia (Hartesveldt, 1964; Hartesveldt and Harvey, 1968). A result of well-intentioned fire protection has been elimination of the one factor which periodically removed the heavy litterfall from under the big trees so that the tiny seeds could come in contact with mineral soil to germinate. The consequence in lack of reproduction is considerable.

As Stark notes above, heavy recreational use of parts of the range has taken its toll in reduction of natural ground cover.

The ultimate results of all of these alterations in growing conditions cannot yet be entirely assessed. Nevertheless, some results are known, and changes in the character of some groves observed.

Preservation of Giant Sequoia

While the great trees were valued for their magnificence by many, there were those who immediately saw them as an unlimited supply of lumber. Logging operations were organized to exploit entire forest groves. Those stands that were most accessible, as at the edge of canyons to permit construction of gravity flow transportation systems out of the mountains, were attacked first. The size of the trees required ingenuity in logging methods (Fig. 5), including augering a series of holes to cut the tree and blasting the mammoth trunks with dynamite into smaller, manageable pieces. Weaver and Biswell (1969:4) quote John Muir's account in 1876 of the logging of Whitaker's Forest:



A falling ax weighed about five pounds and a medium sized Sierra redwood like this might weigh 500 tons, but Henry Talley (L.) and Earl McDonald are making the undercut into chips so large a boy could hardly lift one. The original photo, owned by Joe McDonald of Springville, is captioned "Cutting a Sequoia at Mountain Home about 1901."

Fig. 5. Cutting a sequoia at Mountain Home.

> In this glorious forest the mill was busy, forming a sore, sad center of destruction, though small as yet, so immensely heavy, was the growth. Only the smaller and most accessible of the trees were being cut. The logs, from three to 10 or 12 feet in diameter, were dragged, or rolled with long strings of oxen into a chute and sent flying down the steep mountainside to the mill flat, where the largest of them were blasted into manageable dimensions for the saws. And as the timber is very brash, by this blasting and careless felling on uneven ground, half or three fourths of the timber was wasted.

No thought was given to waste. The Converse Basin stand, probably exceeding 8,000 trees, and considered by John Muir and others to have contained the finest examples of "Sierra redwood" on earth (Johnston, 1966:59, 81), was totally razed (Figs. 6, 7).

The pillage of this unique species finally aroused the public, including George Steward and other citizens in and around Visalia, California, and naturalists like Muir, to work to protect the remaining trees. The last really major logging ended about 1915, although some logging continued even up until the early 1960's (Otter, 1970: pers. comm.). Now nearly all the giant sequoias are under some kind of protection, with over ninety percent in public ownership.

But ironically, with man's eventual protection of the trees, reproduction has been seriously hampered. Protection has inadvertently achieved the virtual elimination of the "natural" conditions, including periodic fires, to which the tree had adapted. This is a species that could remain without reproductive success for a century or two and yet maintain itself after the eventual fire swept over the mountains. Studies made in recent years (Hartesveldt,

Fig. 6. Natural regeneration of sequoias in the Converse Basin in the late 1930's.

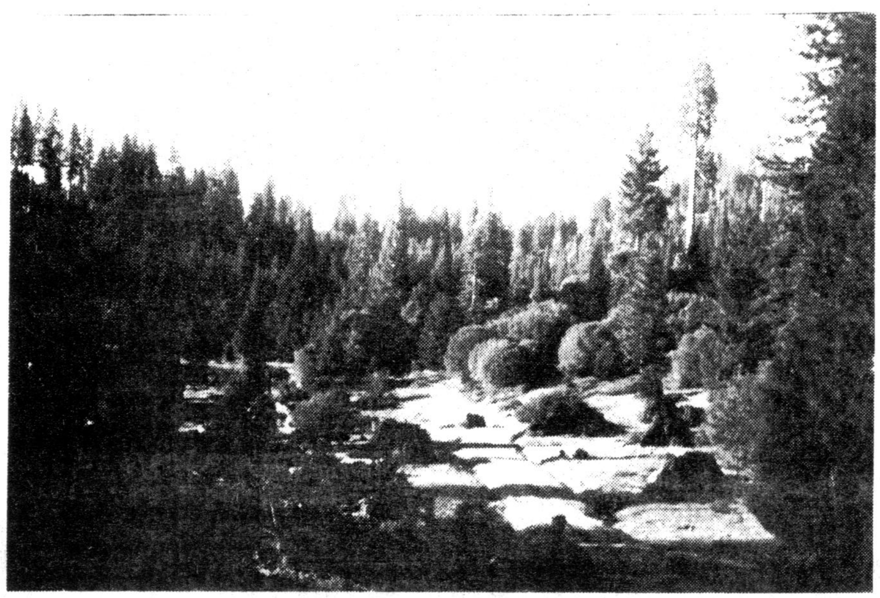


Fig. 7. The second growth stand from approximately the same vantage point in 1968.

1964:15; Hartesveldt and Harvey, 1968:17; Stark, 1968a:275; Weaver and Biswell, 1969:16) indicate the seedling development rate has decreased to a non-sustaining level, threatening to further reduce the present size of the relatively small range.

> Sequoiadendron giganteum under natural conditions without fire protection is a long-cycle fire-climax species. Under protection from fire, it appears to be a subclimax species leading to a climax stand dominated by Abies concolor. The absence of natural wildfires is threatening the future of the giant sequoia.
>
> The undisturbed S. giganteum groves before the advent of white man were adapted to periodic light fires and interims of 7-50 or more years for starting young growth. These light fires cleaned away dead or diseased trees and removed excess litter and debris so that reproduction was possible. Today there are an average of only 1.7 young trees (recent reproduction not yet producing cones) for each mature parent tree in the groves frequented by tourists. This scarcity of reproduction is traceable directly to the accumulation of litter on the forest floor. Where logging has disturbed the litter and exposed bare soil, there are 7.3 young trees to each old parent stump (Stark, 1968a:275).

Man-Induced Distribution in Oregon

Introduction and Spread into Oregon

Planting Period 1870-1885. John Porter brought seeds from the Sierra for the first sequoias grown in Oregon. According to Mark Mathison, (1969: pers. comm.), present owner of the Porter grove near Forest Grove (Fig. 9), one of four trees blown down by the disastrous 1962 Columbus Day storm grew to 160 feet in height in less than a century. In addition to those planted on his own property

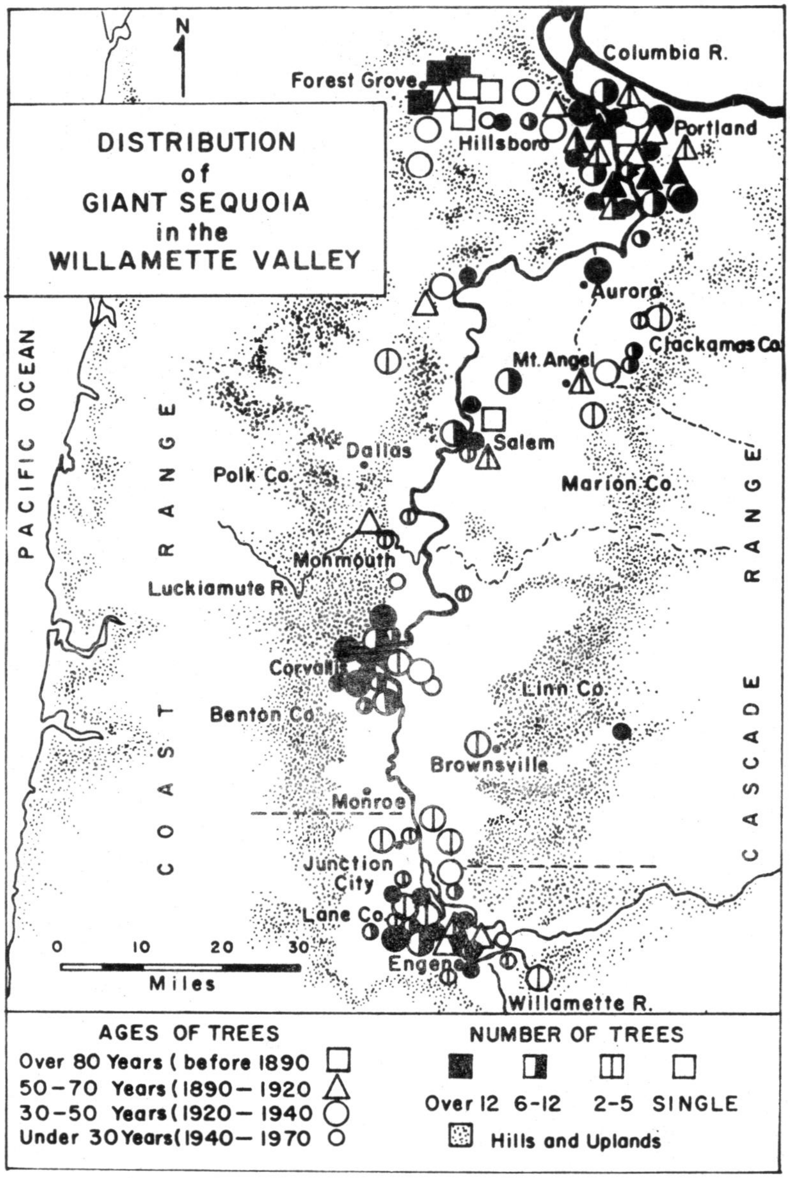


Fig. 8. Distribution of giant sequoia in the Willamette Valley.

Fig. 9. The Porter grove near Forest Grove, Oregon, rises majestically in the distance above every other species of tree (1970).

around 1870, Porter's nursery stock was used in numerous other locations in the northern Willamette Valley in the 1880's (Fig. 8).

Porter gave nineteen sequoia seedlings or small trees to the Verboort Catholic Church about a mile northeast of his nursery in 1882. One was subsequently cut for reasons unrecorded (leaving a large stump); one was blown down in 1962, and another suffered severe vertical cracking in the 1962 storm, but still stands. The remaining sixteen trees appear healthy with full rich foliage (Fig. 10), although several were topped slightly following the 1962 Columbus Day storm (Malyczko, 1970: pers. comm.).

Porter's nursery also provided five seedlings for the Hillsboro courthouse grounds in 1888, all of which survive (Figs. 11, 12).

In Forest Grove, named in the mid-nineteenth century for its already magnificent stand of white oak, Porter's sequoias (there are at least eighteen scattered throughout the south portion of the town) are now more than double the height of the oaks, and range in diameter breast height from 3.5 feet to 7.7 feet.

Porter was probably also the source for the earliest Portland sequoias, which include the four trees marking Daniel Wright's grave which is dated 1874 (Fig. 13), and one other (Fig. 14), in the Lone Fir Cemetery at N.E. 20th and Stark Streets. The cemetery, established in 1866 according to a plaque on its one tall fir, contains ten sequoias in all. Six of these are the tallest trees in the cemetery and contain the greatest volume of wood fiber, the largest measuring a d.b.h. of 5.6 feet compared to the "Lone Fir's" d.b.h. of 3.8 feet. The four

Fig. 10. John Porter's sequoias surround the Catholic Church at Verboort, Oregon in 1970. The trees were topped slightly following the 1962 Columbus Day storm, modifying the normal conical shape.

Fig. 11. Five sequoias (above) planted on Hillsboro courthouse grounds in 1888, as they looked in 1904 at a local gathering

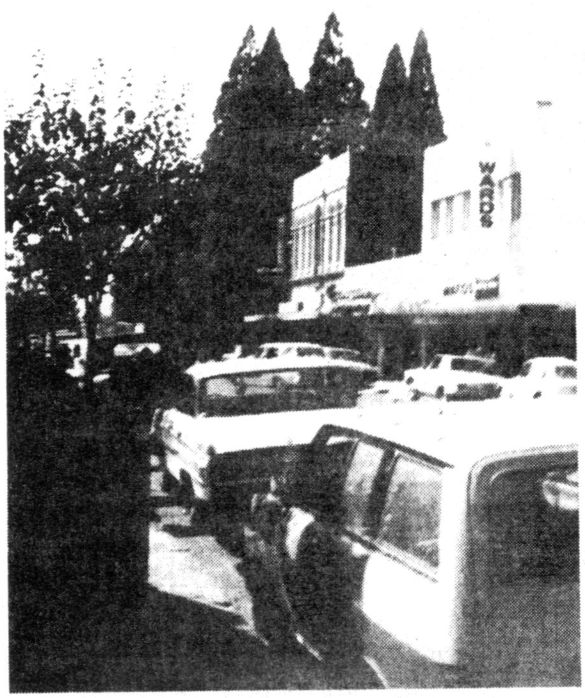


Fig. 12. By 1970 the five sequoias have grown too large to photograph from the same point. This view is from the next street over, and shows the growth by 1970.

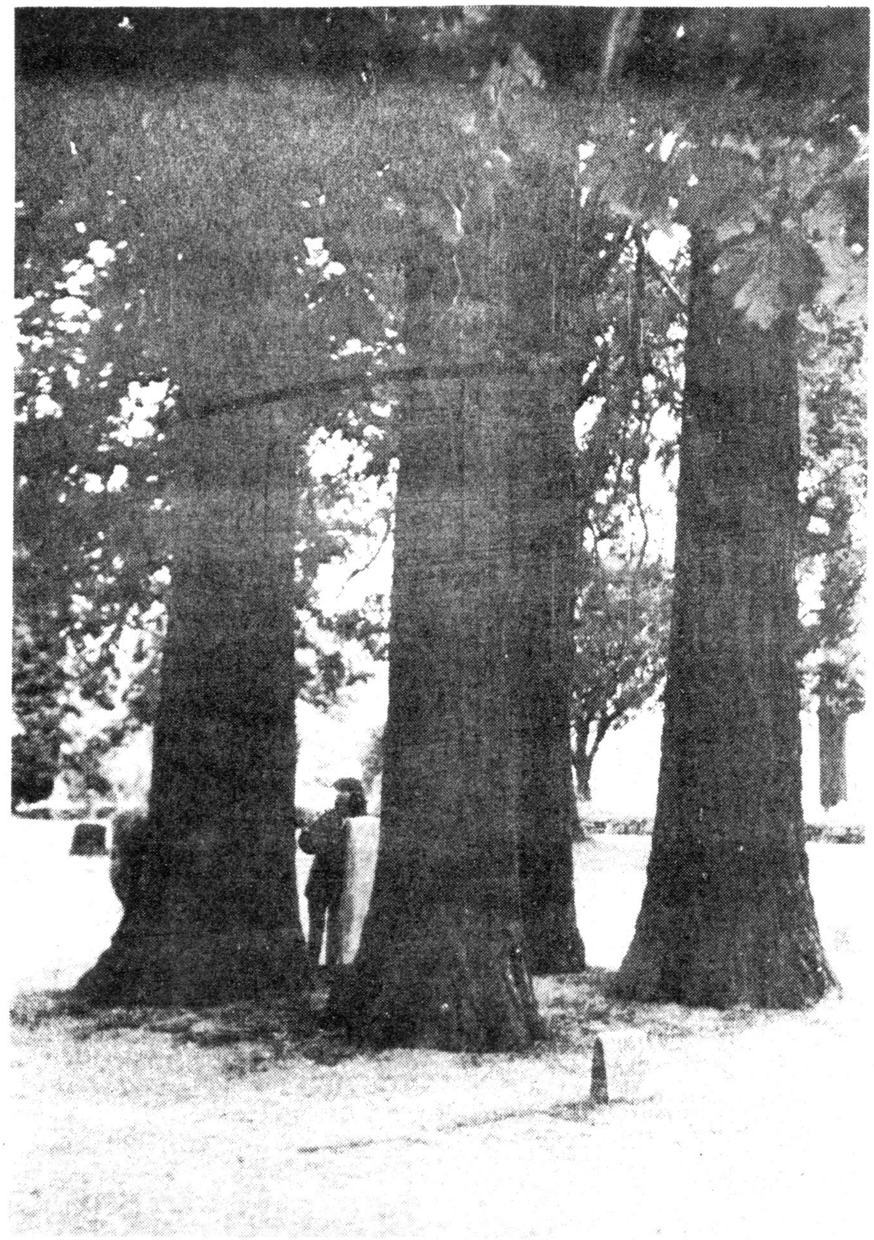


Fig. 13. Sequoias marking Daniel Wright's grave in Lone Fir Cemetery, Portland, presumably planted subsequent to his burial in 1874. Photographed in 1970.

Fig. 14. A single sequoia in the Lone Fir Cemetery in Portland. Date of planting unknown. Note the size in comparison with other trunks in photograph.

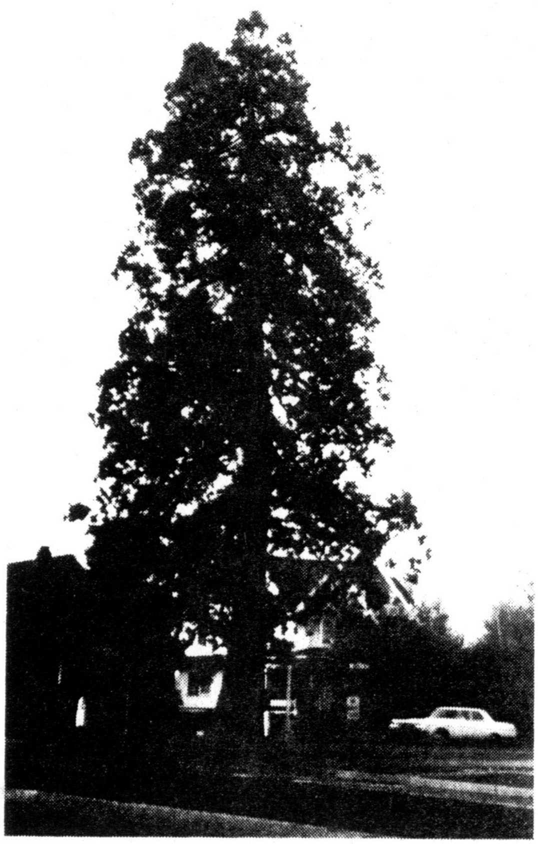


Fig. 15. Waldo Park in Salem, Oregon. The park was established by city ordinance in 1936 solely to protect and preserve, for public enjoyment, the oldest S. giganteum in the city of Salem.

sequoias around Daniel Wright's grave were planted very close together, approximately ten feet on center, and are neither as tall nor as densely foliated as the others.

Both in the Tualatin Valley (Forest Grove, Hillsboro, and Verboort) and in the Lone Fir Cemetery, sequoias planted as seedlings among existing mature trees, have overshadowed the natives. This bears out Schubert's statement, "With an even start, giant sequoias can outgrow any associated species" (Schubert, 1957:9).

The only other tree seeming to date from this period is the Waldo Tree two blocks north of the State Capitol in Salem (Fig. 15). Although some records cite 1872 as the planting date for this tree, bought from a "traveling salesman" (Pollard, 1956), no evidence of any other source of sequoia trees for that period can be traced. Indeed, a traveling salesman from Porter's may well have made occasional tours of the northern valley in those early years before telephones and easy travel. The Waldo Tree is 5.6 feet d.b.h. and is unique in that it is the sole tenant of a city park of an area of 12 x 20 feet, designated Waldo Park by Resolution #3645 of the Common Council of the city of Salem on the 15th of June, 1936. It was named for William Waldo, an early, locally prominent lawyer and county judge who had owned the present park property and who preserved the tree from destruction in the early days of street and utility expansion.

Of these earliest Oregon sequoias, several observations should be noted. Only one tree, in Porter's own grove, has died from an unknown cause, and only five were felled by the Columbus Day storm in 1962, with three others damaged. This near-hurricane, unique in recent Oregon history, destroyed in great strips, countless thousands of trees of all species in western Oregon. The remaining Porter sequoias show no evidence of damage by disease, and exhibit healthy foliage and vigorous growth. The largest, south of Hillsboro, has a d.b.h. of 9.2 feet.

Planting Period 1885-1910. The second planting came in the very late 1880's or early 1890's and covered an extensive area from Portland south: Mt. Tabor, Portland Heights, Riverview Cemetery on the west bank of the Willamette River south of Portland, the Milwaukie-Oak Grove area, Oswego, Mt. Angel, Monmouth, and Eugene (Fig. 8). Individuals from this second planting are nearly as large as the first Oregon sequoias, but no positive information is available concerning sources for this period of planting. It is evident that the species was widely known.

The sequoia's importance as an exotic emerged during this era. It was often used as an ornamental and became a fashionable Victorian status symbol. At this time seeds and seedlings were planted on the estate of the Duke of Wellington in England (Farquhar, 1966:87). In Oregon also, the sequoia became a mark of prestige in the 1890's. Parker F. Morrey, in developing his estate, Glen Morrie, south of Oswego, employed San Francisco landscape architect John Gower, trained at Kew Gardens in England, who specified several sequoias for the formal estate grounds. There were other estates between Oswego and Portland marked off in similar fashion (Goodall, 1958:73). These are now

Fig. 16. The largest of John Porter's original sequoia seedlings, growing in an open, cultivated situation south of Hillsboro, Oregon. Photograph taken in 1970.

Fig. 17. One of numerous sequoias in the area of Mt. Tabor, Portland, that have been preserved in the face of "progress." This tree has survived a considerable drop of grade on the street side when a sidewalk and paving were completed beside it.

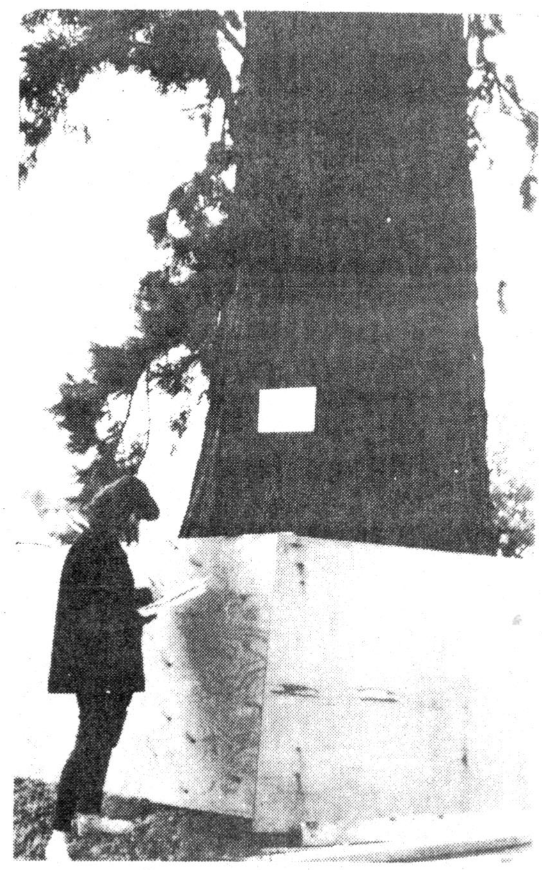


Fig. 18. Although slope was altered considerably on the north gradient of this sequoia at 60th and Belmont, Portland, great pains were taken to preserve the tree during razing of adjoining old buildings and construction of a new hospital parking lot in 1970.

apparent in Briarwood, on Birdshill Road, and Military Road, among others. However, the Glen Morrie trees are the largest, with d.b.h.'s of from four to five feet.

On Portland Heights to the north, many sequoias were used for section markers. Of the nine originally planted "around the turn of the century" on the old Woodard property by Judge George for Carter's Addition, seven are still living. There is no record of the fate of the other two trees (Honeyman, 1969: pers. comm.).

Several trees dating from this era or slightly later are on the west slope of the hills that extend southwest towards Beaverton from Portland Heights. Sequoias were used as property boundary corners or west line markers on what was once the Sealy farm (Honeyman, 1969: pers. comm.). The Montague grove at S.W. 91st and Scholl's Ferry Road consists of seven sequoias with an average d.b.h. of five feet.

In the Milwaukie-Oak Grove area, sequoias were used much less formally than the estate plantings across the river, on large farms as ornamentals around houses (Figs. 19, 20). There are at least forty in this vicinity dating from the Victorian era. The earliest are believed to have been planted about 1892 and were thought to have come from cuttings from slightly older trees on Mt. Tabor in east Portland.*

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*Miss Doris Broetje of Oak Grove states that her great-grandfather maintained a nursery for some time about 1890 on Mt. Tabor (Broetje, 1969: pers. comm.), no other record of which has been found to date.

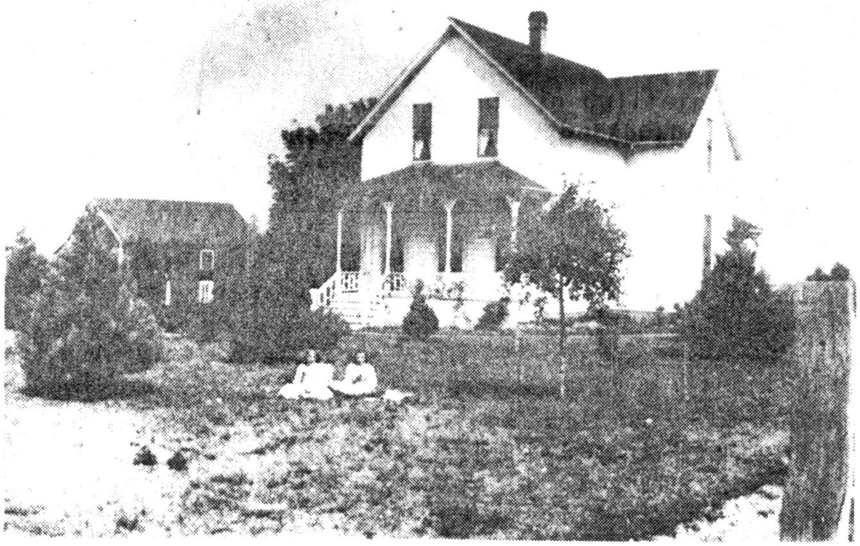

Fig. 19. The Broetje house in the Milwaukie-Oak Grove area. Undated photograph from family records.

Fig. 20. Four of the Broetje sequoias in 1970. The original farmhouse has been replaced or rebuilt, but the sequoias were left.

Sequoias along Oatfield Road in south Milwaukie, source unknown, are thought to have been planted in 1903 (Noon, 1968: pers. comm.).

On the west slope of Mt. Tabor, an area of large farms, sequoias were also planted around farmhouses as ornamentals. A number of these, about six feet tall, were planted in 1900.* Scattered trees, some carefully preserved in the face of newer development, extend from Belmont to Division, and from 55th to Park. In an area of approximately 1/4 mile square, a number of these, ranging from 100-200 feet in height, average a d.b.h. of five feet. The largest diameter tree at 1225 S.E. 60th, with a height of almost 150 feet measures a d.b.h. of just under seven feet. The esteem in which many people hold these trees is notable. A recent example is a tree on property acquired by the Portland Adventist Hospital at 60th and Belmont for a parking lot. Great pains were taken during the period of construction in 1970 to preserve the tree (Fig. 18), a beautiful specimen almost six feet d.b.h. and 120 feet in height, complete with seedbearing cones. On Mt. Tabor as elsewhere, the trees have surpassed both natives and other introduced exotics in size, and appear in excellent health.

Other sequoias from this period include several on the capitol grounds at Salem, two at Mt. Angel College, one in Monmouth and three in Eugene. Ironically, both the largest and the tallest trees on the Oregon State Capitol grounds are these exotics whose seed came from the Sierra Nevada.

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*Information sources differ: Mrs. Merrill C. Roberts, 6040 S.E. Main, whose grandfather E. P. Swetland owned acreage in the area, states (1970) that they were purchased from "a man who came through." However the Broetje nursery is thought to have been in operation in this area at about this time. Neither account can be verified by records of the period.

An unfortunate prank during the 1969 Christmas season at Mt. Angel College established the value now placed on this species. The stripping of branches near the top of a giant sequoia by the entrance to the main campus building (Fig. 21) prompted a lawsuit in which a judgment was awarded in 1970, based on both property damage and aesthetic value lost; the health of the tree was in no way jeopardized.

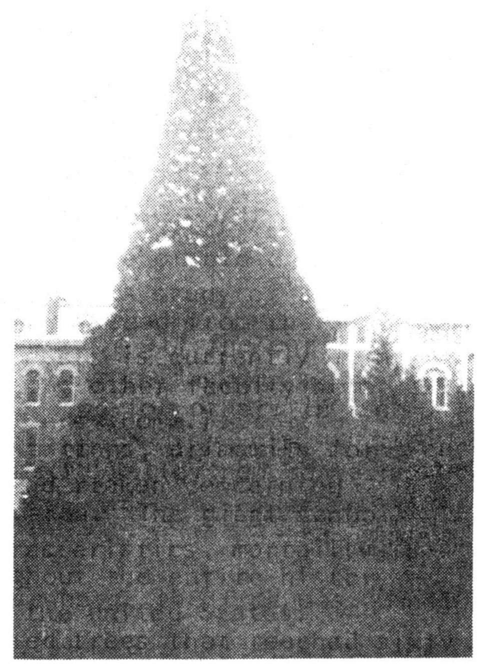
The tree at Monmouth, on the Oregon College of Education campus (Fig. 22) was planted by the Class of 1887 and measures 5 feet 2 inches d.b.h. It is lighted annually during the Christmas season for the community.

Of the three earliest sequoias in Eugene, one, northeast of Villard Hall on the University of Oregon campus (Fig. 25), measures a d.b.h. of seven feet, and has put on good but noticeably slower growth since the top was shattered during the 1962 storm.

Another at Fourth and Lawrence presently survives in the most hampering of circumstances, with a building abutting it on two sides and paving on the other two (Fig. 23). Interestingly, although it is crowded and its foliage is sparse, it has not been removed.

The third early Eugene sequoia, on the flat river-bottom land of the Chase Garden property, is also taller than any of the species growing near it, and lives in happy association with poison oak vines (<u>Rhus diversiloba</u> T.& G.) effectively protecting its lower trunk from measurement.

Fig. 21. The magnificent sequoia by the main building at Mt. Angel College after pranksters stripped an upper portion of the trunk. A legal judgment for damages was awarded for value lost.



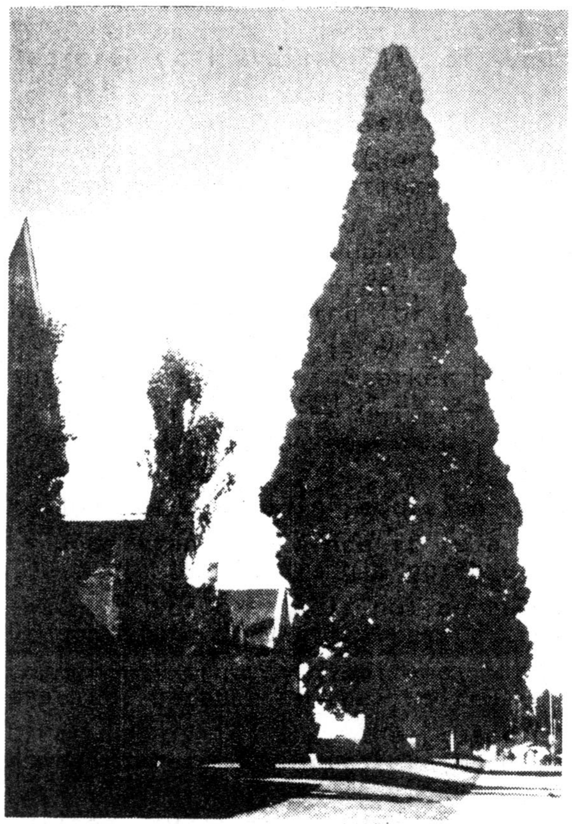


Fig. 22. The Monmouth sequoia, planted in 1877, is lighted annually at Christmas (left).

Fig. 23. A prized sequoia at 4th and Lawrence in Eugene is crowded by warehouse and parking lot on all sides, but has not been removed and continues to grow--slowly (right).

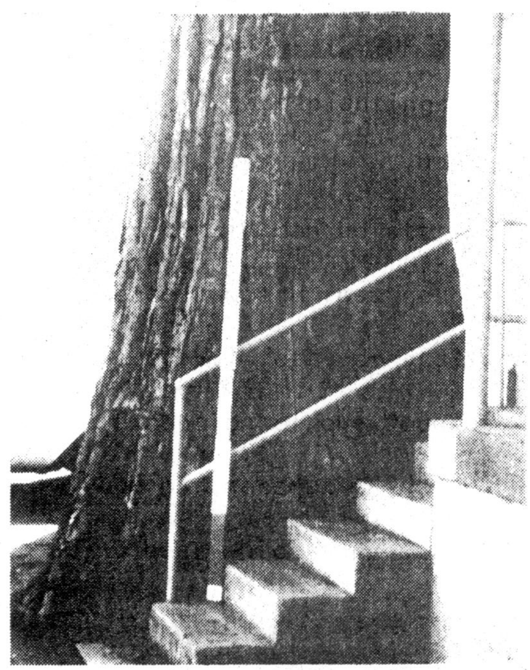


Fig. 24. A Douglas fir, planted on the University of Oregon campus near Villard Hall during the 1890's, has acquired a d.b.h. of nearly four feet.

Fig. 25. A sequoia, planted in the same grouping with the fir in Fig. 24 (above) has achieved a d.b.h. of seven feet during the same period.

Non-Planting Period 1910-1925. Although a few specimens may have been planted during this period, a number of years elapsed before the next major period of planting. The reason for this lapse is open to speculation, but may be as simple as the closing of a local nursery operation.

Planting Period 1925-1940. The third wave or era of planting (before local availability of sequoia seed), spread from the School of Forestry in Corvallis. T. J. Starker, and other faculty members and students, were instrumental in many plantings, primarily for aesthetic value, throughout the Corvallis area. The giant sequoia has never been planted for its wood throughout the entire history of the tree in Oregon. Starker himself planted trees that reached sixty to seventy feet on the Corvallis high school grounds before they were felled for a building addition (Starker, 1970: pers.comm.).

In the quadrangle north of the Student Union Building on the Oregon State University campus are seven sequoias that are generally assumed, because of their size, to date from the 1890's plantings. However, records indicate a much later planting in the middle 1920's (Wilson, 1971: pers. comm.). Their very rapid growth can be attributed to the watering necessary for the adjacent lawn and rose gardens. The central cluster of three average a d.b.h. of 5.1 feet, are taller than all other trees on the campus with the exception of one Douglas fir, and have characteristically dense foliage on the south side, exposed to the sun and away from the building near which they stand.

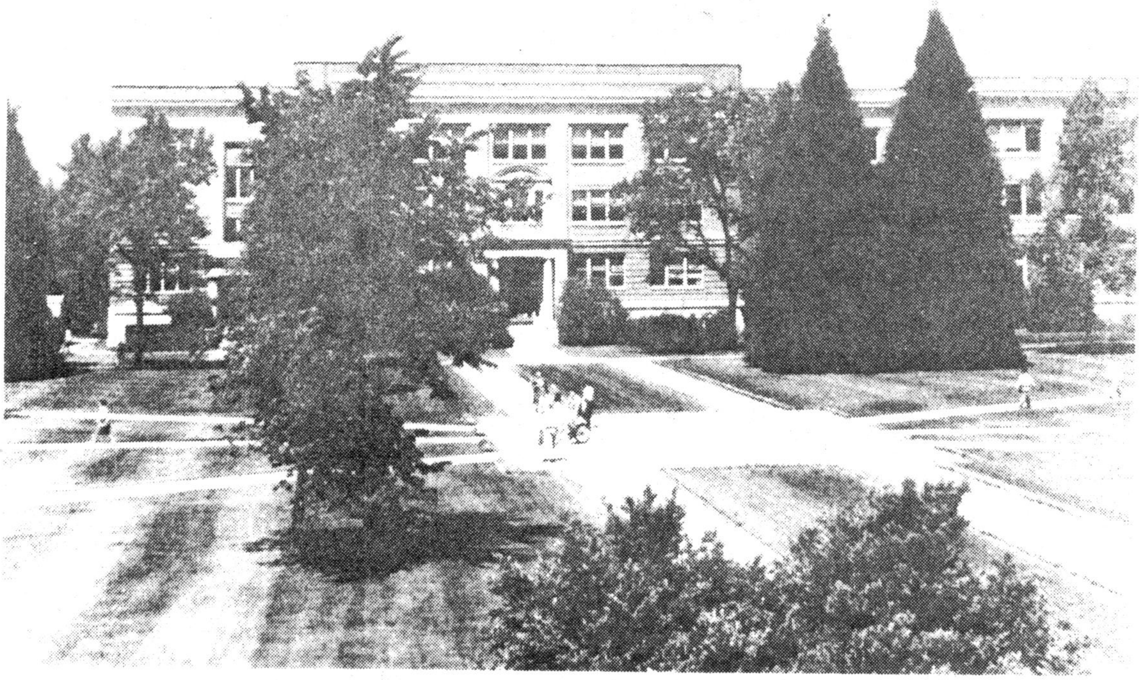
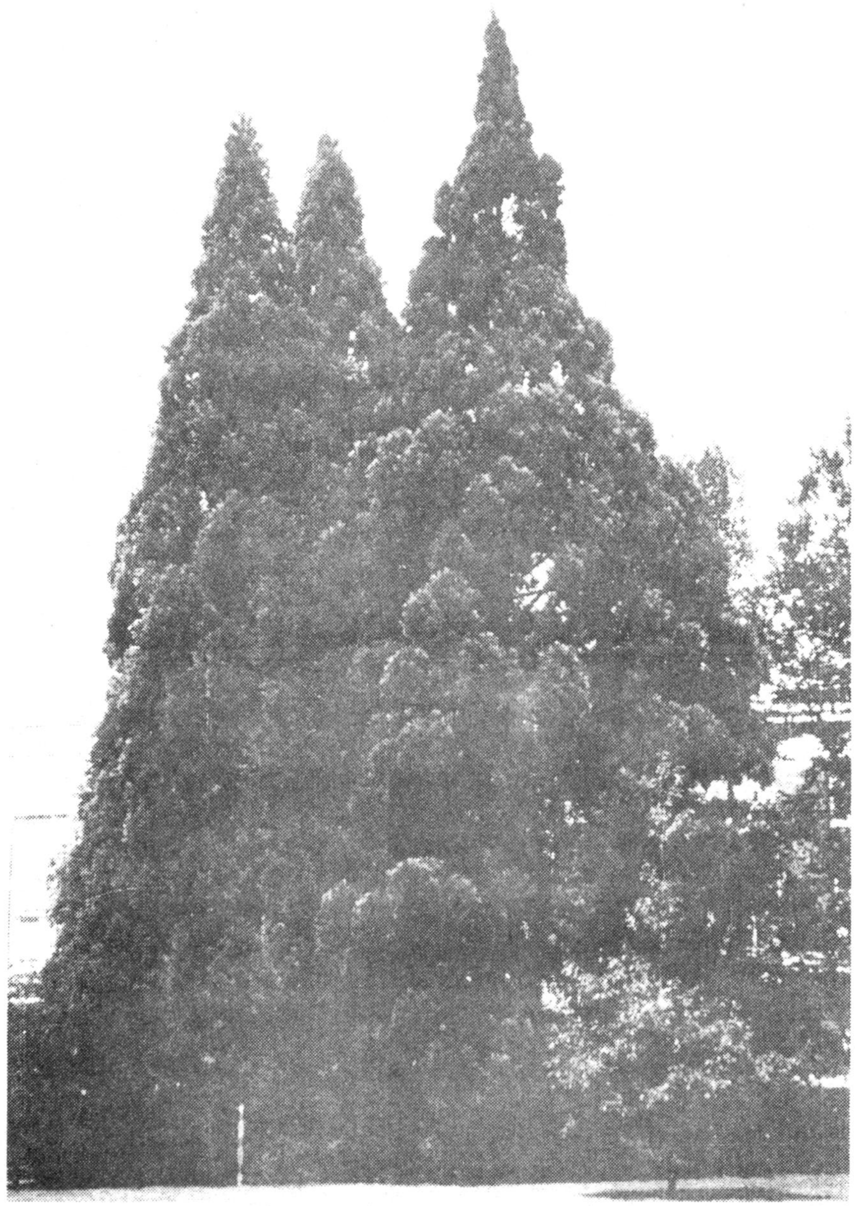
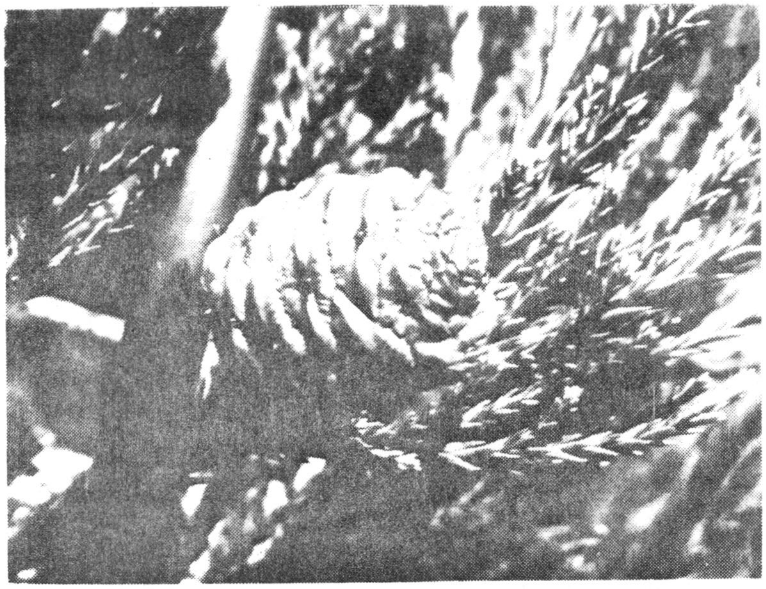


Fig. 27. Sequoias on the Oregon State University campus in about 1939 (see Fig. 26). The early tennis courts have been replaced by carefully tended lawn, providing the best possible growing conditions for the giant species.

Fig. 28. Photographed again in 1970, the Oregon State sequoias tower magnificently. As the branches grow in size, the absolute symmetry of the young sequoia is broken, and the foliage takes on more of the "cluster" appearance of mature trees in the natural range. These specimens continue to retain the characteristic sharp point of young trees, however, showing no signs of the "crowning out" of the top that may be expected sometime after one hundred years of age.





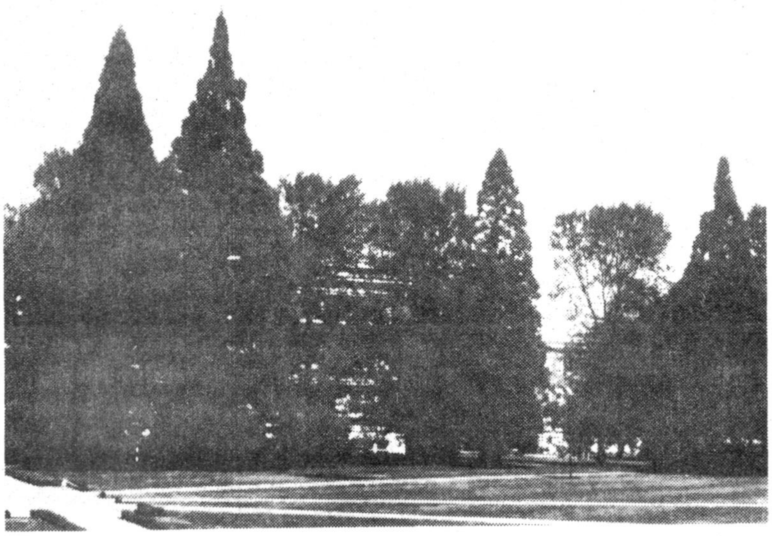


Fig. 29. The young cone (top) is growing on a curved branch at the top of the red and white 6-foot measure stick in the bottom photo. Cones normally cluster in the top one third of the sequoia as shown at right.

An additional phenomenon has occurred in these trees. Normally, on trees mature enough to bear cones (with cultivation, generally 15-20 years of age), cones develop in the top third of the tree. The heavy southern lowest branches of these Oregon State trees sweep the ground so that new growth at their tips curves upward to assume the characteristic shape and growth pattern of a vertical young tree three to five feet in height, with the addition of healthy young cones at the tips (Fig. 29).

Now, around Corvallis, there are hundreds of large sequoias, most of them dating from this third era. One windrow, planted between the railroad tracks and S.W. Allen south of town near Avery Park, has survived scarring of the trunks and bulldozing at the base of the trees (Fig. 30) on the railroad side, with no more serious result than a lack of uniformity in size. Well cultivated trees in Avery Park (Fig. 31) are luxuriant in foliage, a condition termed "thrifty" among botanists.

A notable planting from the very end of this third period is in southwest Eugene. In 1938 Dorvin Dudeck planted 148 one-foot seedlings obtained from the School of Forestry in Corvallis (Dudeck, 1968: pers. comm.). These were planted in several patterns, along with other species of trees, on about thirty acres of marginal farmland. The soil is thin and the drainage poor. However, these trees, which have received no care since infancy, (Dudeck [1969: pers. comm.] does not recall any attention given these seedlings after planting), appear to be in magnificent health. But, they are neither as tall nor as large in diameter as the Oregon State University campus specimens.

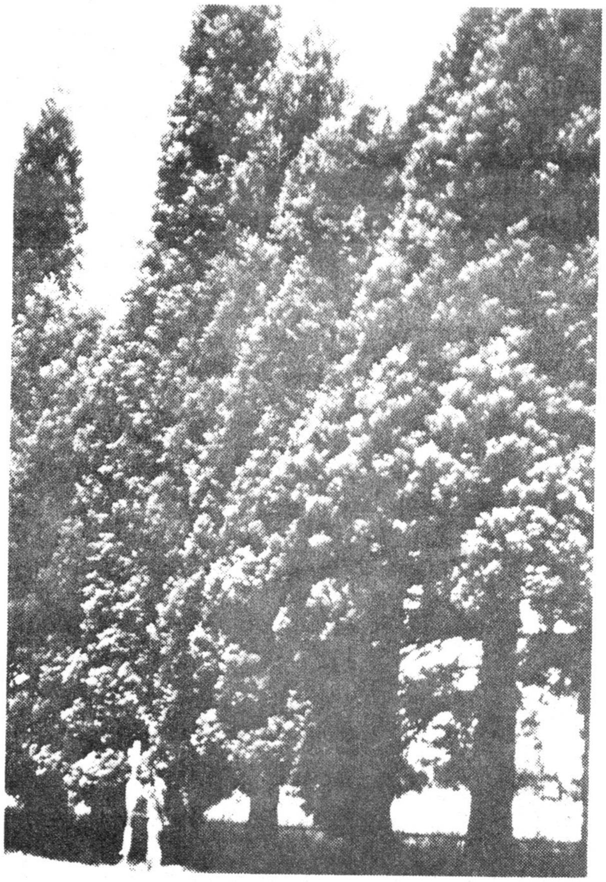
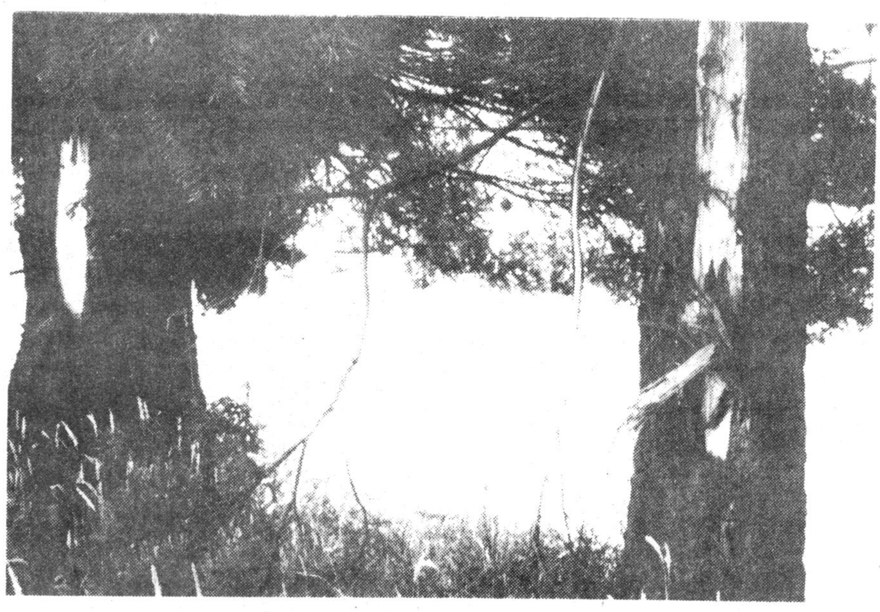


Fig. 30. Sequoias south of Corvallis, planted in the 1920's, have been damaged severely on the east side by railroad equipment, (below) but continue to grow.



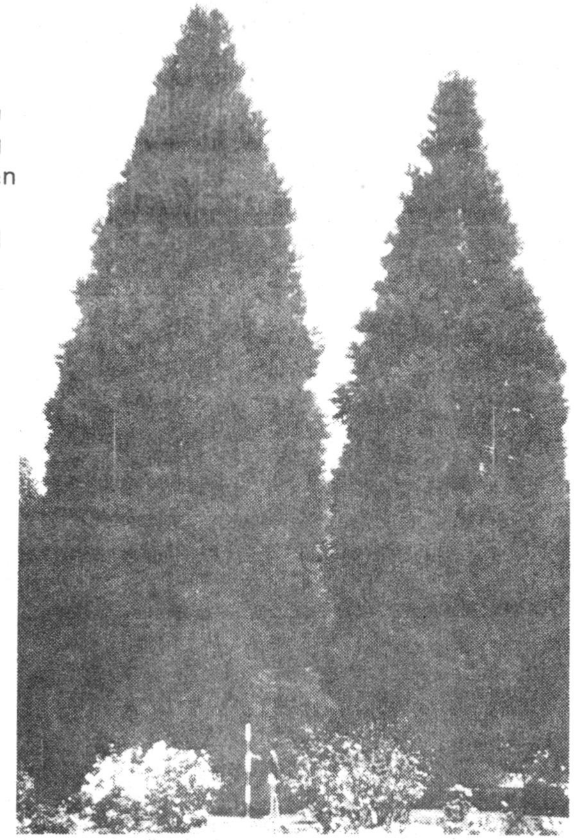


Fig. 31. Sequoias in Avery Park in Corvallis, planted during the late 1920's, and given the same extensive care required by the lawns and rose garden adjacent.

Fig. 32. A very young windrow, planted as seedlings on four sides of a field southwest of Corvallis. Trees of this size are common around Corvallis and throughout the Willamette Valley.

Current Planting Practice. In the three decades since 1940, the sequoia has been recognized as a lovely and hardy ornamental. Many thousands have been planted by private owners throughout the valley, on town lots, on Christmas tree farms and on other farms as windrows or road hedges, or in clusters as handsome exotics. The Oregon State Nursery at Elkton, discussed later, supplies the commercial plantings for Oregon. The sequoia is frequently specified in park plantings for its luxuriant growth and minimal care (Fig. 33).

Characteristically in the Willamette Valley, at any age, the tree displays full rich foliage in a distinctly and sharply conical shape. It varies in color from green to blue-green, and after twenty to thirty years produces a large cone crop, usually in the top one-third of the tree. The trees may be self-pruning when planted in close proximity, but younger trees are likely to have dense foliage to ground level, with a heavy litterfall beneath. No Willamette Valley trees have yet reached the age at which they "crown out," although removal of the leaders from several Verboort trees appears to have somewhat speeded this natural process.

Ecological Research on Giant Sequoia in Oregon

Synecology

The climate of the western third of Oregon is characterized by moderate temperatures, wet winters, and dry summers. About 78 percent of the annual precipitation occurs in the period from October to

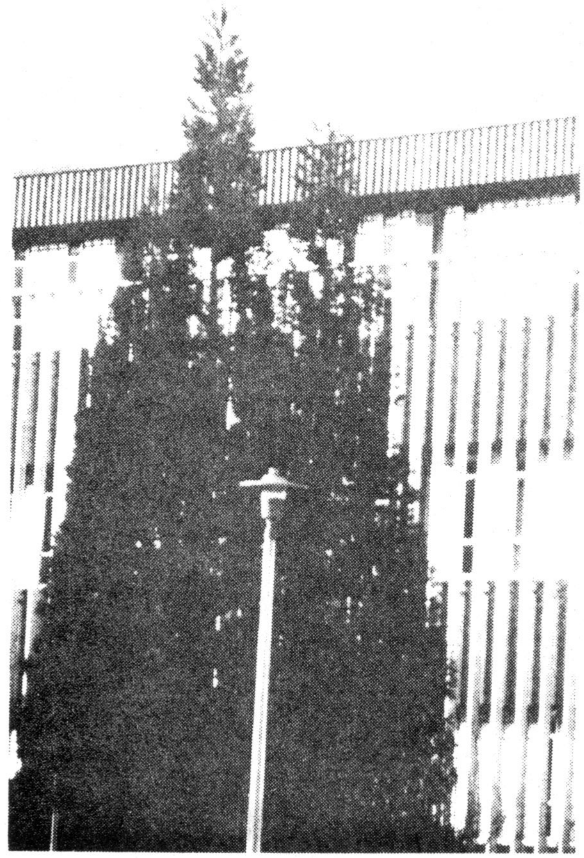


Fig. 33. Sequoias were incorporated into the landscaping of the Lane County Courthouse, built in 1959 on the site of the earlier one. The trees are used extensively throughout the valley in both public and private plantings.

Fig. 34. Climatic Data for Willamette Valley Weather Stations[1]

STATIONS	Elevation	TEMPERATURE (F.)					PRECIPITATION (inches)	
		Average Annual	Average January	Average July	Extremes		Average Annual	July-Sept.
					High	Low		
Cottage Grove	650	52.1	39.6	65.0	105	-15	46.31	.78
Eugene	422	52.5	39.1	66.6	105	-4	39.56	.73
Corvallis	224	53.0	39.4	66.6	107	-14	37.67	.65
Salem	159	52.4	38.5	66.1	108	-10	41.75	.84
Forest Grove	175	52.1	36.9	66.5	108	-18	44.45	.37
Portland	70	56.6	45.7	70.6	107	-3	42.32	1.00
Averages of Stations Listed	283	53.2	39.9	66.9	106	-10.4	42.01	.72
Roseburg *	479	53.4	40.3	67.9	109	-6	33.11	.38

1 Table adapted from "Climatic Summary of the U.S.: Oregon, Supplement for 1951-60," U.S. Weather Bureau. Extremes published 1969.

* Roseburg is not considered part of the Willamette Valley but is included here as the nearest weather station to the Oregon State Nursery at Elkton.

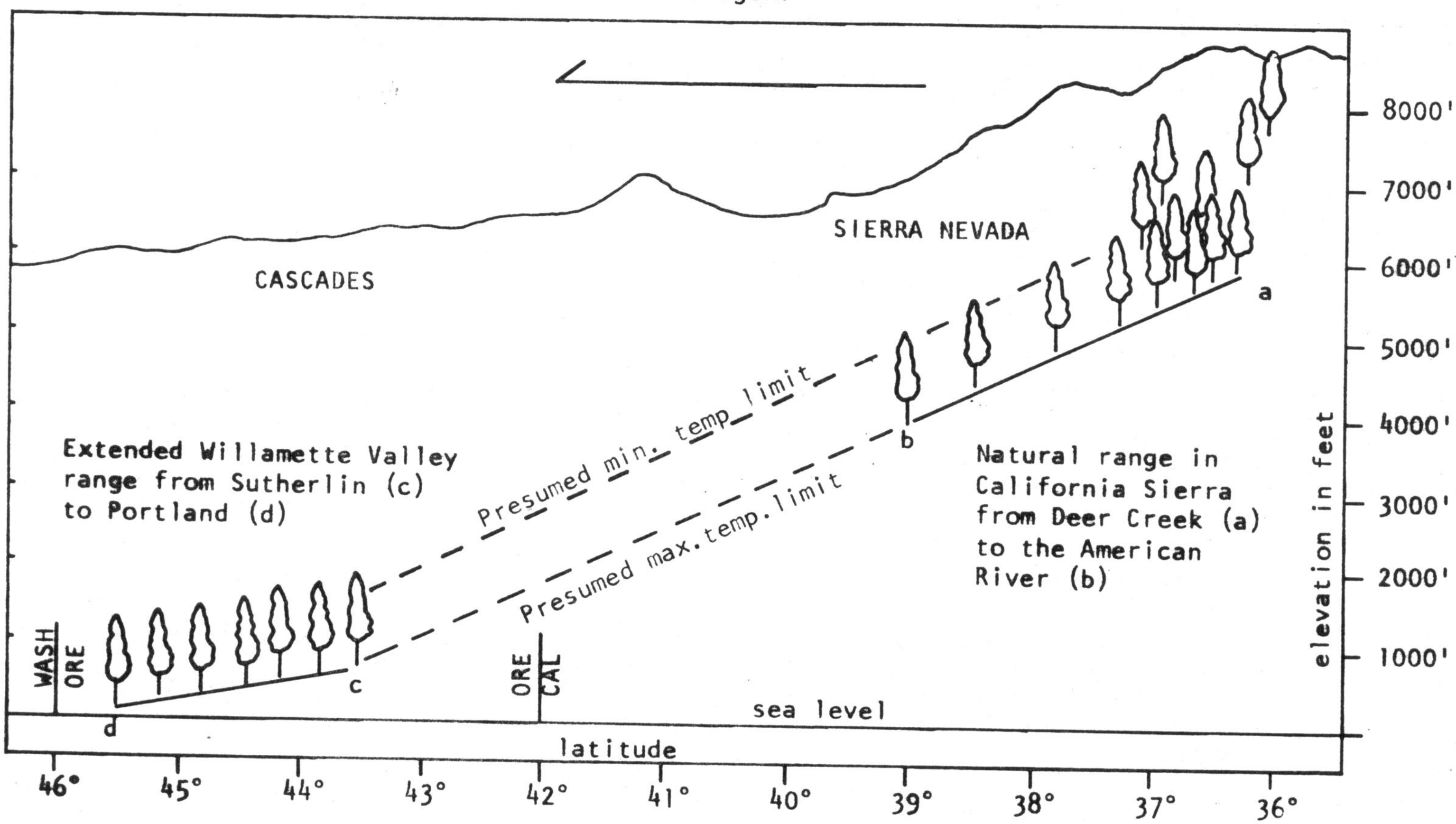
March (USGS, 1969:325). Precipitation in the valley varies from 37 to 47 inches annually, with higher precipitations recorded in both the Coast Range to the west, and the Cascades to the east. Valley precipitation is usually rain, with light brief snowfalls some winters, and occasional foggy days throughout the year (U.S. Weather Bureau, 1960:3). In January the relative humidity ranges between 75 and 85 percent. In July this drops during the afternoons to between 35 and 45 percent with extremes down to 10 to 20 percent at times (U.S. Weather Bureau, 1960:4).

In the Willamette Valley most stations have not recorded a maximum temperature greater than 98°F, or a minimum temperature lower than 16°F for over half their years of record. Temperatures of 90°F or more occur only about six to eight days a year and those below zero occur on an average only about once every 25 years (U.S. Weather Bureau, 1960:2). Normal temperatures are remarkably consistent throughout the valley, from a 39°F January mean to a 66°F July mean and averaging about 53°F annually (U.S. Weather Bureau, 1960:14).

Willamette Valley stations record growing season lengths of 164 to 212 days. This difference in the Willamette Valley does not seem to be a crucial factor in the growth rate, however; trees throughout the Willamette Valley seem to grow equally well.

Not only are the climatic data similar for all the weather stations in the Willamette Valley, but there are some extraordinary correlations between the valley and the western Sierra. The main

Fig. 35. Distribution of *Sequoiadendron giganteum* by latitude and altitude in the natural range and in northwestern Oregon.



differences are that Willamette Valley temperatures average about 3° to 5°F warmer, and precipitation averages from 3 to 5 inches less per year.

Although the average January temperatures are slightly colder in the Sierra, the winter snowpack offers insulation to the root systems of the trees. The average July temperatures for both areas are virtually identical, as are the extreme annual highs. It is interesting that the extreme lows in the Sierra range from -4°F to -18°F while the extreme lows in the Willamette Valley include -14°F at Corvallis and -15°F at Albany.

Hartesveldt (1968: pers. comm.) says of sequoias:

> The rapid rate of growth in the Willamette Valley is undoubtedly due to favorable climate during the growing season and an abundant supply of soil moisture. I have found that if soil moisture is available during the warmer months, sequoias will put on growth from March to mid or late November. If soil moisture is used up by the end of August as it sometimes is, the trees slow their growth rate to a virtual stoppage. ...[concerning] the Converse Basin trees, some are growing rapidly, others less rapidly, but based on soil moisture availability.

With few exceptions, because Sequoiadendron giganteum was planted in the Willamette Valley on or around farmsteads, the topography involved is quite unlike the Sierra. Most sequoias planted in Oregon are on flat to gently rolling sites, with a maximum slope of perhaps five degrees. Even on the west side of Mt. Tabor slopes of ten degrees are rare. On Portland Heights, with topography somewhat more akin to the natural range, the trees seem to do nearly as well for their age as those on the flatter valley sites. In Hoyt Park

Arboretum the slope is steeper than any of the other valley sequoia sites, approximately 25°-35°. Even here, recent growth rate of the tree is 1/2 inch per year d.b.h. With the possible exception of the Hoyt Arboretum in Portland, no site in the Willamette Valley indicates that aspect of slope carries any significance in the development of the sequoia. Sudworth (1908:144) notes the trees are "indifferent to exposure, growing on slopes of every aspect," In Hoyt Arboretum the aspect is generally south to southwest, as well as steep. In the Sierra, the tree conspicuously does not occur in steep canyons (Muir, 1877:250; Sudworth, 1908:144), attributed by both Muir and Sudworth to glacial chill. Since "steep" is not defined, the question arises whether the tree has a slope tolerance beyond which it does not thrive.

With the exception of Mt. Tabor, Portland Heights and Hoyt Arboretum, most Willamette Valley locations where the sequoia has been planted by man are on soils derived from lacustrine sediments, non-marine terrace deposits, and very recent alluvial deposits (Vokes, Myers and Hoover, 1954). Mt. Tabor soil is derived from the Troutdale Formation of conglomerate sandstone shale and mudstone, shading off downslope to the west into quaternary alluvium sand and silt. Portland Heights and Hoyt Arboretum derive from Columbia River basalt and, on slopes farther to the southwest, quaternary Boring lava (Trimble, 1957). Only in areas where the hard-pan comes close to the surface with a clay-gumbo layer above it, do the trees grow poorly.

No significance seems to attach to the parent material of the soils, but drainage conditions and soil depth are important factors in the development of maturing sequoias. However, in no case noted in this study have these factors precluded survival of the tree, even where soil moisture during the summer drought period is nearly zero.

Soil cover appears to be unimportant after the seedling stage. Soil cover is an important factor in reproduction, and in moisture retention for infant seedlings.

Of these several measurable factors relating to the locations in which sequoias grow successfully in the Willamette Valley, climate appears to be the only limiting one. An apparent lower limit for moisture is about 35 inches annual precipitation. The apparent upper limit is about 60 inches natural precipitation, although the trees do well where a maximum of 15-20 inches are added by irrigation during the dry summer.

Since the sequoias in the Willamette Valley were introduced by man, there are no natural plant associations. However, they do very well in all the four major Oregon oak (*Quercus garryana* Dough.) communities in the Willamette Valley recognized by Thilenius (1968). These four communities were named after their understory dominance (apparently in descending order of precipitation): 1) sword fern, 2) snowberry, 3) Mazzard cherry, and 4) poison oak. Trees included as companions in the native range are also found in these zones in Oregon. Douglas fir and big leaf maple are in all four communities. However Franklin and Dyrness (1969:82-85) in their book entitled

<u>Vegetation in Oregon</u>, which otherwise is an excellent and seemingly comprehensive listing of vegetation by climatic zones, fail to include sequoias among these plant communities. The principal trees that live in association with sequoias in the natural range, ponderosa pine, incense cedar and white fir, are also found to be part of the habitat where the Oregon sequoias do well.

Management of official plantings in Oregon (and in southwest Washington) has established among forestry personnel a reputation of unsuitability for the sequoia north of California in direct contrast with popular experience with the tree. At Cascade Head on the Oregon coast, a high precipitation site, U.S. Forest Service field plantings were made in the late 1930's (Kruggier, 1958; Madison, 1957). No record beyond number and location of seedlings planted was kept, but the sequoia was presumed unsuitable to Oregon. The tree has been considered a failure on the basis of this and one other experimental planting in the Cascades in Washington state, with no documentation of response to specific site, and with no attempt made to compare findings with plantings in other precipitation zones.

The Washington state U.S. Forest Service site is at Wind River, at the head of a valley funneling from the Washington Cascades southeastward into the Columbia River Gorge. Precipitation varies from 90 to 120 inches annually. Early in this century fourteen seedlings were planted in the arboretum. Later, in 1928 and 1931, eighteen more were added, and at about the same time field plantings were made in the extremely rugged experimental forest behind the arboretum. No records were kept in any of these cases beyond the number of trees planted and those surviving in 1959 (26 out of 32) (Silen and Woike, 1959). It is evident the field plantings failed to match the growth rate of surrounding hemlock and Douglas fir since they cannot be seen from any access road giving a view over the area of planting (near the base of an extremely steep north-facing mountain ridge: little sun, short growing season, high precipitation). No one can document whether they survive. The trees at the arboretum are small for their age, and ragged, but show no evidence of failure and are listed in "excellent" condition by Silen and Woike (1959). Ornamental sequoias planted along the entry driveway are luxuriant, with the exception of a group which appears to stand in a year-round bog, and shows some browning of foliage (Fig. 36). Neither this site nor Cascade Head in Oregon is typical of the largest areas of western Oregon and western Washington, yet failures at these sites (despite the successes, recorded above) have led to the elimination of this tree as a serious candidate for commercial planting by foresters.

Hoyt Arboretum in Portland and Peavey Arboretum north of Corvallis also maintain no records of tree performance. Interestingly, in neither of these sites has the sequoia developed as well as it does in almost any other random location in the valley. Possible reasons for this reduced performance are impossible to determine since no regular documentation of growing conditions have been kept.

Fig. 36. Sequoias planted as ornamentals approaching the Wind River Arboretum in the Washington Cascades. Although sequoias planted within the official arboretum are small, they appear healthy, with a low mortality rate. These ornamentals are the only unhealthy specimens, with the exception of one that "cooked" in Salem that were observed during the course of this research.

In Hoyt Arboretum, slope may be a factor (25°-35°) as well as dense crowding of the understory. In both Hoyt Arboretum and Peavey Arboretum, evidence of heavy underground water, visible as adjacent streams or in moisture loving ground cover, may account for this inhibition.

To date, Oregon sequoias have grown only in those areas where man has seen fit to plant them. In nearly all of these areas they have grown well, and demonstrate an extraordinary survival rate even in the few situations where their development is noticeably inhibited.

Reproduction and Early Growth in Oregon

The many thousands of seedlings sold annually in Oregon as in many other parts of the world are germinated from seed gathered in the California Sierra. Floyd Otter (1963: pers. comm.) states:

> Sequoia gigantea seed is now nearly all collected within the Sequoia National Forest in Tulare County at altitudes of 6000 to 7000 feet. In the middle 1950's thousands of pounds were collected from "Camp Conifer" which was then being logged....It is still being sold through commercial channels....The seed keeps well and seed dealers may sell seed they have had on hand so long they don't know where they got it...The cones are collected 1) from trees felled in logging (no longer done) or 2) in spring from trees or branches that fall in winter, or 3) in fall from squirrel caches. Mostly from #3 now. The cones can be collected any time of year.

Ronald S. Adams of the California Forest Management Nursery at Sacramento offers similar information on the ranges of seed gathering with slight variations (from 5000 to 7200 feet elevation).

The minimum age of viable seed bearing is estimated by Adams to range from 150 to 500 years (Adams, 1968: pers. comm.); he estimates a maximum tree age at 3000 years.

Herbert Sampert, present administrator of the University of California's Whitaker Forest, offers interesting observations about the seeds, cones and germination rate of the big tree (1968: pers. comm.)

> Like the coast redwoods, the [Sierra] big trees are heavy cone bearers, and there is a lot of seed available each year. The lack of reproduction is not a problem of seed volume or seed viability; even if 1/10 of one percent were viable, we would have young growth of varying ages "sticking out of our ears." After all, these trees have been around for a few years, and even a very low germination rate just one point above zero would give us the reproduction we need to maintain the existing stands....The seeds of big tree are easy to come by. After a storm the ground is covered with cones and cone bearing branches. On one branch you will have new cones, last year's cones, and old cones we don't know the age of. All have seeds, and a percentage are viable. So the germination rate will vary from batch to batch even if they come from the same tree or more likely from the same group or grove of trees.

Sampert's last sentence (above) and the statement by Adams (1969, pers. comm.) that "It is difficult to give information as to which slopes, aspect and soil are most productive in terms of seed bearing cones," reinforce Hartesveldt's statement (1968: pers. comm.):

> I don't believe that viability studies have been conducted on the basis of geographic locale. We have done considerable sampling and have found the viability to be greatly variable on individual trees depending upon the age of the cones. Sequoia cones, after maturity, may remain green on the tree for 20 years or more and the viability reaches a peak about the fifth or sixth year and then tapers off. We have found individual batches of seeds (from green cones) to be as high as 80% viable, but this is very high. More often, 30% viability is found.

It is apparent that, although all commercial sequoia seed comes from the California Sierra, no reliable studies have been made regarding quality of seed or variations among parent stock. Interestingly, in the Pacific Northwest, economic pressure has pinpointed very well the best parent stock for top quality commercial seed of Douglas fir. Douglas fir seed from British Columbia surpasses Douglas fir seed from any other parent stock in quality of performance in any location where it is planted within the general Douglas fir belt (Ching and Bever, 1960:11-17). Little concern is given to the sources of sequoia seed.

Some of the largest sequoia seed brokers, who contract with local seed collectors, are in Pennsylvania, New York and Washington state as well as in California. Nurseries, such as the Oregon State Forest Nursery at Elkton, obtain seed on bid from these brokers each year. These nurseries in turn sell well-rooted 3-4 foot _S. giganteum_ seedlings rather than seed.

The nursery at Elkton is the biggest Oregon producer of sequoia seedlings, and sells trees to individuals for Christmas tree farms and windbreaks, with a minimum fifty-tree purchase. Their germination rate in laboratory tests runs thirty to thirty-five percent, and in field tests, twenty percent. Their annual production is 50,000 to 75,000 trees per year on twenty-five acres from twenty-five pounds of seed, with a germination rate in the field of a maximum of twenty-five percent. When asked about mortality, Lyle Baker, superintendent of the nursery, answered, "Too large" (1968: pers. comm.). No shade is used in the Elkton nursery with a hotter, drier summer climate than the Willamette Valley to the north; instead, they add summer spraying. Baker states that the first year mortality in cooler summers is only five to ten percent (Baker, 1968: pers. comm.). The nursery keeps these seedlings through a second summer, and the mortality is zero for the second year, indicating that the first year is the crucial one to survival.

William Libby of the University of Washington states (1968: pers. comm.):

> The lore is that Giant Sequoia should be 300 years old to reproduce. We have cones on five-year-old trees, which we have pollinated, and hope to get some seed out of them this year. I know of no trees outside of the native range reproducing themselves. (I haven't looked very much.) I did see some in Victoria, B.C., loaded with cones.

Contrary to previous folklore, some Oregon sequoias are producing viable seeds. Although Mrs. Dorothy Porter, who lives adjacent to John Porter's grove of sequoias, states that she has never seen any seedlings from those trees (1969: pers. comm.), Ralph Myers of Beaverton collected seed from the Porter grove and states (1969: pers. comm.):

> I have germinated seeds from the trees in Hillsboro and Verboort with about 25% success, but at the tender age of up to three weeks they are subject to damping-off disease, so a nurseryman might be able to give you some pointers on growing them from seed. I have one that survived the critical stage and now at three years it is about ten inches tall. I have another I germinated from seeds that I got from the Sequoia National Park trees and at four years it is just four feet tall. They respond to watering in the summer and to a good balanced fertilizer.

Myers' results were twenty-five seedlings germinated from one hundred counted seeds from the Porter grove. Of those, as of March 1970 (Myers, 1970: pers. comm.) only one tree survived, and at four years of age was fifteen inches tall. In comparison with the seedling of the same age germinated from Sierra sequoia seed, the Oregon seedling has not done well. On the basis of two surviving seedlings it is impossible to draw conclusions regarding growth rate as related to parent stock, but it does seem apparent that "damping-off disease" was critical in the mortality rate. Other information on germination and raising sequoias from seed, including an undated mimeograph sheet obtained from an Oregon State extension office and titled "Raising Sequoias from Seed," indicate that damping-off disease is critical at this period and recommend sterilization of the soil and fungicides. However in commercial operations such as the Oregon State Nursery (Elkton) and Portland City Nursery, damping-off disease seems controlled well enough so that it is not a factor in seedling survival.

In another instance of Oregon reproduction, Andrew C. Smith of Portland has five sequoia seedlings naturally, and somewhat casually, germinated from a tree no more than sixty years old in his yard. In 1969, he found these small sprouts growing out of cones half-buried under the tree, and placed them, with balls of dirt about two inches in diameter, all together in one No. 10 can. In March 1970 they were about three inches high (Smith, 1970: pers. comm.).

Another possible germination of sequoia seedlings from Oregon parent stock has taken place in the thirty-three-year-old Dudeck grove in southwest Eugene. The site is open pastureland, and contains numerous juvenile seedlings which have been tentatively identified by a local nurseryman, Louis Piha (1971: pers. comm.), as resembling sequoia seedlings (Fig. 37). Mr. Piha has in past years germinated sequoia seed and grown the seedlings for sale. Since the grove contains other species, at least one of which produces juvenile seedlings similar to sequoia, verification is not possible until the trees have attained several years' growth.

Smith's experience with natural reseeding proves the tree can reproduce in this ecological setting and confirms the suitability of Sequoiadendron giganteum to the Willamette Valley.

Interestingly, the Wind River Arboretum in 1959 (Silen and Woike, 1959:30) reported that "one volunteer S. gigantea has been observed in the arboretum," with no additional information. Since sequoias can only "volunteer" by germination from seed, this implies an extraordinary event in that inhospitable setting, further confirming the probability of natural reproduction.

Here are two, and perhaps three, cases of trees germinated from Oregon parent stock, ranging in age from one hundred years and less in age. It is reasonable to assume that other germination within existing older Oregon groves may occur in circumstances conducive to survival through the critical first-year period.

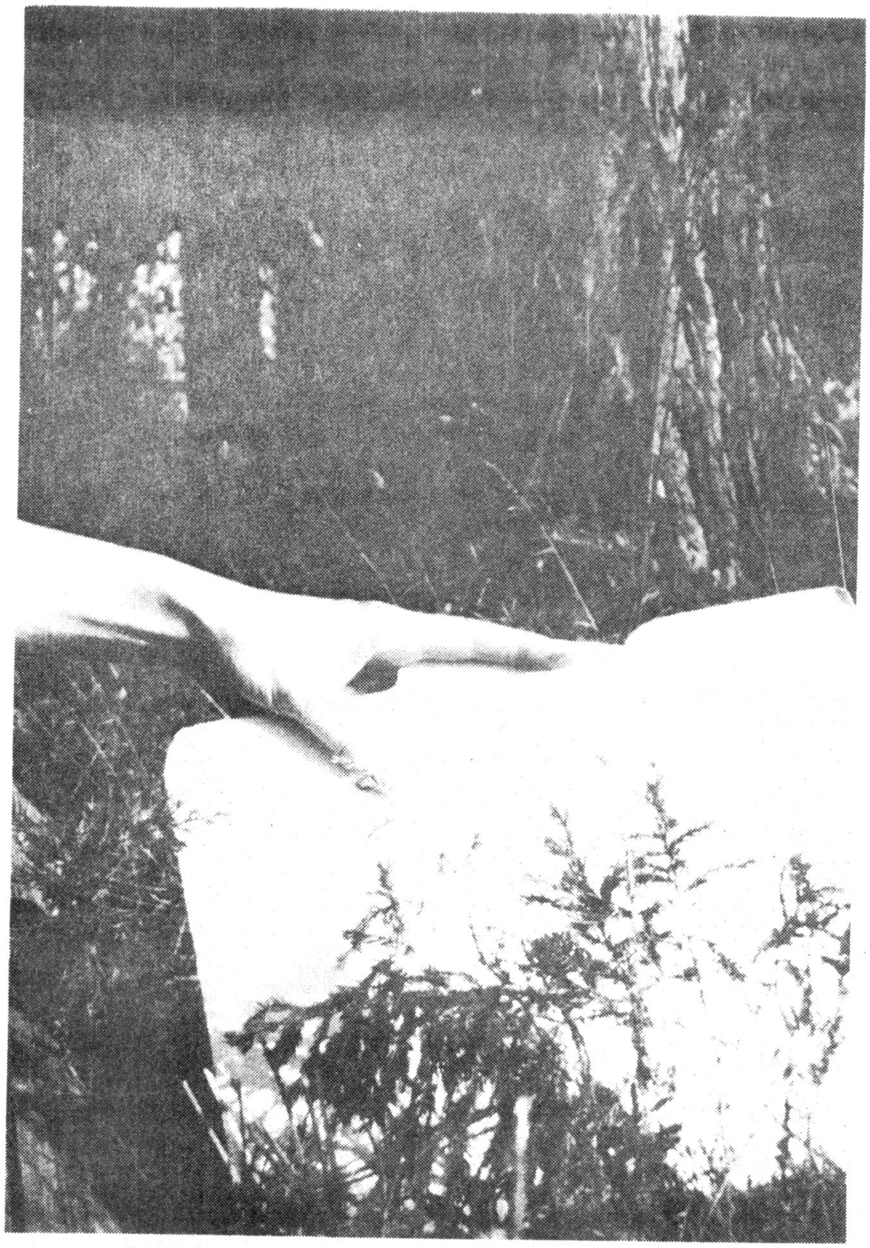


Fig. 37. Seedlings, tentatively identified as sequoias, growing in open pastureland to the west of a row of thirty-three-year-old sequoia trees in the Dudeck grove in southwest Eugene. Photograph 1970.

The cultivation that has promoted the development of sequoias in the Willamette Valley has, in turn, been inhospitable to natural reseeding in most situations, due to regular mowing of surrounding lawns or the heavy traffic of animals or people around the base of the trees.

It is apparent from observations in the Sierra that germination of seeds is the most critical of the stages of the life cycle of the sequoia in those mountains. The seeds are minute and must come to rest on the surface of mineral soil. They will not germinate in the litterfall of the parent tree (Fig. 38), nor in heavy ground cover. Sunlight and soil moisture are also vital factors.

Lack of moisture for first-year seedlings not only affects sequoias, but also affects all other coniferous seedling habitats (Ore. Ext. Serv., 1963:12). Herbaceous vegetation takes available water from seedlings and transpires it. When an area is fully vegetated, evapotranspiration removes soil moisture to a depth of thirty-six inches, whereas in non-vegetated soils evaporation takes place only in the top six inches (Newton, 1964).

If this contention is correct, removal of this herbaceous material is not only conducive to coniferous plants native to the Pacific Northwest, but in view of first-year data already cited, would assist the first-year sequoia seedlings in becoming established, with a root system reaching below this six inch evapotranspiration level.

Fig. 38. Normal litterfall surrounding the base of a sequoia within the drip line. Natural resistance to rot permits the duff to become many inches deep over a number of years if left undisturbed.

Propagation by cuttings from sequoias is used extensively in Portland's city nursery, and according to Director William Robinson (1970: pers. comm.) successful new starts are "easy to make, very easy."

The nursery in Portland also buys seedlings from the Oregon State Forest Nursery at Elkton, and from the U.S. Forest Service Wind River Nursery. However, although the Elkton nursery normally only sells sequoia stock two feet tall or two years old, the Portland city nursery buys one-year-old stock from them (6-12 inches tall). Portland also grows sequoias from seed it obtains, but keeps no record of percentage germinated. They evidently plant them adequately so that "so many germinate they leave some" (Robinson, 1970: pers. comm.), with no record of seed source in relation to germination success. According to Robinson, mortality is zero, both in developing seedlings and in older trees after transplantation. In his experience, they have no critical period, and are watered only a "couple of times" during the summer. He comments also, in this context, that "firs are very touchy"(Robinson, 1970: pers. comm.).

Portland transfers from the nursery to permanent sites mostly when the trees are 5-6 feet tall, but occasionally at 4 feet, when the root system is more adequately developed.

Ernest Fischer (1968: pers. comm.), curator of the Hoyt Park Arboretum in Portland, provided detailed history of sequoias planted there. Seeds obtained from Herbst Bros. in New York were sown at the city's Mt. Tabor nursery in 1931. The sprouted seedlings were planted there in 1932, then moved in November 1933 and 1934 to the Hoyt Arboretum; fifty when they were three feet tall and twenty when two feet tall. In 1935, they moved in twenty more trees, three feet tall, for a total of ninety planted. Further records of development were not kept. These trees were planted on a very steep site, 25° to 35°, with a southwest aspect, closely intermixed with coast redwood, and have suffered a mortality rate of eleven percent, extraordinarily high for sequoias within the Willamette Valley.

In 1929 or 1930 the Portland Park Bureau planted a number of sequoias in the Rose City Golf Course. All have survived, including those on the slope above the actual course which receive no added water (Fig. 39).

Dudeck stated that when he planted his seedlings in Eugene they were only a year old. In his grove seedling loss was evidently zero since the planting pattern is very uniform. It is possible they were given additional water the first summer or two, although he has no record or recollection of this detail.

Paper mulch around seedlings has been suggested for southern exposures to increase seedling survival by reducing transpiration by weeds and evaporation from bare soil. The suggestion refers to Douglas fir but may be applied equally to sequoia.

Lyle Baker, superintendent of the Oregon State Forest Nursery at Elkton, states that during the seedling stage of the sequoias, they experience no trouble with rodents or birds. The only control used

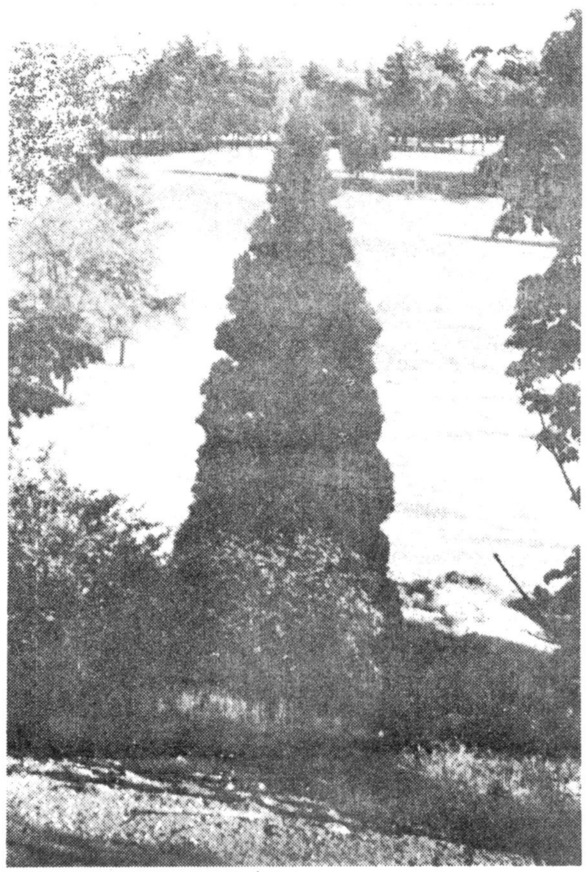


Fig. 39. One of many young sequoias planted by the city of Portland in its park landscaping program. This one is on the south-facing slope above Rose City Golf Course.

is against the cutworm or strawberry weevil (Baker, 1969: pers. comm.). This is noteworthy in view of William Libby's statement:

> Rodent control in the San Francisco Bay Area is crucial. The majority of planted Giant Sequoia in our regional park are killed by girdling (mice I think). (Libby, 1968: pers. comm.)

Neither T. J. Starker, Ernest Fischer, William Robinson, nor any others experienced in seedling growth in Oregon, have mentioned damage from rodents, birds or insects to Oregon grown sequoia seedlings. From the observations of those working with sequoias in the field, and from this investigation, it is apparent that adequate moisture during the first growing season is the critical factor in the survival of sequoia seedlings in Oregon.

Growth Rates and Configuration of Documented Trees

One of the difficulties of quantifying growth rate against a so-called norm is that most sequoias in the Willamette Valley have had some tending by man, if only in the form of added water during droughts. Dudeck's grove of 148 trees is probably the most important because of its size and its nearly natural growing conditions, even though it is on Pengra silty clay loam soil which is only one and a half feet thick above a hard clay pan (Soil Cons. Serv., 1970: pers. comm.).

This grove compares favorably with the second-growth trees in California's Converse Basin, in the natural range, which germinated around 1910 following intensive logging in the 1890's and early 1900's.

Dudeck's trees, on a year-by-year basis, show a consistently twenty percent better growth rate than the Converse trees in California (Figs. 40 & 41).

In spite of relatively poor soil, the average diameter growth at breast height for Dudeck's higher based trees was about 0.7 inches per year. Recent d.b.h. growth is 0.375 inches per year (Fig. 42). (As noted before, trees rooted in a swale achieved only one third of this growth rate.) This is about average for all the trees on higher sites, including some trees planted as close together as six feet on center, although most are nearer twelve feet apart. The only other grove in Oregon that approximates natural conditions is in the Hoyt Park Arboretum, and even on that difficult site (steep site, southwest exposure during early life, crowded conditions) the average d.b.h. growth rate for all surviving trees is 0.375 inches per year with recent d.b.h. growth rate at 0.25 inches. The maximum d.b.h. growth per year noted was 0.75 inches at age twenty-five.

The reduction in rate of growth with age is the expected pattern. This does not imply that the total amount of wood laid down necessarily decreases; it is distributed around a larger circumference and greater height.

The sequoias in all groves seem to thrive in relative proximity, although in the two areas described above, it appears that too close spacing has somewhat inhibited growth rate. Crippen (1968: pers. comm.) notes that in the natural stands, sequoias perform better in proximity to each other, and that single trees seldom occur naturally.

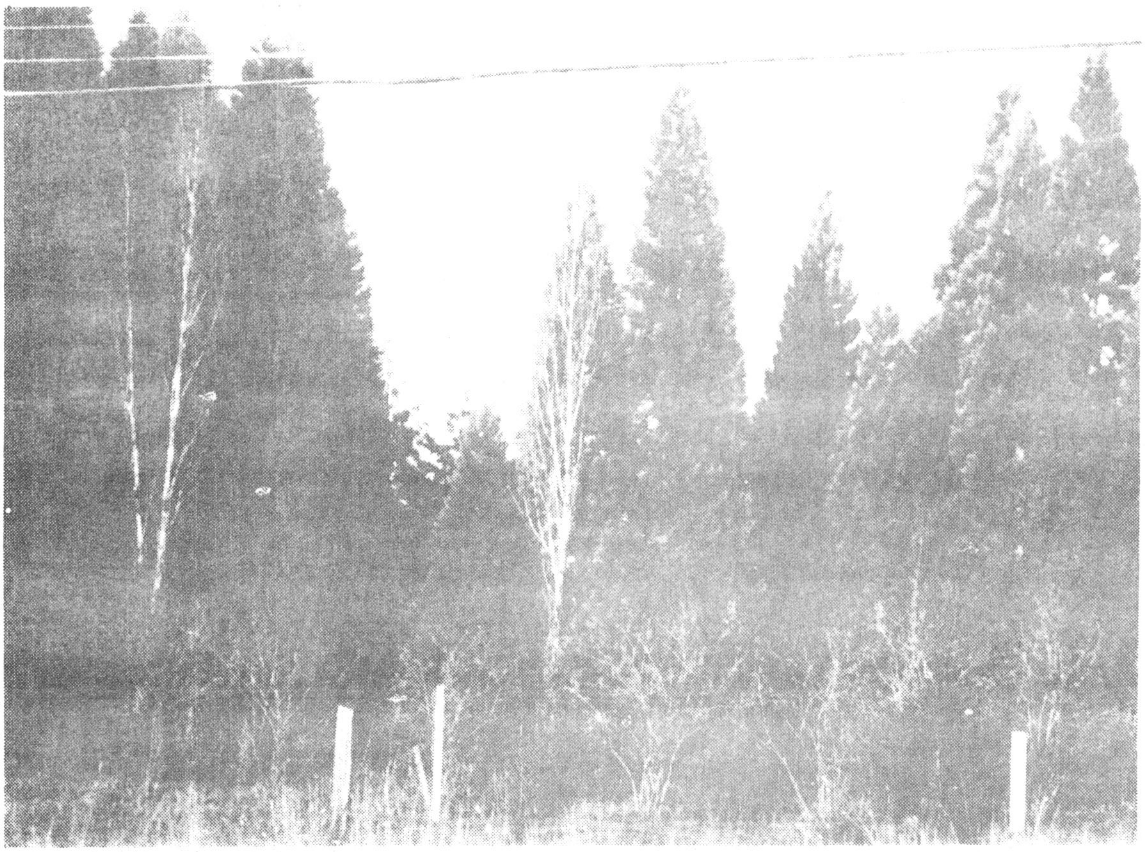


Fig. 40. Sequoias growing in a winter bog in the Dudeck grove in southwest Eugene, Oregon. Variation in size relates directly to height of water table below root system.

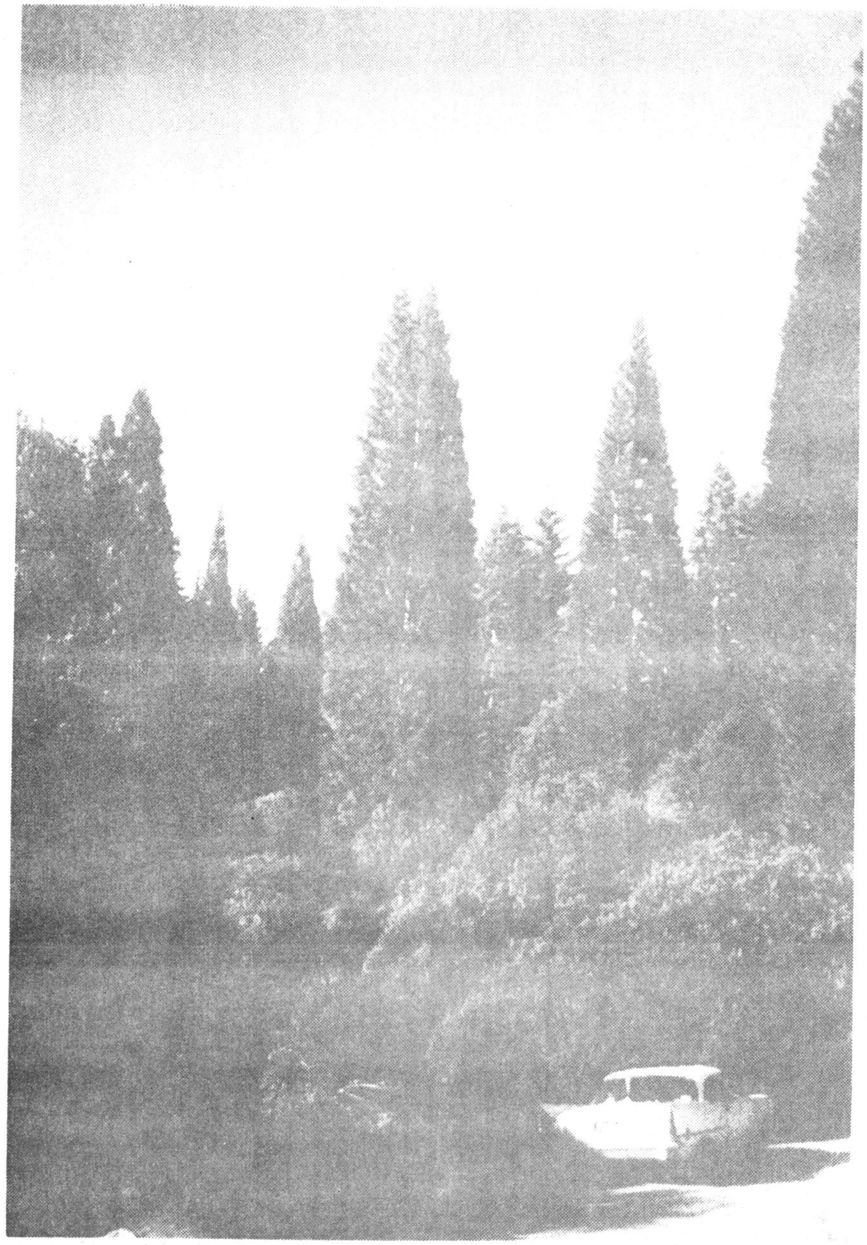
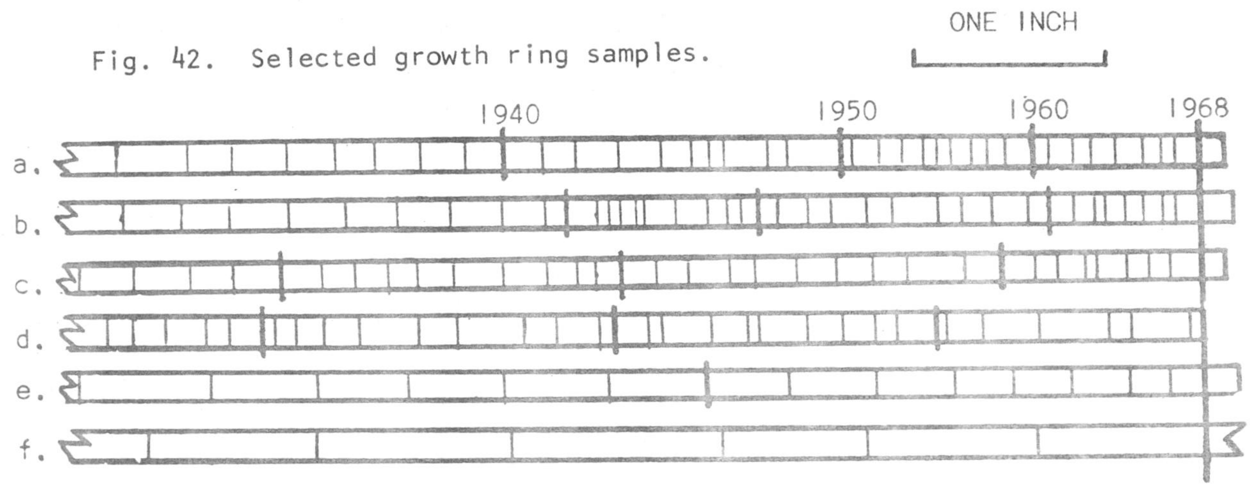


Fig. 41. Second growth sequoias in Converse Basin California in 1968. The original stand was completely cut in the late 1800's, except for one giant known as the Boole Tree about one mile upslope to the right of the picture. Natural regeneration may be presumed to have begun from this tree.

Fig. 42. Selected growth ring samples.



a. Douglas Fir. University of Oregon campus. Age 70+
b. Western Red Cedar. University of Oregon campus. Age 70+
c. Giant Sequoia. University of Oregon campus. Age 70+

} augmented water supply

d. Giant Sequoia. Converse Basin, Sequoia National Forest, Calif. Natural second growth regeneration of area logged 1890's. Age 70.
e. Giant Sequoia. Dudeck Grove, west of Eugene. No augmented water supply, and little or no maintenance. Age 34.
f. Giant Sequoia. Betzel Grove, northwest of Eugene. Augmented water supply, intensive cultivation and maintenance. Age 26.

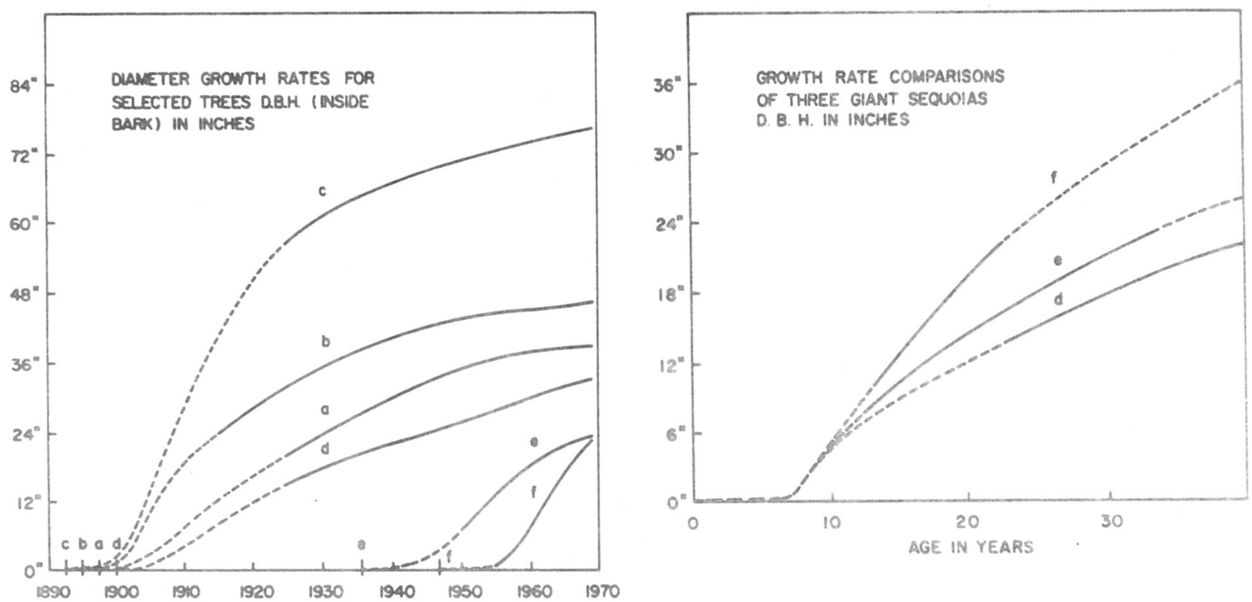


Fig. 43.

a. Douglas Fir. University of Oregon campus. Age 70+ } augmented water supply
b. Western Red Cedar. University of Oregon campus. Age 70+ } augmented water supply
c. Giant Sequoia. University of Oregon campus. Age 70+ } augmented water supply
d. Giant Sequoia. Converse Basin, Sequoia National Forest, Calif. Natural second growth regeneration of area logged 1890's. Age 70.
e. Giant Sequoia. Dudeck Grove, west of Eugene. No augmented water supply, and little or no maintenance. Age 34.
f. Giant Sequoia. Betzel Grove, northwest of Eugene. Augmented water supply, intensive cultivation and maintenance. Age 26.

The original Oregon sequoias in the Porter grove are still putting on substantial growth. The most recent annual growth measured on a blow-down stump from the 1962 storm was 0.32 inches at the age of ninety-two years. On this particular tree, the fastest growth was during the period from eight to fifty-eight years, during which they received little, if any additional watering, and then continued quite even for several years. There appeared to be a definite slow-down of growth when the tree reached seventy to seventy-two years. In the early years the tree put on one inch or more d.b.h. per year (1/2 inch ring width). This stump had a 5 foot 7 inch d.b.h.

One of the old trees from John Porter, planted three miles south of Hillsboro, has the largest diameter of any sequoia in Oregon, 9.1 feet, but is considerably shorter than other Oregon "venerables."

Most of the other trees that came from the Porter nursery have been irrigated for some time, being located in church yards, court-house yards, and in some house lots in Forest Grove. One of the latter has a d.b.h. of 7.7 feet, and average d.b.h. growth (as far as the increment borer could penetrate) of 0.85 inches, a recent d.b.h. growth of 0.25 inches, and an estimated height of at least 140 feet.

Sequoias on Mt. Tabor, dating from the second planting in the 1890's, and also undoubtedly receiving additional water, range from 3.5 feet d.b.h. to more than 6.3 feet d.b.h., with heights up to 150 feet (Fig. 44). The biggest in terms of d.b.h. (6.3 feet) is located at 1225 S.E. 60th, and as closely as can be determined was planted in 1906 as a seedling no more than eight years old. It cannot be over

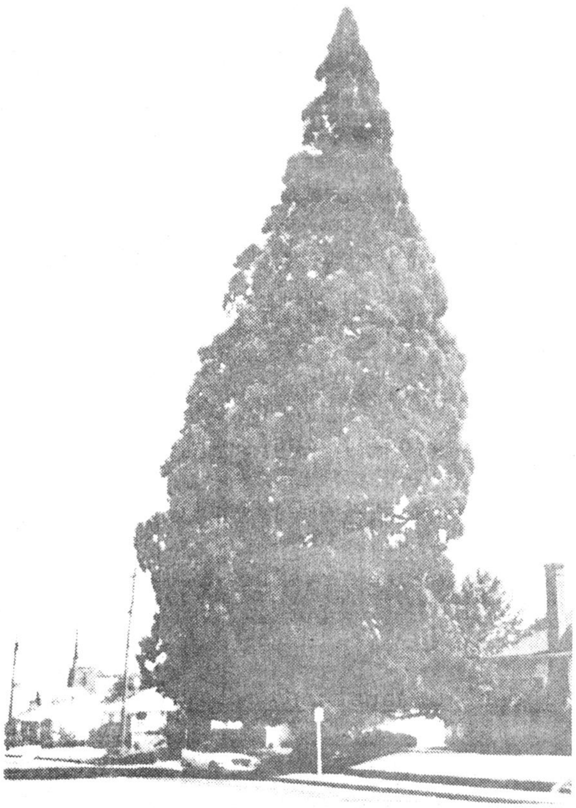


Fig. 44. Mt. Tabor sequoias dating from the 1890's.

seventy-two years of age in 1970. This sequoia has little taper, a circular basal growth pattern, and is quite tall, containing a large volume of timber for its age. According to Mrs. Merrill C. Roberts, a resident since childhood, this tree was near the original farmhouse and in all probability received more care than others used as section markers (Roberts, 1970: pers. comm.).

Another Mt. Tabor tree, located farther downslope at 5231 S.E. Stark has pronounced butt swell, so a core sample was taken at 5 1/2 feet rather than at the standard 4 1/2 feet above ground level. It also has considerably more taper and is shorter, with a height estimated at 110 feet. The core sample indicates a maximum growth of 0.9 inches in 1938, an average of 0.5 inches, and recent growth rate of just under 0.25 inches per year. This sample shows fluctuating patterns of growth with intermittent large and small rings. It also has a more fluted cross-section near the base than most of the Mt. Tabor trees.

No count was made of the sequoias on Mt. Tabor (Fig. 45), although there are at least thirty large ones, of which eighteen or more date from the 1900 planting. It is interesting to note that although parent material changes and the boundary cuts through the area of Mt. Tabor sequoias, this difference in soils has had little if any apparent effect on the growth rate, shape, volume or height of these trees. Again the height and volume seem to depend on irrigation alone.

Fig. 45. The sharpest points as well as the tallest trees are sequoias. The view is from the slope of Mt. Tabor in Portland, looking southwest. Photograph 1970.

An even more striking example to illustrate this contention is the group of seven sequoias in the quadrangle north of the Student Union Building on the Oregon State University campus (Figs. 25-28). These trees are so large, as stated earlier, that they were generally attributed to the 1890-1900 planting. However, photographs from the Oregon State University Archivist (Wilson, 1968: pers. comm.) prove that these were planted just prior to 1930. They all show considerable taper, particularly in the basal portion of the trunk.

One mile southwest of the Oregon State campus at Corvallis is a windbreak of about fifty sequoias in a north-south line (Fig. 46). An average tree sample here had an average d.b.h. growth of 0.866 inches, although recent growth was only 0.125 inches. This drastic slowing of growth rate may be attributed to the marked shallowness of the soil, thinning to the north to about one foot in thickness above blue clay gumbo above hard pan. Three trees of the original planting are missing, one broken by a cow, one by fire, both in infancy, and one by wind in 1962. An Extension Bulletin on windbreaks states: "Giant sequoia or big tree has averaged 1 1/2 feet height growth (annually) since 1912, and has shown a high survival (rate). It is rated excellent." (Purnell and Ross, 1951:18).

Nearly all the sequoias in this T. J. Starker era of planting have done well. In the Dudeck grove, in the better drained situation, one tree has an average annual d.b.h. growth of 1.0 inch, and a maximum d.b.h. growth of 1.625 inches at age eleven. The average d.b.h. growth from a general sampling of these trees is 0.7 inches per year.

Fig. 46. A windbreak in southwest Corvallis planted in the 1930's.

The sequoia with the biggest growth rate measured, outside an intensive care situation, is the middle-sized of three planted as two-foot seedlings in 1929 in a cemetery at 40th and Willamette Streets in Eugene. Its average d.b.h. growth is 1.04 inches per year, and it is about sixty feet high. In an undeveloped area of the cemetery, it has had no care since infancy. However one of its companions about three hundred feet to the south, which has received some added moisture, is at least twenty feet taller and has a d.b.h. seven inches greater.

Characteristics of Oregon Sequoias

Most Oregon sequoias have a sharply conical shape with dense foliage. From observation of the many trees in the valley, the density of the foliage is related to the ground water supply, although those growing in shady situations may also have thinner foliage. The tree does seem to enjoy full sunlight, and frequently demonstrates this both with denser foliage on the south side within the symmetrical cone shape, and with a barely perceptible "lean" toward the south. In no case, however, do sequoias vary their conical shape to compensate for needed sunlight by extending branches more on one side than on the other as do other conifers.

There appears to be more than one variety of sequoia in the valley, indicated by pronounced color differences between specimens, ranging from intense green to almost blue. As seed sources are impossible to trace, there is now no way to determine any correlation between these trees and their ancestors in the natural range. This color difference is distinguishable within single groves, indicating no correlation with soil type.

With few exceptions, Oregon sequoias show an extraordinary symmetry (Fig. 47) unmatched even by incense cedar, which they may appear to resemble from a distance, but on closer inspection the cedar shows ragged edges. Only storm damage to crowns, or other damage in early infancy, appears to modify this unique shape. Oregon trees have not yet, of course, reached full maturity.

The one noted exception to this symmetry, south of Milwaukie (Fig. 48), has a multiple curved trunk whose appearance is quite similar to wind-blown Monterrey pine on the coast, but which is in fact a Sequoiadendron giganteum. No information regarding its history or unique shape could be found.

Resistance to Damage. Crippen (1968: pers. comm.) has made the statement that there are no known "old" sequoia trees in the natural range in the sense of declining health. The high phlobotannin content of the wood, bark, and cones, make the mature trees nearly impervious to killing insects and diseases (Schubert, 1957:13). This factor also makes the mature trees highly resistant to fire since the sap is water-base rather than oil-base. Those giants which topple unaccountably (as a few do each winter) seem to be as healthy as those left standing, and are still solid logs on the forest floor centuries later (Crippen, 1968: pers. comm.).

Fig. 47. Symmetry characteristic of sequoias in the Willamette Valley, still "adolescents" under 100 years of age. Older trees in the Sierra crown out at the top and lower foliage begins to cluster with increasing age.

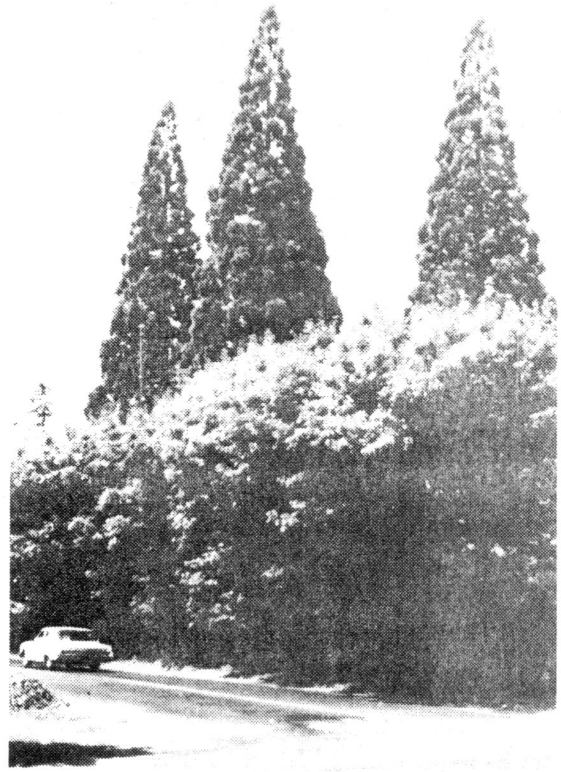


Fig. 48. A unique specimen of sequoia, south of Milwaukie, which has developed multiple trunks and contorted branching pattern.

> Once established, giant sequoia is known for its resistance to insect and disease attacks. None of the insects reported found on giant sequoia has caused the death of a single tree. An unidentified brown heart rot caused some decay in large trees where heartwood had been exposed, but no trees have been killed by this disease. Although sapwood rots rapidly, old trees that fell centuries ago show little evidence of decay in the heartwood (Schubert, 1957:12).

As further evidence of this resistance, Harold Biswell states that the massive stumps of giant sequoia left by logging in Whitaker's Forest, are still standing, showing little decay (Weaver and Biswell, 1969:18).

Hartesveldt (1964:13), speaking of fire damage, states:

> ...85 to 95 percent of the tree can be burned without resulting in the tree's death. When one does die through total destruction of the crown, the wood rots very slowly. One burned remnant of a stump, tested by radio-carbon dating methods, was found to be 2,100 years old on its outer edge, and it had only begun to decay! It is also significant that while fire scars are universal, there is scant evidence that there were many intense crown fires.

As in the natural habitat, resistance to insects, disease and rot seem to hold true for sequoias in the Willamette Valley. The bark on Willamette Valley trees is younger and therefore thinner than on the ancient giants in the Sierra, and their fire resistance may be assumed to be somewhat less for this reason. However, the sequoia's water-base resin further aids its fire resistant bark to make it somewhat more resistant to fire than Douglas fir of the same size.

The highest loss, in addition to storm damage, in a single planting in Oregon was in the windbreak row south of Corvallis where two were lost to fire and one to cow damage when the trees were young. No losses can be traced to insect damage or disease.

Because most of the trees are in non-forested situations, no losses from possible deer browse and other animal damage can be evaluated properly, although Glenn Crouch of the USDA wrote an extensive monograph in 1969 relating to the native species.

> Browsing was the most common problem regionwide... also the most frequently reported injury in each geographic area except the southern Cascades. The browsing category includes foliage removal by deer, elk, and livestock (Crouch, 1969:4).

Crouch lists damage in seven categories, of which foliage browsing (62 percent in western Washington and 68 percent in west-central Cascades) caused by far the greatest loss. He adds,

> According to the Timber Management Division, Pacific Northwest Region, about 25 percent of all reforestation work must be redone (Harold A. Dahl, pers. comm.). Animal damage makes necessary much of this costly supplementary work (Crouch, 1969:13).

There is no evidence in data gathered in this study that deer browse or other animal damage is a problem in the sequoia's natural range, particularly when the trees are past seedling stage (about two feet tall). No professional gardeners planting for the city of Portland, nor landscape architects in Portland or Eugene mentioned any loss due to small animal or deer depredations.

Very healthy trees have been noted outside the Willamette Valley, even in hot, summer-dry areas such as Grants Pass, Roseburg and Elkton. The only unhealthy appearing trees seen in any location were individuals among those planted along McLoughlin Blvd. in Portland, and those at Wind River Experimental Forest. The McLoughlin trees' variation in size and health may be due to genetic factors alone (Wiley, 1970: pers. comm.), although their roots do receive constant pounding from more than 38,000 vehicles per day.

Approximately ten dead trees, or less than one percent, were noted in the course of investigating several thousand specimens in the Willamette Valley. One of these, a large tree planted on the Capital Mall in Salem, was noted in the fall of 1968 to be quite brown and obviously sick. In the fall of 1969 the tree had died but was still standing. This tree was located next to the south face of white marble and glass of a three-story building which was built within the last ten years. Several people are studying the demise of this tree, but I am convinced it was due to sunstroke: the intense reflection of heat and lack of air circulation caused by the large wall with high reflectance immediately to the north (Fig. 49).

This very low rate of mortality in the Willamette Valley is unusual for an exotic, particularly one from such a restricted natural range. Natural conditions in the Willamette Valley seem favorable to the sequoia. Some cling to life in spite of all encroachments by man. As an example, an old Porter tree in the town of Forest Grove is surrounded by asphalt on four sides, one of which is a heavily traveled arterial, yet the tree thrives. Other Porter trees in Forest Grove have been crowded by buildings, sidewalks, and streets, with accompanying changes of grade and exclusion of moisture, and show no adverse effects. Changes in grade in paving streets, both on Mt. Tabor and in the Milwaukie area, have left numerous trees isolated high above

Fig. 49. Not even a stump remains of a sequoia on the Salem Capital Mall which probably died because of its proximity to the heat-reflecting building constructed recently to the north of it. The 6-foot measure marks the center of the trunk where the tree stood.

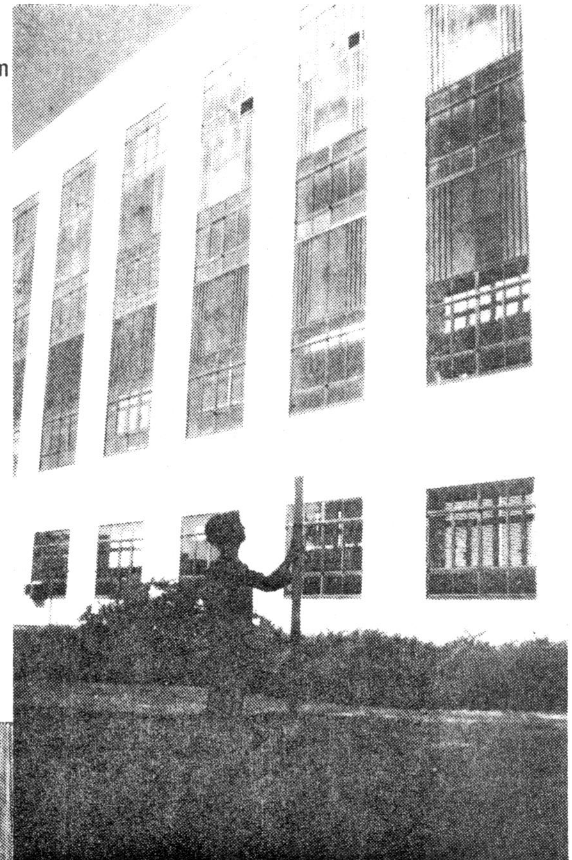


Fig. 50. A slice from the tree removed from the Salem Capital Mall. Note the nearly 3-foot diameter, and the sharp discoloration on the right side which was facing the building in the figure above.

original ground level on one side, again with no apparent damage to the trees' development. Previously mentioned was the tree in Eugene at Fourth and Lawrence, crowded on four sides by asphalt and building, neverthless healthy, although its foliage is notably more sparse than normal.

Management of Forest Trees

Intensive management of forests as a practice, although controversial, is becoming more widely discussed. Perhaps the most controversial aspect is managing for a shorter tree-crop rotation (this is used to justify an increased allowable cut on government-owned timber lands). There is no doubt, however, that management can increase growth rate, and consequently yield per year, as well as quality of lumber product, as is recognized in examples of current Douglas fir literature dealing with spacing and other control measures (i.e., USDA, 1959:1-4; USDA Annual Report, 1968:18-19).

Biswell, Sampert, and others are undertaking extensive controlled thinning projects to determine criteria for maximum yield from sequoias at Whitaker's Forest in the sequoia's natural range (Biswell, Buchanan and Gibbens, 1966:633). Pacific Northwest U.S. Forest Service and commercial studies in the popular press recently have indicated broad application of fertilizers on forest stands not only increases yield but is economically feasible.

The Betzel grove northwest of Eugene in the Santa Clara district is an example of intensive management. The Irwin Betzels began developing a slightly oversized city lot into an intensive miniature forest around 1946. In addition to many other exotics including palm trees, they have approximately sixty-eight Sequoiadendron giganteum on this small plot. The land is flat, the soil is Malabon silty loam with good drainage, and the subsurface water supply is very good, the property being situated beside, but approximately eight feet above, a natural drainage way. Some of the trees are planted in very close association in rows, six feet on center; other rows are more widely spaced. The first row of seedlings, three feet high and three years old, was planted in 1946. In an inner row planted four years later, where the trunk spacing was eleven feet, a core sample taken from a median tree shows average ring growth of 0.93 inches, or an average d.b.h. growth of 1.86 inches per year (Fig. 42). The improbability of this growth rate led to a second sampling of this inner row, and resultant measurements were comparable.

It should be noted that these trees are comparatively young, and that growth rate of all sequoias sampled, from the Porter trees to these youngest sampled, is much more rapid during their early years (Fig. 43). However, the outer ring showed a d.b.h. growth rate of 1.50 inches. Of all trees sampled, those in the Betzel grove showed the most consistent year-to-year growth. Twenty Betzel trees planted at close east-west intervals along the south property line, and close to a heavily travelled arterial (Fig. 51), although appearing very vigorous and healthy, are not as large as the trees already cited. However, another twenty planted in a north-south line

Fig. 51. The southwest corner of the Betzel grove in Eugene. Note consistency of development of all specimens in spite of very close growing conditions.

on the west side of the property just above the drainage way resemble the trees sampled, both in height and d.b.h. The Betzels also have younger sequoias planted at water level along the drainage way which do not seem to be affected by their proximity to the water, and their growth rates (by visual inspection) now approximate two vertical feet per year.

My personal experience with sequoias includes two five-foot trees planted in my own yard in 1965. The soil is poor and is mostly rock from a Spencer Butte lava flow. Rocks were removed for the root balls, but no loam was added. The area is shaded by native oaks and is on a gentle north-facing slope. After a four-year period in which the root systems became established, they now grow at a rate of 1 1/2 feet per year vertically and 0.37 inches in diameter.

Real correlations cannot be made between age and ring size. For example: a 2.25 inch d.b.h. growth at forty-five years of age (University of Oregon campus, Eugene); a 1.75 inch d.b.h. growth at seventy-four years of age (Forest Grove); and a 2.0 inch d.b.h. at twenty-five years (24th and Willamette, Eugene). This last tree is under power lines, and is trimmed, but grows a three to four foot sprout above the trim line every year.

Summary. The sequoia is quite at home in the Willamette Valley, for an exotic whose native habitat is 6000' in elevation in the Sierra Nevada. The climatic conditions are highly suitable; its growth rate exceeds that of Douglas fir up to the sixty inch isohyet;

its resistance to fire, insects, rodents, animals and disease exceeds that of Douglas fir and other natives. Its rot resistance is equal to or exceeds western red cedar, and its mortality rate is less than one percent.

William Robinson of the Portland city nursery is enthusiastic about the tree. Ervin Thorsen, landscape architect for the Portland Park Bureau, refers to the tree as "excellent" (Thorsen, 1970: pers. comm.). They use 250-300 per year in city plantings. The enthusiasm of members of the School of Forestry at Corvallis accounted for a wide distribution before the seeds and seedlings became readily available on the market. One of T.J. Starker's former students, Herbert Sampert, is now resident manager at Whitaker's Forest, and is intensively studying the giant sequoia. As an exotic and ornamental, sequoia has received widespread approval in the Willamette Valley.

Economic Potential of Big Tree Production in Oregon

An exotic that has proven remarkably well-suited to the growing conditions of the Willamette Valley, and that thrives in those areas not best suited to the native timber species, may make a valuable contribution economically to the future of the wood products-oriented Willamette Valley.

Unfortunately, although endless study has been devoted to the Douglas fir in Oregon and the ponderosa pine in California, and lesser study to the standard secondary species in both states, almost

almost nothing is known statistically about the wood fiber characteristics of the sequoia.

Since the big tree has been protected in its natural range, only R.A. Cockrell's manuscript studies have been made relative to its potential economic value, even though in earlier years the highest percentage of lumber production in the southern Sierra was Sequoiadendron giganteum, followed by ponderosa pine, white fir, and incense cedar (Otter, 1970: pers. comm.).

Cockrell, in association with R.M. Knudon, and A.G. Stangenberger, all of the University of California at Berkeley, has spent the last three years studying the wood properties of S. giganteum in comparison with other species native to California. The results of their findings appear in Fig. 52, and show on superficial examination that in maximum crushing strength and in compression perpendicular to grain, the sequoia shows a respectable performance in comparison with coast redwood, incense cedar, and even with white fir. It should be noted, regarding results for incense cedar, that there is variation between reports from two different government sources, and that figures for white fir and Douglas fir, also from a government report, do not indicate a distinction between old growth and second growth. It may be reasonable to assume there is no longer commercially significant old growth timber available for either species.

Fig. 52. Wood Properties of (A) Giant Sequoia, (B) Coast Redwood, (C) Incense Cedar*, (D) White Fir, and (E) Douglas Fir.

Species	Specific gravity**	Modulus of rupture (p.s.i.)	Modulus of elasticity (1,000 p.s.i.)	Total work (lbs.per cu.in.)	Maximum crushing strength (p.s.i.)	Compression perpendicular to grain (p.s.i.)	Hardness End (lbs)	Hardness Side (lbs)	Shear (p.s.i.)	Cleavage (p.s.i.
Green										
A	0.36	6,670	1,100	15.5	3,510	380	500	410	740	150
++	0.30	5,200	558	6.1	2,725	230	430	280	730	150
B	0.34	5,900	960	9.3	3,110	270	520	350	890	160
++	0.38	7,500	1,180	15.2	4,200	520	570	410	800	170
C	0.36	7,170	1,010	16.1	3,590	320	600	410	810	180
++	0.30	5,500	639	9.6	2,760	270	480	320	740	170
+	0.35	6,200	840	8.8	3,150	460	570	390	830	160
+D	0.35	5,700	1,050	11.4	2,710	370	380	330	750	170
+E	0.45	7,600	1,550	19.2	3,890	510	510	480	930	160
Dry										
A	0.38	9,340	1,290	16.4	5,400	570	740	470	940	130
++	0.31	5,870	680	3.4	4,420	740	740	360	970	120
B	0.35	7,900	1,100	5.2	5,220	520	740	420	110	140
++	0.40	10,000	1,340	8.8	6,150	860	790	480	940	150
C	0.39	9,300	1,150	9.7	5,570	610	790	440	1010	150
++	0.33	7,350	789	8.0	3,620	410	720	400	970	150
+	0.37	8,000	1,040	8.2	5,200	730	830	470	880	---
+D	0.37	9,300	1,380	11.4	5,350	600	730	440	930	160
+E	0.48	11,700	1,920	22.9	7,420	910	760	670	1140	180

* Adapted from Table 6 of the manuscript for <u>Mechanical Properties of Central Sierra Old Growth and Second Growth Incense Cedar</u>, by R. A. Cockrell, R. M. Knudon, and A. G. Stangenberger, Univ. of California, Berkeley, 1971.

** Based on volume at test and weight oven-dry

\+ Indicated data for White Fir, Douglas Fir and Incense Cedar previously reported from USDA Tech. Bull. 479.

++ Results for second growth on (++) line following species (A) Giant Sequoia, (B) Coast Redwood and (C) Incense Cedar; letter keyed line indicates old growth. Coast Redwood data from USFS Research Paper FPL 53(2) and USDA Tech. Bull. 479(8).

When he embarked on this study in 1968, Cockrell wrote:

> With respect to wood properties of Sierra redwood, I am presently conducting tests on both second growth and old growth material. Tests on four second growth trees about 85 years old, 12 to 20 inches d.b.h., and 100 feet high obtained from our Whitaker's Forest (western slope of Redwood Mountain Tulare County; adjacent to the Redwood Mountain Grove of Sierra redwood in Kings Canyon National Park) indicate that this wood is comparable to better quality second growth coast redwood. The data for coast redwood (second growth closely grown) from Mendocino County, reported on the last data sheet in USDA Technical Bulletin 479 almost parallels my data (Cockrell, 1968: pers. comm.).

As has been noted before, those agencies, such as the National Park Service and the U.S. Forest Service, which have jurisdiction over most of the remaining sequoia stands, are doing little in the way of research. They offer some support to the academic community that does carry on research on *S. giganteum* and that continues to gather data to better understand the tree, its performance and its limitations in its native habitat.

In Oregon, Roy R. Silen, Principal Plant Geneticist for the USDA Forestry Sciences Laboratory in Corvallis states,

> The problem with any exotic tree at the present time in the Northwest is that we are not at the stage of reforestation where such trees command much interest unless they show far superior growth to native trees. *This phase of forest history might end when the old growth commercial forests are at their practical end.* To give some perspective to this statement, the fact that we are only now beginning to grow our No. 2 tree, western hemlock, on a commercial scale in our nurseries shows how far we have to go in using other species for planting besides Douglas fir (Silen, 1970: pers. comm.) (Emphasis mine.)

This approach to trees by reforestation agencies as only and exclusively a current economic asset seems at best shortsighted. It leads to the prescription, in this region, of Douglas fir for every site regardless of its suitability to the site or its performance ratio compared to another species.

> The dearth of information and publications on the subject of Sequoia gigantea is very real, and is in my estimation quite serious in consequences. Value judgments are constantly being made relative to the advantage or disadvantage of one species to another for regeneration needs;...How can such a serious judgment be made let alone even be considered within the light of our present lop-sided body of information...we favor...studied species as being obviously best, but we continue to study them becase of the broad base of information....they have become the "sacred cows" of field forestry research (Sampert, 1968: pers. comm.). (Emphasis mine.)

A general feeling prevails that a wider variety of timber material in planting programs is a need to be considered only in the future. In view of the persistent demands by commercial timber interests to increase the annual allowable cut by shortening the rotation of the timber crop from eighty to seventy or even sixty years and perhaps less, it is obvious that research is needed now on numerous species and on a wider variety of sites.

Roy Silen maintains that "the niche (for Sequoiadendron giganteum) is outside of the major portion of the Douglas fir region." (Silen, 1970: pers. comm.).

The lower limit of the large commercial Douglas fir region, (called the Tsuga heterophylia Zone, western hemlock climax, by Franklin and Dyrness [1969:557-67]) coincides rather loosely with the outer fringe of the Willamette Valley, in which the giant sequoia does especially well. Within the agricultural valley and up to the National Forest are numerous wood lots, and many areas not now producing that will be needed later for some crop production. The success of the Dudeck grove indicates that marginal farmland can be utilized to advantage in potential wood crops. The sequoia seems especially well suited to this purpose, since it needs care only in infancy, grows on any slope and in any soil, resists most hazards to other tree crops, and boasts an extraordinary growth rate. A tree of any species that puts on 1.75 inches d.b.h. growth per year at age seventy-five, whose diameter is seven feet at one hundred years of age, and which reproduces naturally, merits further study and indicates economic potential.

The Betzel grove of some seventy sequoias, mixed with numerous other species on a large town lot, shows an average annual d.b.h. growth rate of 0.875 inches. On this basis, crop rotations on intensively managed woodlands could feasibly be as low as thirty to forty years.

Louis Hamill (1963:126-27) cites several forecasts for the lumber industry in Oregon, specifically for Lane and Douglas counties, considered typical timber producing counties. One of the most important forecasts is that increased productivity will occur without additional employment. He forecasts little increase of employment in the forest industry between now (1970) and the year 2000. He, as others, forecasts increased utilization of a greater percentage of the total tree. This has been apparent in the last ten years with the vast increase in the chip market alone.

Even with the 1970 interest in re-use and recycling, increases in population are creating pressures for ever greater land productivity and utilization. No indications at this juncture suggest any change in this trend in the foreseeable future.

The Department of Agriculture's Products of American Forests (Champion, 1961:29) states:

> The volumes of forest products used seems likely to increase, because modern research is leading to new technological developments and because the growing population will need more of these products. In the field of technology the trend is to more use of the wood fiber as such or in the form of chips or other easily managed forms. This trend points to the solution of the problem of using wood wastes. In the long run it will aid in the disposal of low-quality material as well....
>
> Outstanding among the increases in forest products utilization is the consumption of pulp and paper. Demand grows along with a rising standard of living and continuing improvement and diversification of paper products. There are indications of an increase in the use of improved papers, moisture-proofed or otherwise fortified, for structural purposes. Paper honeycomb sandwich cores for building panels and paper overlays for improved panel materials are typical of the new uses. If the promise in these materials is fulfilled, the per capita consumption of paper will climb at a more rapid rate than in past years.

Other products are reported which can be made from chemically converted wood (Champion, 1961:18-19). At present, cost of extracting chemicals exceeds return, but as costs are reduced through further research, these products will provide an outlet for the more than 100 million tons of wood residues that are available every year, and for low-grade second growth trees.

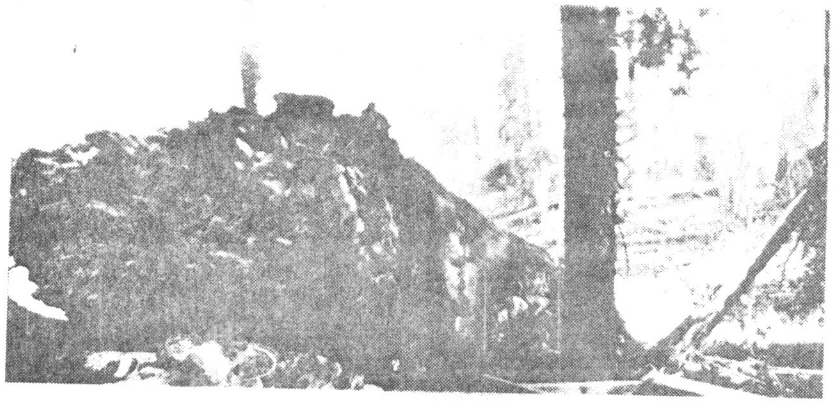
In discussing the sequoia as a possible timber tree in Oregon, the myth of its "brittleness" should be dispelled at the outset.

> ...much or most of the information in the existing literature relative to this specie's wood and wood fibre characteristics is based on old growth studies, ...[and] does suggest bias or speculation....The reputation for "extreme brittleness" probably comes from the Converse Basin. Here mature trees of unusual large size were felled with inadequate equipment in a spirit of financial desperation; and, as any farm boy knows, a ripe pumpkin or watermelon doesn't have to be dropped very far to cause it to burst. We had the same problems with large yellow fir in Oregon when I worked in the woods; sugar pine will do the same; and we surely have the same breakage problems with the large coast redwoods. On the coast standard harvesting practices call for preparation of felling beds, and even with great care it is normal to expect 40% breakage (Sampert, 1968: pers. comm.).

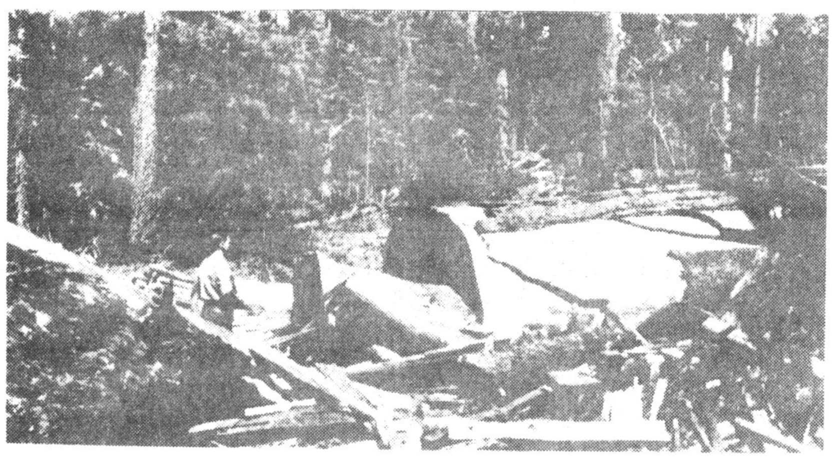
Sampert's comments are reinforced by this observation from Floyd Otter, former manager of Mountain Home State Forest and author of Men of Mammoth Forest,

> My observation is that there is not much difference between the wood of *Sequoia gigant.* and *S. sempervirens*. The extreme brittleness is largely a matter of *age* of the tree and its weight. Breakage was also a result of inexperienced loggers and the rough rocky terrain of much of the Sierra. If you compare a 100-year-old *gigantea* on the same terrain, your recovery would probably be equal and no one could distinguish the lumber, one tree from the other (Otter, 1970: pers. comm.).

In the course of this study, none of the trees observed lying on the forest floor in Sequoia National Park and Yosemite National Park showed cracks or signs of brittleness (although observations were limited to areas of normal access). One of the difficulties of this study has been that there have not been many analyses of strength and other wood properties of *Sequoiadendron giganteum*, except for Cockrell's findings already cited.



A redwood downed with dynamite about 1944 on Michigan Trust Company land. Note man between down tree and standing tree. U. S. Forest Service Photo #436259.



Breakage in the brittle Sierra redwood. About [illegible], Michigan Trust Company. U. S. Forest Service Photo #436236.

Fig. 53. (From <u>They Felled the Redwoods</u> by Hank Johnston, 1960.)

It is apparent that during the intensive logging of the sequoia forests, its wood was considered entirely satisfactory for structural purposes. Fry and White (1930:20), describing the logging operations in the Converse Basin in the late 1800's, comment:

> ...there are millions [of feet of lumber]...in the chutes and trestles on which the logs were conveyed to the mills. These structures are often built of sequoia and pine logs three feet and more in diameter. On one trestle, the foundations were of seven- and ten-foot sequoia logs, lying there today as sound as ever, although the pine and fir logs above them are crumbling into dust. There are milles of such trestles and chutes.

Nevertheless, it can be seen that for structural purposes in the present economy, where tensile strength is most important, sequoia as well as native cedar cannot approach D. fir. In fact, it is comparable to western red cedar (*Thuja plicata*) in most respects, and exceeds cedar in hardness, an important characteristic for paneling. The wood of well-aged giant sequoia has beautiful coloration (Fig. 54), and easily matches cedar or coast redwood for esthetic desirability.

As lumber, its highest use appears to be in paneling and siding, and for other non-structural purposes. No data is available on its lathing capability; it can be assumed from other available comparisons that it will perform similarly to cedar.

An important use indicated by its resistance to rot is for posts and pilings, even though slightly greater diameter would have to be specified to match the compression bearing qualities of D. fir. It has been noted earlier that giant sequoia heartwood is highly resistant to decay. Oregon trees contain a low proportion of sapwood

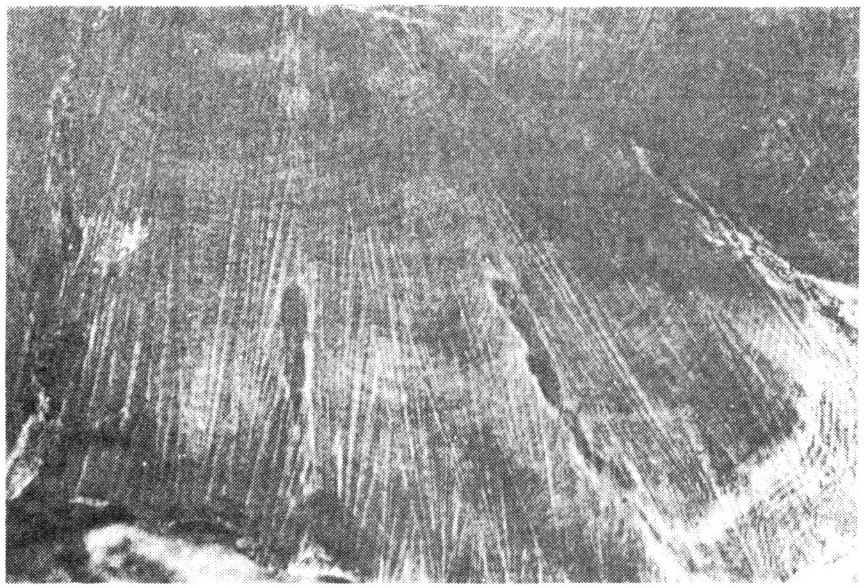


Fig. 54. A portion of the outer edge of a sequoia stump. The tree, one of John Porter's original planting, was broken off in the severe 1962 Columbus Day storm, and was subsequently cut near the ground. Coloration becomes redder toward the center of the stump, and has intensified in eight years of weathering. (Photograph 1970).

to heartwood. In some installations the use of untreated sequoia would be much more economical than treated D. fir.

In the later years of the logging operations of the sequoia in California thousands of board feet were used for fence posts and grape stakes (Otter, 1970: pers. comm.). Many of these fences are standing today in the central valley of California, with no signs of deterioration. This is cited as evidence of the long life of the cut wood, however, not as a suggested use for managed timber stands.

Literature on sequoia fiber and pulping qualities is apparently non-existent, as the following letter from L. Dieruf, Administrative Assistant, Division of Wood Fiber Products Research, Forest Products Laboratory of the U.S. Forest Service in Madison, Wisconsin, indicates:

> A rather brief literature search revealed no pulping information that pertained specifically to Sequoia gigantea. If such studies have been made the results seem not to have been published or else researchers have not necessarily differentiated between S. gigantea and S. sempervirens. However, since S. gigantea has been a protected species for so many years, it is understandable that research data are not plentiful.
>
> As to differences in fiber properties between S. gigantea and S. sempervirens, one of our wood scientists at Forest Products Laboratory tells me that each species varies considerably in fiber length within itself and therefore it is difficult to establish a realistic average length for each one on a limited number of samples. He informs me that average fiber lengths of the two Sequoias reported by various scientists through the years, based on very small samplings, ranged from 4.6 to 5.0 millimeters for S. gigantea and 4.8 to 6.5 millimeters for S. sempervirens. However, there were single measurements of 7.0 millimeters for both species. He would expect the density of S. gigantea to be a little lower than the reported 23-24 pounds per cubic foot (moisture-free weight/green volume basis) of S. sempervirens. This would indicate that pulp yields per wood volume could be proportionately lower also.

We have to rely on redwood rather than sequoia for pulp and papermaking experiments by the Forest Products Laboratory at Madison, Wisconsin:

> Old- and second-growth redwood (Sequoia sempervirens) were digested by the sulfate pulping process by normal procedures, but the yields of pulp (35.6 and 40.7 percent by weight, respectively) were lower than that obtained from Douglas-fir cooked to the same permangante number. The yield of redwood pulp was also low on a volume basis (pounds of pulp per cubic foot of wood) because of its low density (Martin, Simmonds and Fahey, 1960:1).

This yield was only 5.6 percent lower than that obtained from a sample of D. fir, and through examination of growth rates can be expected to be compensated for by the more rapid growth rate of sequoia. More importantly,

> ...bursting strength, folding endurance, and breaking length of the unbleached redwood pulps were better than those of the Douglas-fir pulp....The redwood pulp papers were stronger than papers made entirely from the Douglas-fir pulp, except in tearing strength. The paper made from the old-growth redwood pulp was equal to the Douglas-fir paper in formation, and that made from the second-growth redwood pulp was noticeably better in this property....The redwood pulp fiber appeared to be suitable material for making porous paper such as filter papers....The appearance of the sheet indicated the possibilities of the redwood fiber in filter and other porous paper products (Martin, Simmonds and Fahey, 1960:2, 4, 5).

It appears that the addition of redwood fibers can increase the strength of papers primarily made from D. fir in bursting strength, folding endurance and breaking length, and can be used alone in the production of filter papers. The United States now consumes paper and paper board at a rate of about 47 million tons per year. Of this, 37 million tons are made from domestic wood pulp (Hall, 1969:54).

Hall further comments:

> The Pacific Northwest (Oregon and Washington) produces about 15 percent of the national production of woodpulp. Production in these States has just about doubled in the last 20 years and, if predictions as to demand hold true, must be doubled again in the next 20 years....
>
> As to wood supply for expansion, it must come from three sources:
>
> 1. Better use of logging waste
> 2. Thinning and intermediate cuttings of young forests
> 3. Use of little-used species, such as lodgepole pine and the high-elevation conifers.
>
> Numbers 2 and 3 will require capital expenditures and operating costs not yet adequately provided on publicily owned lands and in effect in only a few companies on privately owned lands (Hall, 1969:54, 55).

Thinnings and cuttings (#2 above) are already being used from many Willamette Valley woodlots. The possibility that sequoia in some instances can improve paper quality, and that it does indeed grow at a faster rate than other species, indicates higher yield for the same capital expenditure and operating costs.

As for Hall's third source of wood for expansion, distance to mills will be a restrictive factor in the use of species such as lodgepole and most high elevation conifers. However these are largely in wilderness or other recreation areas now prohibited to logging. The relatively short distance from farmer's woodlot to the mills in the valley can make high elevation logging unnecessary, reserving these higher areas for the increasing demand for recreational use.

More research must be undertaken by those agencies presently responsible for our wood resources. S. Blair Hutchison, Assistant Director, Intermountain Forest and Range Experiment Station at Ogden, observes:

> The role of scientific analysis in public resource evaluations is not diminished in the slightest by recognizing the limitations of the procedures. The job to be done requires great skill and perception and proper use of modern economic tools. It involves laying out in a logical fashion all of the factors that must be taken into account in the public decision. Some values can be neatly measured in dollars. Some can best be expressed in physical equivalents. Others cannot be measured empirically but only sensed or appreciated by an overall value judgment. Some are economic, some sociological, some ethical. Some involve what is known; others relate to unknowns. Many of the factors can be weighed quite accurately, others only approximated. Still others can be described only in very broad and sometimes unclear terms....
>
> Individuals and companies also have different spans of interest insofar as the future is concerned--spans that are rather strongly related to circumstances....
>
> If we can assume that this is a country with a strong sense of destiny, the economic and social well-being of future generations is a matter of prime importance. Those defects in the resource situation today that are the result of cumulative actions of the past may in part be laid to conscious or unconscious discounting of today by our predecessors (Hutchison, 1969(10):523-24).

In light of facts gathered in this study (resistance to disease and fire, its favorable symbiotic relationship in this area, and especially its high growth rate), it seems past time to consider the sequoia seriously from an economic aspect, in this rainfall zone and below the extensive D. fir forests. Reforestation for economic uses should be considered for farmers' woodlots on the valley floor and on Bureau of Land Management and state forest lands. Private commercial interests might well consider this tree in the areas of their holdings where conditions are best suited to giant sequoia.

CONCLUSION

Since the late 1870's, when seed was brought from the Sierra by John Porter for germination in Oregon, <u>Sequoiadendron giganteum</u> has been spread with remarkable success throughout the Willamette Valley. It grows by the thousands in town and country yards, in formal plantings, city parks, windbreaks and along country roads.

Its oldest examples have reached 160 feet in height and up to 7 feet d.b.h. Its youngest grow a foot or more in height and up to 1.86 inches d.b.h. per year. It grows on any soil, in any aspect, in a precipitation range from thirty to eighty inches annually, with a wide tolerance of temperature extremes. From its seedling stage onward, its principal requirement is adequate soil moisture with good drainage. It demonstrates a tolerance of summer drought, prefers sunlight to dense shade, but will grow in either situation. Its upper limits coincide with the lower edges of the heavy Douglas fir forests, suggesting it as complementary rather than competitive.

The sequoia is beginning to germinate naturally, in addition to the extensive state nursery germination program that has been in existence for some years.

Its magnificent size and luxuriant foliage have brought it widespread popular attention. These qualities, coupled with its unusual resistance to disease and its easy adaptibility to valley locations, have recommended it to numerous local park and recreation landscape planners. Large-scale commercial growers, such as the

U.S. Forest Service and the Bureau of Land Management, alone have failed to recognize this exotic from the Sierra as a potential Oregon tree.

The sequoia's potential in the Willamette Valley in intensive management situations is impressive. Its phenomenal growth rate, its resistance to most natural hazards, wood qualities comparable to cedar, and the outlook for increased demand for fiber, all indicate a real economic potential for the tree.

It may, in the near future, find acceptance, along with native species, in the lumber economy of Oregon. In any case *Sequoiadendron giganteum* has thoroughly established its aesthetic contribution to Oregon, and its acceptance of the Willamette Valley habitat as its own.

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