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The WIND RIVER ARBORETUM

FROM 1912 TO 1956

by
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and
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PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U. S. DEPT. OF AGRICULTURE · FOREST SERVICE

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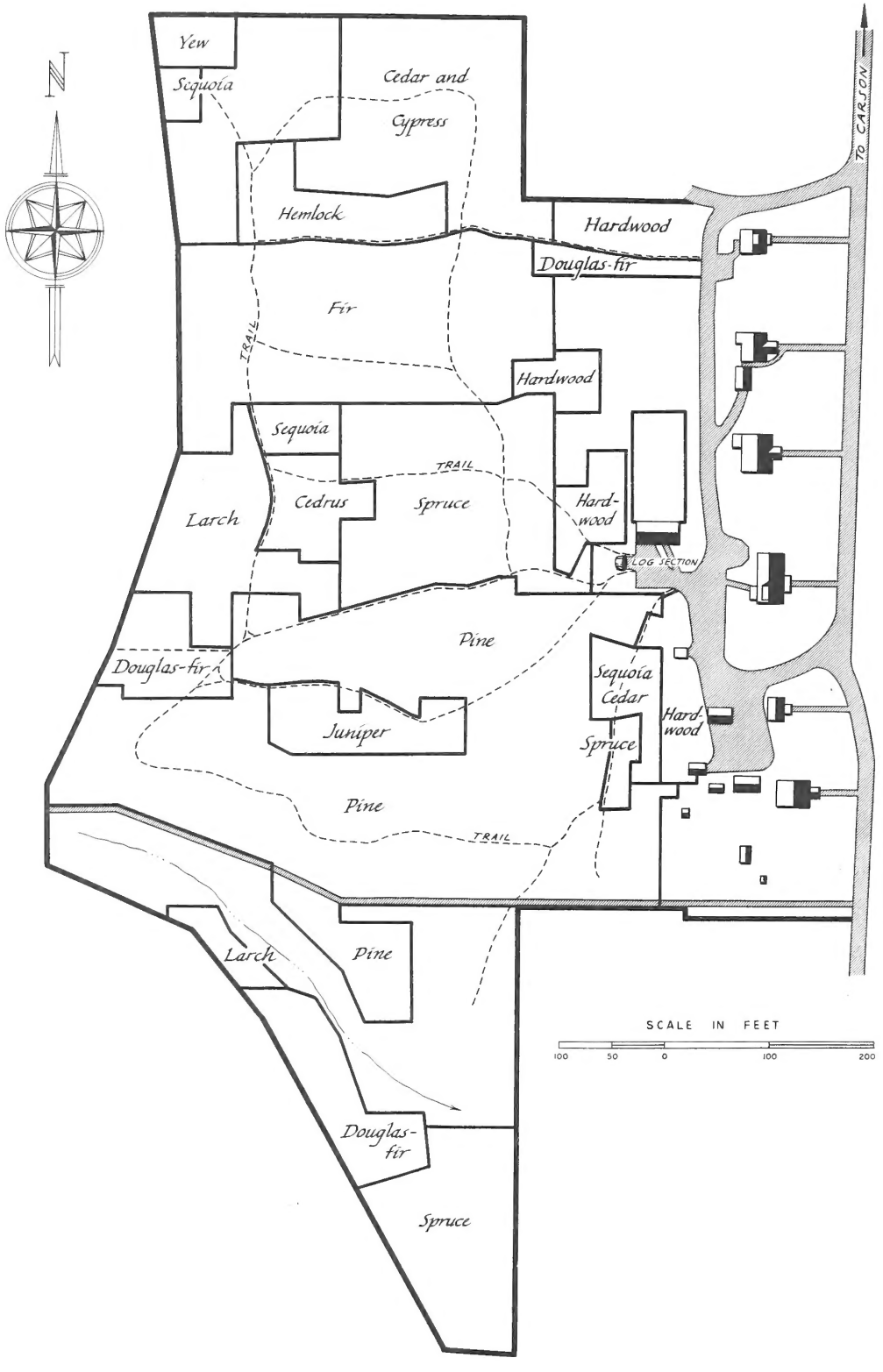

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R. W. Cowlin, Director Portland, Oregon

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

	Page
INTRODUCTION	1
LOCATION	2
SITE	2
CLIMATE	3
HISTORY	4
Arrangement and Treatment of Arboretum Trees	4
Source of Seed and Planting Stock	6
Acquisition of Seed or Stock, 1947-56	7
Disease and Pest Control	7
Damaging Factors	10
PERFORMANCE OF CONIFERS	12
The Pines (Pinus)	24
The Larches (Larix)	26
The Spruces (Picea)	27
The Hemlocks (Tsuga)	27
The Douglas-Firs (Pseudotsuga)	28
The Firs (Abies)	29
The Cedars (Cedrus)	30
The Sequoias (Sequoia)	30
Incense-Cedar (Libocedrus)	30
Thujopsis (Thujopsis)	30
The Thujas (Thuja)	31
The White-Cedars (Chamaecyparis)	31
The Cypresses (Cupressus)	31
The Junipers (Juniperus)	31
The Yews (Taxus)	32
The Araucarias (Araucaria)	32
PERFORMANCE OF BROAD-LEAVED TREES	32
CONIFERS FOUND UNSUITED TO THE WIND RIVER SITE	35
GENERAL COMMENTS ON PERFORMANCE	40
LITERATURE CITED	49

INTRODUCTION

Wind River Arboretum, located in the Wind River valley near Carson, Wash., was established in 1912 with the planting of a few species of introduced trees on stump land adjacent to the Wind River Nursery. It is the oldest arboretum in the Northwest and ranks among the earliest forestry projects of an experimental nature still in existence in the region.[1/] The initial objective was to test the suitability of trees from all parts of the world for forest planting under conditions generally prevailing west of the Cascade Range in Oregon and Washington. This objective was later broadened to include establishment of as many forest-tree species as possible to serve for dendrological study and exhibition purposes. In more recent years, the objective has been broadened still further to provide for planting different races of species in an attempt to determine racial variation within certain species and hybrid strains.

The arboretum is best known as an area for testing suitability of introduced species for forest plantings. The study may be broadened

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1/ Human persistence and vision have been major factors in sustaining the 44 years of effort at the Wind River Arboretum. Names of many prominent foresters of the Northwest are recorded in the files. Thornton T. Munger had overall supervision from 1912 to 1919 and from 1924 to 1946. J. V. Hofmann was in immediate charge from 1913 to 1924. Leo A. Isaac and Ernest L. Kolbe had immediate charge from 1924 to 1930 and from 1930 to 1938, respectively. A. Gael Simson was resident officer from 1920 to 1940. Charles J. Kraebel helped in early establishment and R. H. Westveld made the first systematic plan in 1925. Large contributions in effort were made by R. W. Steele, G. S. Meagher, E. G. Dunford, L. Bransford, R. N. Young, W. Peterson, W. Allyn, E. Lofgren, T. Kachin, and E. Elm. James Hutchins and George Lopez assisted in the field work in 1956.

The authors are indebted to T. T. Munger, L. A. Isaac, and E. L. Kolbe for critical technical review of this report.

eventually to include every species in the world that has reasonable promise for this climate. To date, the study covers 621 lots of seed or planting stock, and is well along toward attaining this goal.

The arboretum occupies 11 acres and is arranged systematically to include space for species from most genera of conifers. A few hardwood species still remain from early plantings; but, because of very poor results with almost all hardwoods, no attempt has been made since 1928 to establish additional species.

Previously published reports (Munger and Kolbe, 1932; Munger and Kolbe, 1937; Munger, 1947) give a detailed description of the locality and history of the Wind River Arboretum. A brief summary of the most pertinent information from these previous reports is included in the present report.

LOCATION

Wind River Arboretum is situated at an elevation of 1,150 feet at the western edge of Wind River valley, which extends in a north-south direction in the Cascade Range in western Washington. It is surrounded by forested hills that rise 1,000 to 3,000 feet above the valley floor. Located 10 miles northwest of Carson, Wash., the arboretum may be reached by way of the Wind River road, which junctions with U.S. Highway 830 a few miles east of Stevenson, Wash. Wind River Forest Nursery, Hemlock Ranger Station, and Wind River Experimental Forest--all U.S. Forest Service installations--are immediately adjacent.

SITE

The site now occupied by the arboretum was originally a Douglas-fir forest. It was logged in 1908 or 1909, and the slash was broadcast burned. In 1934 and 1935, CCC workers cut the stumps and removed much of the debris from the area.

The soil is a deep, coarse, sandy loam that is stony in places. It was deposited as an alluvial bench or fan on an approximate 10-percent slope along the edge of the valley, bordering the steep hills. The soil is fairly porous, appears to have no hardpan subsoil, and dries out very rapidly. It has a Douglas-fir site index of 130.

Annual dense growth of bracken, a fern, has covered the floor of the arboretum since its establishment. No attempt has been made

to remove the bracken except around very small trees when it might cause damage by shading or by lodging upon and weighting down young trees. Other competing vegetation includes vine maple, hazel, whortleberry, huckleberry, alder, chinkapin, blueberry elder, and volunteer native and introduced conifer seedlings. These have been cut down periodically since the arboretum was established and have never been allowed to become serious competitors of arboretum trees.

CLIMATE

The climate is typical of much of the area along the west slopes of the Cascade Range in Oregon and Washington. It is characterized by heavy precipitation occurring mostly between October and May; acute summer drought with hot, dry days; absence of excessively cold winters; accumulation of 6 to 10 inches of heavy, wet snow; a rather short frost-free period; and cool nights, even in summer. Because the valley is surrounded by mountains, precipitation is somewhat heavier than would be expected at this altitude and the frost-free period is shorter because of cold-air drainage common to these valleys. Climatological data from the Wind River weather station for 1911 to 1950 are summarized as follows:

Mean annual precipitation	89.89 inches
Maximum annual precipitation	142.60 "
Minimum annual precipitation	54.15 "
Mean annual temperature	48.1° F.
Mean maximum annual temperature	59.7 "
Mean minimum annual temperature	36.5 "
Highest recorded temperature	107° F.
Lowest recorded temperature	-18 "
Average July temperature	63.8° F.
Average January temperature	31.5 "
Average length of season without frost	131 days
Shortest season without frost	73 "
Longest season without frost	193 "
Clear days per year	34 percent
Partly cloudy days per year	22 "
Cloudy days per year	44 "

It should be pointed out that similar conditions are common at this elevation from southern Oregon to northern Washington in narrow valleys along the west slopes of the Cascades. For instance, climatological records at Prospect and McKenzie Bridge in Oregon and Darrington and Kosmos in Washington show similar temperature minimums and frost-free periods. Wide-valley locations, such as Albany and Corvallis in Oregon and Centralia in Washington, have recorded lower minimum temperatures, even at elevations under 500 feet. Apparently the location of the arboretum, within 12 miles of the Columbia Gorge, has had little effect on extremes of weather as reflected in climatological data.

HISTORY

ARRANGEMENT AND TREATMENT OF ARBORETUM TREES

As mentioned earlier, a few species of introduced trees were planted in 1912. Additions were made every year until 1925, with little regard to uniformity of treatment or systematic arrangement. During these early trials, plantings of hardwoods were made in at least equal proportion to the conifers. Their almost universal early failure strongly indicated that introduced hardwoods are poor risks in the long summer droughts and short growing season of the Cascade Range.

In 1920, a considerable number of species were moved to an area adjacent to the arboretum with the expectation of spreading the plantations over more area. Because the trees moved were quite large, many died. The trees were moved back to the original arboretum in 1924 with more loss resulting. The double transplanting seriously reduced growth rate of survivors for many years.

The plan for planting by a taxonomic arrangement of species was completed in 1925, with a section of the area allocated to each coniferous genus. Most subsequent plantings have followed this plan so that now most species in each genus are found in blocks an acre or more in size (fig. 1). Later plantings provided about 2,500 to 3,000 square feet for each species: 16 to 25 trees (if that many were available) were set 12 to 15 feet apart, avoiding regular rows where possible.

The trees have usually been set out when about 1 foot high. Care given to new lots is usually limited to removing competition and

Figure 1.--Interior view of the arboretum. An acre or more is devoted to each of the more important genera. The pine block shown here contains 38 surviving species and varieties of the 63 tested at Wind River.

spading the ground well to give the trees adequate opportunity to become established. Some groups have been shaded during establishment. Snowbent or broken trees have been guyed or braced with splints.

Once established, trees are usually given very limited care in order to test their suitability for planting in this locality (fig. 2). This is especially true for species vigorous enough to show promise as forest trees. Poorer lots that might be lost from representation in the arboretum are given great care, however. Water pipes were

Figure 2. --Two 44-year-old Jeffrey pines from the same seed lot show marked differences in growth rate under stand conditions of the arboretum (left) and on a watered lawn (right). Tallest tree in the arboretum group is 54 feet in height and 12.1 inches d.b.h. The individual specimen on the lawn is 73 feet tall and 30.2 inches d.b.h. Comparative volumes are 17 and 138 cubic feet.

laid over most of the area in the 1930's as a CCC project, largely for fire protection. Some sprinkling was done to assist in the establishment of new lots, but most of the plantings have received no artificial watering. The water system has not been used in recent years.

SOURCE OF SEED AND PLANTING STOCK

Most of the planting stock used in the arboretum has been grown from seed in nearby nursery beds. Some stock, however, has been shipped from as far as the East Coast States. Some of the earlier lots of seed were purchased from commercial seed houses, but almost all of the later lots have come from original collections

of forest experiment stations, agricultural explorers, or arboreta. Many organizations and individuals have contributed seed and seedlings for the Wind River Arboretum, and gratitude is due them for their cooperation.

Of 621 lots of seeds and plants acquired for the arboretum since 1912, 192 were never adequately tested. Fifty lots, obviously unsuited for the climate, were sent elsewhere for trial. The remaining 142 lots either failed to germinate, were destroyed as seedlings by frost heaving or rodents, or arrived in poor condition.

ACQUISITION OF SEED OR STOCK, 1947-56

Only 66 new lots were tried during the past 10 years because emphasis has been placed on acquiring rare species and those which might do well in the Northwest. A number of species from milder climates have been sent to locations having a less severe climate than that of the Wind River valley so they will have a better chance of becoming established. Acquisitions of the past 10 years are numbered 540 to 604. Table 1 gives the present location and condition of the new lots.

DISEASE AND PEST CONTROL

In 1928, in an attempt to safeguard the nursery and arboretum from white pine blister rust, crews began removing native Ribes species abundant in the locality. Eradication was continued through 1931 and repeated in 1939 and 1941. In spite of these efforts, blister rust has appeared on several species of five-needled pines and new infections continue to appear.

For a number of years between 1939 and 1946, a program of excising stem cankers and removing infected limbs was carried out. This has been discontinued in more recent years because the disease is too well established in the infected trees.

Aside from the work on blister rust, little has been done to control diseases or other pests. The firs were sprayed in 1956 to control the balsam woolly aphid (Chermes piceae), and minor effort was made earlier to control the Cooley spruce gall aphid (Chermes cooleyi) on Sitka spruce (Picea sitchensis).

Except for sporadic hunting, little attempt has been made to control the red-bellied sapsucker--a bird which has damaged many

Table 1.--Acquisitions to Wind River Arboretum, 1947-56

Lot No.	Species	Range	Present location or condition
540	Larix lyallii Parl.	Pac. NW.	No germination
541	Larix lyallii Parl.	Pac. NW.	No germination
542	Juniperus formosana Hayata	Formosa	Cascade Head, 1947?
543	Chamaecyparis obtusa var. formosana Hayata	Japan	Cascade Head, 1947?
544	Taxus cuspidata Sieb. & Zucc.	E. Asia	No germination
545	Juniperus rigida Sieb. & Zucc.	E. Asia	No germination
546	Taxus cuspidata Sieb. & Zucc.	E. Asia	No germination
547	Fitzroya cupressoides (Molina) Johnston	Chile	Destroyed
548	Libocedrus chilensis Endl.	Chile	Destroyed
549	Nothofagus dombeyi (Mirb.) Oerst.	Chile	Destroyed
550	Laurelia aromatica Fuss. ex Pair.	Chile	Destroyed
551	Persea lingue Nees	Chile	No germination
552	Nothofagus obliqua (Mirb.) Oerst.	Chile	Destroyed
553	Metasequoia glyptostroboides Hu and Cheng	Cen. China	Cascade Head, 1949
554	Taxus cuspidata Sieb. & Zucc.	E. Asia	No germination
555	Juniperus formosana Hayata	Formosa	No germination
556	Pseudotsuga menziesii (Mirb.) Franco	N. U.S.	Arboretum, 1952
557	Pseudotsuga menziesii (Mirb.) Franco	N. U.S.	Arboretum, 1952
558	Pseudotsuga menziesii (Mirb.) Franco	N. U.S.	Arboretum, 1952
559	Tsuga chinensis (Franch.) Pritz.	W. China	No germination
560	Cunninghamia konishii Hayata	Formosa	No germination
561	Libocedrus formosana Florin	Formosa	Frost killed in nursery
562	Pseudotsuga wilsoniana Hayata	Formosa	Not known
563	Pinus gerardiana Wall.	Himalayas	No germination
564	Chamaecyparis pisifera (Sieb. & Zucc.) Endl.	Japan	Arboretum, 1952
565	Podocarpus salignus Don	Chile	No germination
566	Nothofagus obliqua (Mirb.) Oerst.	Chile	Not known
567	Araucaria araucana (Molina) K. Koch (?)	Chile	No germination
568	Nothofagus dombeyi (Mirb.) Oerst.	Chile	Not known
569	Persea lingue Nees	Chile	No germination
570	Pinus cembra L.	Alps	Mice ate seed
571	Taiwania flousiana Gaussen	China	Not known
572	Abies firma Sieb. & Zucc.	Japan	Not known
573	Thuja orientalis L.	N., W. China	Not known
574	Metasequoia glyptostroboides Hu & Cheng	Cen. China	Distributed
575	Larix lyallii Parl.	Rocky Mt.	Mice ate seed

Table 1.--Acquisitions to Wind River Arboretum, 1947-56 (Continued)

Lot No.	Species	Range	Present location or condition
576	Cupressus lusitanica Mill (?)	Mexico	Not known
577	Cryptomeria japonica (L.f.) D. Don	Jap., China	Sent to Cascade Head
578	Thuja occidentalis L.	E., N. Amer.	Not known
579	Picea maximowiczii Reg.	Japan	Not known
580	Abies homolepis Sieb. & Zucc.	Japan	No germination
581	Juniperus conferta Parl.	Japan	Not known
582	Juniperus rigida Sieb. & Zucc.	E. Asia	Not known
583	Picea glehnii (Fr. Schmidt) Mast.	Japan	Not known
584	Pseudotsuga japonica (Shiras.) Beiss.	Japan	Not known
585	Tsuga diversifolia (Maxim.) Mast.	Japan	Not known
586	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
587	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
588	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
589	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
590	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Not known
591	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Died in nursery
592	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Not known
593	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
594	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
595	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Not known
596	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Not known
597	Pseudotsuga menziesii (Mirb.) Franco	W. U.S.	Arboretum, 1952
598	Juniperus occidentalis Hook.	W. U.S.	Arboretum, 1952
599	Pinus ponderosa Laws. (Hybrid)	W. U.S.	Arboretum, 1953
600	Pinus ponderosa Laws. (Hybrid)	W. U.S.	Arboretum, 1953
601	Pinus ponderosa Laws. (Hybrid)	W. U.S.	Arboretum, 1953
602	Pinus ponderosa Laws. (Hybrid)	W. U.S.	Arboretum, 1953
603	Pinus ponderosa Laws. (Hybrid)	W. U.S.	Arboretum, 1953
604	Pinus contorta Dougl.	W., N. Amer.	Arboretum, 1954

species by pecking rings of holes around the trunk, in some cases killing trees by girdling (fig. 3).

Figure 3.--Scotch pine damaged by the red-bellied sapsucker. Partial girdling by this bird has seriously deformed several introduced species.

Some trapping was done in earlier years to control root-gnawing rodents.

DAMAGING FACTORS

At the end of the 1956 growing season, all trees in the arboretum were remeasured and checked for general vigor, disease or insect infestations, and damage by other agencies.

The 10-year period 1947-1956 probably provided the most severe test of suitability for introduced species since the establishment of the arboretum. During this period, many species that had shown considerable promise as forest trees were severely damaged--and some killed--by the very severe winter of 1949-50 and by the exceptionally early and extremely low subfreezing temperatures in November 1955.

A severe drought in the spring and summer of 1951, during which no appreciable amount of rain fell from April to early September, provided a severe test for drought resistance.

Snowbreak continues to be a problem in some species, especially the larches. Some smaller trees below snow level have suffered severely from freezing of hard-packed snow to limbs and subsequent tearing of limbs from the trunk.

The balsam woolly aphid has appeared within the last 10 years as a killer of Abies (fig. 4). Blister rust has continued as a major

Figure 4.--The arboretum serves to test relative susceptibility to disease and insects. A, Balsam woolly aphid infestation of Fraser fir, shown here, has almost destroyed the arboretum group. Of 24 species of Abies, 6 have been attacked by this insect, with Fraser fir the most susceptible. B, Closeup of a gouted branch.

source of mortality among susceptible white pines, and root rot has become established in several promising species of pines since 1946. Deer browsing has been a problem in the establishment of yew species.

PERFORMANCE OF CONIFERS

Table 2 shows the condition of all living groups of conifers in the Wind River Arboretum at the end of the 1956 growing season. Explanations of the column headings are:

Species. Approved names listed in the U.S. Forest Service's "Check List of Native and Naturalized Trees of the United States (including Alaska)" (Little, 1953) have been used for species native to the United States. 2/

Additional references, consulted for introduced species, are:

Dallimore, W., and Jackson, A. Bruce.
1948. A handbook of coniferae. Ed. 3, 682 pp., illus. London.

Kelsey, Harlan P., and Dayton, William A.
1942. Standardized plant names. Ed. 2, 675 pp. Harrisburg, Pa.

Rehder, Alfred
1940. Manual of cultivated trees and shrubs hardy in North America exclusive of the subtropical and warmer temperate regions. Ed. 2, 996 pp., illus. New York.

Rehder, Alfred
1949. Bibliography of cultivated trees and shrubs hardy in the cooler temperate regions of the northern hemisphere. 825 pp. Jamaica Plain, Mass.

Lot number. The serial number given each acquisition, beginning with number 1 in 1912.

2/ The authors are grateful for the assistance of Dr. Elbert L. Little, Jr., who visited the arboretum to check identification of species and who verified nomenclature used in this report.

Table 2.--Status of living conifer species, Wind River Arboretum

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Abies (the firs):										
alba Mill.	silver fir	288	1927	20/20	11.5	22.0	.40	N		Fair; yellowish needles, snow-break, heavy Chermes without apparent damage.
amabilis (Dougl.) Forbes	Pacific silver fir	190	1922	19/16	18.9	27.0	.41	N		Good; aphid (probably Mindarus)
"	"	484	--	5/4	11.7	14.0				Good
balsamea (L.) Mill.	balsam fir	295	1924	11/10	24.4	35.0	.57	N		Fair; moderate Chermes infestation
bracteata D. Don	bristlecone fir	511	1938	16/7	4.6	7.0	.29	N	S	Poor; bent; many almost dead; repeatedly frozen back
cephalonica Loud.	Greek fir	491	1935?	20/15	4.9	8.0	.24	N	S	Fair; repeated freezeback, snow-break
fabri (Mast.) Craib	Faber fir	365	--	7/1	4.0	4.0		N	S	Poor; snowbreak, repeated freeze-back
fraseri (Pursh) Poir.	Fraser fir	286	1927	21/11	8.0	16.0	.29	L		Poor; tops of most trees killed by Chermes
grandis (Dougl.) Lindl.	grand fir	236	1926	20/7	15.1	21.0	.37	N		Good
"	"	280	(1/)	20/4	14.7	26.0	.40	M		Excellent
"	"	300	1925?	7/7	43.8	53.0	.89	M		Excellent
"	"	356	(1/)	6/5	43.4	50.0	.81	M		Excellent
"	"	473	1931	7/5	13.8	22.0	.49			Good
"	"	529	1942	4/4	5.7	14.0	.97	N		Good
grandis (hybrid)	grand fir (hybrid)	529A	1950	1/1	2.0	2.0	.91	N		Good
holophylla Maxim.	Manchurian fir	124	1925	4/3	4.3	6.0	.10	N	S	Poor; snowbreak, repeatedly frozen back
"	"	272	1926	2/1	4.0	4.0	.07	N	S	Poor; snowbreak, repeatedly frozen back
"	"	425	1931	20/5	2.8	4.0	.09	N	S	Poor; snowbreak, repeatedly frozen back
homolepis Sieb. & Zucc.	Nikko fir	359	1926	20/1	19.0	19.0	.33	L	L	Good; snowbreak
koreana Wils.	Korean fir	412	1931	21/14	7.4	12.5	.28	M		Fair; many snowbroken
lasiocarpa (Hook.) Nutt.	subalpine fir	276	(1/)	10/7	20.5	28.0	.43	N		Good; many badly damaged by Chermes
"	"	485	1933?	5/5	9.8	12.0	.31	N		Good; many badly damaged by Chermes
lasiocarpa var. arizonica (Merriam) Lemm.	corkbark fir	294	1927	21/18	12.0	19.0	.35	N	L	Fair; 4 of 18 have snowbreak, light Chermes infestation

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Abies (the firs)--Continued										
magnifica A. Murr.	California red fir	291	1927	20/20	10.3	24.0	.44	N		Excellent
magnifica var. shastensis Lemm.	Shasta red fir	277	(1/)	6/5	20.0	26.0	.40	N		Good
"	"	406	1927	20/19	12.2	29.0	.53	N		Good
mariesii Mast.	Maries fir	464	1931	20/5	10.3	14.0	.31	N		Good; snowbroken but recovering
nephrolepis (Trautv.) Maxim.	Khingan fir	411	1931	20/5	6.8	11.0	.25	N		Good; doing well after repeated snowbreak
pinsapo Boiss.	Spanish fir	492	1935?	21/19	4.3	9.0	.27		S	Poor to good; snowbreak and repeated freezeback, light Chermes infestation
procera Rehd.	noble fir	34	1913	15/10	36.4	49.0	.59	N		Good
"	"	189	1922	8/8	29.9	46.0	.70	N		Good
sachalinensis (Fr. Schmidt.) Mast.	Sakhalin fir	125	1925	20/5	21.2	39.0	.66	N	L	Good; crooked stems
sibirica Ledeb.	Siberian fir	463	1931	20/8	2.6	5.0	.11	N	S	Poor; snowbent
veitchii Lindl.	Veitch fir	462	1931	25/9	12.8	16.5	.37	M	M	Fair
Araucaria (the araucarias):										
araucana (Molina) K. Koch	monkey-puzzle	102	1913	2/2	7.5	7.5	.09	N	S	Good; doing well after repeated freezeback
Cedrus (the cedars):										
atlantica Manetti	Atlas cedar	47	1913	8/5	34.8	46.5	.55	N	L	Good
deodara (Roxb.) Loud.	deodar cedar	244	1926	13/4	16.9	22.0	.38	N		Fair; some crooked boles
libani A. Rich.	cedar-of-Lebanon	48	1913	19/7	27.3	35.5	.42	N	L	Good
"	"	528	1938	3/2	5.2	5.5	.23	N	M	Poor
Chamaecyparis (the white-cedars):										
lawsoniana (A. Murr.) Parl.	Port-Orford-cedar	39	1912	13/5	42.6	51.5	.60	L	L	Good
"	"	440	1929	20/16	21.4	30.0	.60	H	M	Excellent
nootkatensis (D. Don) Spach	Alaska-cedar	404	1927	23/20	13.7	24.0	.44	L		Excellent

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Chamaecyparis (the white-cedars)--Continued										
pisifera (Sieb. & Zucc.) Endl.	Sawara false-cypress	564	1947	27/19	2.0	3.0	.59	L	M	Fair; some freezeback
thyoides (L.) B.S.P.	Atlantic white-cedar	480	1931	25/12	2.9	5.0	.11	N	S	Poor; repeated freezeback
Cupressus (the cypresses):										
bakeri Jeps.	Modoc cypress	117	1925	18/17	22.7	33.0	.54	M	S	Good; 1 tree frost killed
"	"	242	1926	3/2	24.0	24.0	.42	M		Good; 1 tree frost killed
macnabiana A. Murr.	MacNab cypress	42	1913	2/1	15.0	15.0	.18	H		Fair; some needles yellowing gradually; being shaded out by neighboring pines
Juniperus (the junipers):										
chinensis L.	Chinese juniper	472	1931	20/17	5.8	12.0	.27	VL	S	Poor; repeated snowbreak
occidentalis Hook.	western juniper	269	(1/)	6/4	3.3	5.0	.07	N	M	Fair; snowbreak & twisted stems
"	"	279	(1/)	12/11	3.6	6.0	.09	N	M	Fair; snowbreak & twisted stems
"	"	598	1950	12/8	2.0	2.5	1.14	N	S	Fair
scopulorum Sarg.	Rocky Mountain juniper	228	(1/)	14/14	9/2	15.0	.22	L	M	Good; some snowbreak; best looking of all junipers in arboretum
virginiana L.	eastern redcedar	40	1912	13/1	7.0	7.0	.08	N	L	Fair to good; snowbreak
"	"	301	1925?	8/7	6.7	10.0	.17	N	L	Fair to good; snowbreak
"	"	317	1926?	3/3	6.3	7.0	.12	VL	L	Fair to good; snowbreak
"	"	481	?	6/6	8.0	11.0		N	L	Fair to good; snowbreak
Larix (the larches):										
decidua Mill.	European larch	183	1923?	3/2	56.5	58.0	.91	H	L	Excellent; some snowbreak, sapsucker injury
"	"	302	1925?	6/6	50.3	57.0	.96	H	L	Excellent; some snowbreak, sapsucker injury
"	"	308	1925	10/10	40.0	51.0	.86	H	L	Excellent; some snowbreak, sapsucker injury
decidua X leptolepis (X eurolepis Henry)	Dunkeld larch	422	1931	19/13	34.2	45.0	1.00	H	L	Excellent; some crooked trees
decidua var. polonica (Racib.) Ostenfeld & Syrach-Larsen	Polish larch	451	1932	20/18	30.6	46.0	1.18	M		Excellent; 7 of 17 snowbroken

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Larix (the larches)--Continued										
decidua var. polonica (Racib.) Ostenfeld & Syrach-Larsen	Polish larch	451A	1933	2/2	29.0	34.0	.87	H		Good; both snowbroken
gmelinii (Rupr.) Litvin.	Dahurian larch	459	1933	20/13	22.1	33.0	.84	H		Good; snowbreak, sapsucker injury, epicormic branches common
"	"	459A	1934	15/5	24.5	27.0	.75	N		Fair; some snowbend
gmelinii var. japonica (Reg.) Pilger	Kurile larch	112	1924	19/18	26.0	51.0	.83	H		Good; some snowbreak, sapsucker injury
"	"	265	1926	1/1	30.0	30.0	.52	H		Good; some snowbreak, sapsucker injury
gmelinii var. principis-rupprechtii (Mayr) Pilger	Prince Rupprecht larch	128	1925	6/2	27.5	28.0	.47	L		Fair; extreme snowbreak
"	"	241	1926	14/4	23.8	29.0	.51	L		Fair; extreme snowbreak
laricina (Du Roi) K. Koch	tamarack	184	1923?	1/1	25.0	25.0	.39	VL		Fair; spike top
"	"	530	1939?	13/13	12.9	18.0	.84	VL		Good; some snowbend
leptolepis (Sieb. & Zucc.) Gord.	Japanese larch	30	1913	10/6	33.3	41.0	.49	M	S	Fair; snowbend, heavy sapsucker injury
occidentalis Nutt.	western larch	192	1922	10/2	17.0	18.0	.27	N	S	Poor; severe snowbreak
"	"	229	(1/)	11/4	22.2	36.0		N	S	Poor; severe snowbreak
sibirica Ledeb.	Siberian larch	32	1913	12/7	49.5	66.0	.79	M		Good; severe snowbreak, sapsucker injury
Libocedrus (incense-cedar):										
decurrens Torr.	incense-cedar	36	1912	13/5	44.6	49.5	.58	N	S	Good; tendency to lean
"	"	318	1926	24/23	17.5	25.0	.44	N	L	Good
Picea (the spruces):										
abies (L.) Karst.	Norway spruce	26	1912	10/6	42.0	55.0	.64	M		Good; severe sapsucker injury
"	"	478A	1936	8/7	22.8	40.0	1.33	N	L	Excellent; 1 tree snowbroken
bicolor (Maxim.) Mayr	Alcock spruce	247	1926	11/4	4.6	7.0	.12	L	L	Poor; yellowish needles, snowbreak
breweriana S. Wats.	Brewer spruce	360	1925?	8/6	11.4	16.0	.27	L		Fair; crooked stems
"	"	469	1931	16/15	6.0	9.0	.20	N		Good; many double tops

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Picea (the spruces)--Continued										
engelmannii Parry	Engelmann spruce	25	1913	13/10	33.9	42.0	.50	H		Good; many spruce galls (Chermes cooleyi), sapsucker injury
"	"	405	1926	7/4	23.2	29.0	.51	H		Good; spruce gall (Chermes cooleyi) and sapsucker injury
glauca (Moench) Voss	white spruce	24	1914	15/13	33.7	40.0	.49	M	L	Good; many spruce galls (Chermes cooleyi)
glauca var. albertiana (S. Brown) Sarg.	western white spruce	495	1937	20/20	7.7	15.0	.55	L		Good; many spruce galls (Chermes cooleyi), 1 tree snowbent
jezoensis (Sieb. & Zucc.) Carr.	Yeddo spruce	470	1931	14/11	4.1	10.0	.56	N		Fair; snowbent
koyamai Shiras.	Koyama spruce	249	1926	20/16	9.8	19.0	.52	L		Fair; some snowbreak
mariana (Mill.) B.S.P.	black spruce	27	1913	4/1	26.5	26.5	.32	L		Fair
"	"	467	1931	20/16	12.1	20.0	.45	M		Fair; snowbreak and snowbend
"	"	532	--	7/6	4.7	7.0		N		Good
omorika (Pancic) Purkyne	Serbian spruce	474	1929	20/19	23.1	30.0	.60	L		Excellent
orientalis (L.) Link	Oriental spruce	266	1919	21/21	22.5	31.0	.43	M		Good; many double trunks
polita (Sieb. & Zucc.) Carr.	tigertail spruce	478	1928?	18/3	2.0	3.0	.06	N	L	Poor; repeatedly snowbroken
pungens Engelm.	blue spruce	28	1915	14/6	24.3	51.0	.64	N		Excellent
"	"	243	1920	12/4	15.5	23.0	.33	N		Good; 1 tree snowbroken
rubens Sarg.	red spruce	312	1928	5/4	7.5	10.0	.19	L		Good; some snowbreak
"	"	468	1931	19/15	10.0	18.0	.40	L		Good; some snowbreak
sitchensis (Bong.) Carr.	Sitka spruce	29	1913	10/5	29.6	45.0	.54	L		Fair; many spruce galls (Chermes cooleyi)
"	"	358	1927	18/12	24.8	36.0	.66	L		Good; many spruce galls (Chermes cooleyi)
smithiana (Wall.) Boiss.	Himalayan spruce	448A	1933	12/2	3.5	4.0	.10	N	L	Poor; repeated snow damage
"	"	523	--	20/1	1.0	1.0	.05	N		Poor; repeatedly snowbroken
Pinus (the pines):										
albicaulis Engelm.	whitebark pine	1	1917	10/5	27.0	40.0	.53	M		Fair, but all have blister rust
aristata Engelm.	bristlecone pine	2	1913	12/1	12.5	12.5	.15	N		Poor; snowbent
"	"	9	1912	7/6	4.2	5.9	.07	N		Fair; slow growth; heavy scale on needles
"	"	466	1931	20/12	4.2	7.0	.14	MF		Poor; severely snowbent
balfouriana Grev. & Balf.	foxtail pine	498	1938	28/27	2.6	4.0	.16	N		Good; 1 killed by blister rust

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Pinus (the pines)--Continued										
banksiana Lamb.	jack pine	8	1914	11/2	51.2	54.0	.66	H	L	Good; crooked boles, some branches girdled by animal gnawing
bungeana Zucc.	lacebark pine	209	?	9/1	1.5	1.5		N	S	Almost dead; repeatedly frozen back
"	"	296	1924	2/1	4.0	4.0	.06	N		Almost dead; repeatedly frozen back
contorta Dougl. var. contorta	shore pine	539	1947	20/20	6.5	8.5	1.67	N		Excellent
contorta var. latifolia Engelm.	lodgepole pine	6	1913	11/4	48.4	56.0	.67	H	S	Poor; diseased foliage, damaged by dry, east winds
"	"	604	1/ 1951	20/19	1.5	2.7	1.22	N		Good
densiflora Sieb. & Zucc.	Japanese red pine	130	1925	8/1	30.0	30.0	.50	H	L	Poor; considerable snowbreak
"	"	175	1925?	21/7	27.0	37.0	.58	H	L	Poor; considerable snowbreak
echinata Mill.	shortleaf pine	178	1923	18/2	24.5	26.0	.41	N	M	Fair; yellow foliage
"	"	270	(1/)	13/3	14.7	20.0		N	S	Poor; yellow foliage, snowbreak
echinata X rigida	hybrid pine	389	1929	9/8	22.1	27.0	.57	N	N	Good
engelmannii Carr.	Apache pine	16	1912	11/2	44.5	48.6	.57	N		Good; tendency to snowbreak
"	"	409	1930	30/14	18.5	30.0	.63	N		Poor; tendency to snowbreak
flexilis James	limber pine	299	1925	9/9	27.9	32.5	.55	L		Good; light blister rust, some snowbreak
"	"	407	1927	10/10	28.4	38.5	.70	L		Good; light blister rust, some snowbreak
flexilis James var. reflexa Engelm.	Mexican white pine	408	1930	42/38	27.0	39.0	.82	L		Good; many have blister rust, some crooked and forked
griffithii McClelland (?)	Himalayan pine	534	1945	1/1	11.0	11.0	1.10	N		Excellent; possible drought damage
heldreichii Christ var. leucodermis (Ant.) Markgraf	Bosnian pine	339	1928	18/18	7.0	12.0	.23	L		Fair; occasional snowbreak
jeffreyi Grev. & Balf.	Jeffrey pine	13	1912	11/9	43.5	54.0	.63	L	L	Fair; 1 tree damaged by frost
koraiensis Sieb. & Zucc.	Korean pine	131	1925	23/20	19.3	25.0	.42	N		Good; evidence of root rot
lambertiana Dougl.	sugar pine	14	1911	10/2	52.5	56.0	.64	N	M	Good; blister rust on all trees
"	"	230	1924	10/2	49.0	59.0	.96	N		Good; blister rust on all trees
massoniana Lamb.	Masson pine	392	1929	22/17	19.2	25.0	.42	H		Good; heavy snowbreak
monticola Dougl.	western white pine	17	1912	21/12	61.2	70.0	.82	L		Excellent, except for blister rust
mugo Turra	Swiss mountain pine	476	1929	20/20	22.8	26.0	.44	H		Good; many trees well formed, some multiple stems

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Pinus (the pines)--Continued										
mugo var. mugo	mugho Swiss mountain pine	282	1925?	3/3	16.0	18.0	.30	M		Excellent
"	"	352	1928	21/21	13.5	19.0	.36	H		Excellent; 1 tree snowbroken
mugo var. rostrata (Ant.) Hoopes	tree Swiss mountain pine	341	1928	20/20	18.2	24.0	.46	H		Excellent; shrubby form
nigra var. caramanica (Loud.) Rehd.	Crimean pine	180	1923?	15/11	46.8	58.0	.91	N		Excellent; some forked trees
nigra Arnold var. nigra	Austrian pine	4	1912	7/7	45.1	60.0	.71	M		Good; rapid taper, slight frost damage to foliage
"	"	4A	1914	5/3	56.7	60.0	.73	M		Good; some sapsucker injury
nigra Arnold var. poiretiana (Ant.) Schneid.	Corsican pine	15	1912	12/3	33.3	40.0	.47	N		Excellent; slight sapsucker injury
"	"	398	1929	21/20	27.7	36.0	.60	L		Good; some sapsucker injury
"	"	503	1936	20/19	20.1	26.0	.87	N		Fair; several trees dying, probably root rot
parviflora Sieb. & Zucc.	Japanese white pine	252	1926	22/18	18.1	27.0	.47	H		Fair; stem cankers, evidence of root rot, heavy sunscald
peuce Griseb.	Balkan pine	351	1928	3/3	23.3	24.0	.46	N		Excellent; good ornamental qualities
"	"	505	1936?	17/17	7.8	14.0	.47	N		Excellent
ponderosa Laws.	ponderosa pine	18	1912	18/15	57.8	76.0	.89	N	L	Excellent; 4 best trees are forked, probably from snow
ponderosa (hybrid)	ponderosa pine (hybrid)	599-603	1950	60/55	2.2	4.0	1.82	N		Excellent
ponderosa var. scopulorum Engelm.	ponderosa pine	330	1928	20/14	22.0	33.0	.63	H		Fair to excellent; some snowbreak, unidentified top disease
pungens Lamb.	Table-Mountain pine	177	1923?	18/11	24.5	39.0	.61	H		Good; some snowbreak, twisted stems, some yellow foliage
resinosa Ait.	red pine	19	1914	8/3	48.3	51.5	.63	MF		Excellent
"	"	111	1924	20/18	38.4	43.0	.70	MF		Excellent
rigida Mill.	pitch pine	20	1914	15/12	23.1	38.0	.46	VL		Good; badly snowbent
"	"	475	1929	15/11	13.2	21.0	.42	VL		Good; considerable snowbreak and snowbend
sabiniana Dougl.	Digger pine	274	1926	18/3	29.3	30.0	.52	N		Poor; snowbreak, needle blight
strobus L.	eastern white pine	21	1912	8/8	55.7	62.0	.73	M		Good, except for blister rust
sylvestris L.	Scotch pine	22	1912	14/6	36.5	39.0	.46	L		Fair; heavy sapsucker injury, acute branch angle

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Pinus (the pines)--Continued										
sylvestris L.	Scotch pine	179	1923?	18/12	40.1	49.0	.77	H		Good; some snowbreak, severe sapsucker injury
sylvestris var. mongolica Litw.	Scotch pine	361	1929	20/20	26.8	31.0	.62	H		Good; light sapsucker injury
tabulaeformis Carr.	Chinese pine	253	1926	18/13	21.0	32.0	.56	H		Fair; half show snowbreak or snowbend
"	"	264	1926	18/17	29.5	43.0	.75	H		Good; some snowbreak, sapsucker injury
tabulaeformis Carr.(?)	Chinese pine (?)	314	1928	20/1	14.0	14.0	.27	N		Fair; snowbreak and snowbend
thunbergii Parl.	Japanese black pine	132	1925	18/4	22.5	26.0	.44	N	S	Poor; crooked and snowbroken
virginiana Mill.	Virginia pine	176	1923?	16/2	18.5	20.0	.31	N	M	Poor; severe snowbreak
"	"	488	(1/)	20/2	18.0	22.0		N	S	Poor; severe snowbreak
Pseudotsuga (the Douglas-firs):										
macrocarpa (Vasey) Mayr	bigcone Douglas-fir	285	1927	24/1	5.0	5.0	.09	N	S	Poor; barely above fern
menziesii (Mirb.) Franco	Douglas-fir (Rocky Mountain form)	33	1914	20/2	23.0	27.0	.33	N		Poor; severe snowbreak, thin foliage, Rhabdocline infected
"	" (N. Mex., 9,000')	556	1948	14/11	2.81	4.5	.70	N		Good
"	" (Mont., 3,100')	557	1948	12/11	2.76	4.1	.64	N		Good
"	" (Idaho, 2,200')	558	1948	12/11	3.32	6.7	1.04	N		Good
"	" (Calif., Sierra N.F.)	586	1948	12/4	1.20	1.9	.30	N		Good
"	" (Wash., Olympic N.F.)	587	1948	11/11	3.85	6.2	.97	N		Good
"	" (Oreg., Siuslaw N.F.)	588	1948	7/6	2.80	3.7	.58	N		Good
"	" (Wash., Fidalgo Island)	589	1948	11/10	2.5	4.1	.64	N		Good
"	" (Mont., Flathead N.F.)	593	1948	12/11	1.95	3.3	.52	N		Good
"	" (Idaho, Nez Perce N.F.)	594	1948	12/11	1.50	2.0	.31	N		Good
"	" (Ariz., Tucson)	597	1948	10/10	1.26	1.9	.30	N		Good

See footnote at end of table.

Table 2.--Status of living conifer species, Wind River Arboretum (Continued)

Species		Lot number	Year sown	Number planted; number alive (1956)	Average height in 1956 (feet)	Tallest tree in 1956 (feet)	Growth index	Cone production	Frost damage in 1955	Condition
Scientific name	Common name									
Sequoia (the sequoias):										
gigantea (Lindl.) Decne.	giant sequoia	35	1912	14/9	70.1	76.0	.89	N		Excellent; leader dead in 1 tree, frost in 1955
"	"	461	1932	2/2	4.5	6.0	.13	N	S	Excellent; 1 previously cankered tree killed by frost, few others damaged
"	"	479	1928?	16/15	18.7	39.0	.75	N		Excellent
sempervirens (D. Don) Endl.	redwood	233	1926	21/5	4.5	5.5	.09	N	S	Poor; repeatedly frozen back
Taxus (the yews):										
baccata L.	English yew	421 & 432	1931	29/19	1.3	1.5	.03	N	S	Poor; repeated freezeback
brevifolia Nutt.	Pacific yew	357	(1/)	21/5	1.3	1.5	.02	N	S	Poor; repeated freezeback
Thuja (the thujas):										
occidentalis L.	northern white-cedar	182	1923?	20/5	9.2	17.0	.27	H	L	Good
plicata Donn	western redcedar	37	1912	10/9	46.5	58.0	.68	H	L	Excellent
"	"	497	(1/)	17/3	3.3	4.0	.09	N	S	Poor; repeated freezeback, browsed
Thujopsis (thujopsis):										
dolabrata (L.f.) Sieb. & Zucc.	Hiba arborvitae	256	1926	5/5	14.6	25.0	.44	L		Excellent; planted in lawn
Tsuga (the hemlocks):										
canadensis (L.) Carr.	eastern hemlock	181	1923?	18/12	19.7	26.0	.41	H		Good
caroliniana Engelm.	Carolina hemlock	506	1938	8/8	11.4	18.0	.74	N		Good; snowbreak
heterophylla (Raf.) Sarg.	western hemlock	353	(1/)	16/10	41.1	51.0	.83	H		Excellent
mertensiana (Bong.) Carr.	mountain hemlock	278 & 354	(1/)	19/13	20.7	26.0	.41	L		Excellent
sieboldii Carr.	Siebold hemlock	414	1931	12/4	5.2	8.0	.18	N	M	Fair

1/ Wild seedlings of unknown age.

Year sown. In the case of fall-sown seed, this is the year of germination. A question mark indicates that stock was of indeterminate age or grown elsewhere, and that the date of sowing is approximate.

Number planted; number alive (1956). Number planted does not include first-year replacements of trees that probably died from transplanting. Replacements were not made in many instances. The ratio of trees alive to trees planted is not a good measure of the suitability of a species since early lots were moved when the trees were too large for successful transplanting. Some other lots were also mechanically injured or killed by rodents.

Average height in 1956. Average height in feet of all living trees in each group at the end of the 1956 growing season.

Tallest tree in 1956. Height of tallest tree at the end of the 1956 growing season.

Growth index. Ratio of height of tallest tree in each lot to height of average dominant Douglas-firs on the same site at the same age (table 3).

Cone production. Noted as "N" for none, "L" for light, "M" for moderate, and "H" for heavy if cones have been produced. Where male flowers were being produced and no visible evidence of cones was present, the symbol "MF" was noted under "Cone production."

Frost damage in 1955. This column was included mainly to show the relative damage caused by the severe, early, regionwide freeze in November 1955. Following unusually mild weather, temperatures dropped rapidly to -1° F. and remained below 32° F. for 6 days (Duffield, 1956). Several lots were completely killed. In most cases, the injured species had previously shown susceptibility to damage by freezing, as noted in the "Condition" column. Damage is listed as light (L), medium (M), or severe (S).

Condition. Taken from field records to indicate the general condition of each group with regard to (1) vigor and (2) damage by insects, diseases, or other agencies.

Table 3.--Height-age relationships for dominant Douglas-firs native to the Wind River Arboretum[1/]

Age (years)	Height	Age (years)	Height
	Feet		Feet
1	0.2	24	42.0
2	0.4	25	44.8
3	0.6	26	47.4
4	1.0	27	49.8
5	1.6	28	52.3
6	2.2	29	54.8
7	2.8	30	57.3
8	3.9	31	59.5
9	5.1	32	61.6
10	6.4	33	63.5
11	8.2	34	65.7
12	10.0	35	67.8
13	11.9	36	69.8
14	14.4	37	71.9
15	16.7	38	74.0
16	19.0	39	75.9
17	21.5	40	77.8
18	24.3	41	80.0
19	27.2	42	81.9
20	30.0	43	83.7
21	33.0	44	85.4
22	36.0	45	87.2
23	39.1		

[1/] These height-age relationships were determined by averaging measurements from 11 dominant Douglas-firs, all volunteers within the arboretum.

Exact age of each tree was determined by boring to tree center at ground line. Heights at ages beyond 10 years were found by measuring to the appropriate whorl. Heights were averaged at 5-year intervals, and a smooth curve was drawn through these points. Data for the lower end of the curve, from 1 to 10 years, were determined from four saplings less than 12 years old.

THE PINES (PINUS)

Sixty-two species and varieties of pines have been tried at the Wind River Arboretum. Of this number, 38 are living and doing reasonably well, and 4 are living but doing very poorly.

Many pines have shown rapid initial growth, but none tested for more than 20 years have shown a growth rate equal to that of the native Douglas-fir. Many lots of white pines tested have shown excellent thrift and form but hold no eventual promise, because of susceptibility to white pine blister rust. The white pines have shown greater resistance than the hard pines to frost and snow damage and are not attacked by sapsuckers.

The white pines (P. monticola, P. lambertiana, and P. strobus) continue to grow very well and are of excellent form and vigor. However, they are rather heavily infected with blister rust.

P. peuce is in excellent condition though it is slow growing. The older group displays a very symmetrical pyramidal crown that reaches to the ground, and the younger group is beginning to assume the same form. This species would be a most attractive ornamental or windbreak tree.

The high-altitude white pines (P. aristata, P. flexilis, P. balfouriana, P. albicaulis, and P. flexilis var. reflexa) are doing reasonably well. They are typically slow growing, and most have suffered some snowbreak and snowbend.

P. griffithii, P. koraiensis, P. peuce, and P. aristata have shown immunity to blister rust. P. flexilis var. reflexa, P. balfouriana, P. flexilis, and P. strobus have shown some susceptibility; P. monticola is very susceptible; P. lambertiana is extremely susceptible; and P. albicaulis is the most susceptible of all the white pines in the arboretum. This substantiates the pattern of resistance to blister rust found by Childs and Bedwell (1948).

With the exception of the faster growing P. ponderosa and P. contorta, hard pines from both eastern and western United States do equally well in this climate. Those from the more southern latitudes have done poorly in general, and those from the Northeast and Northwest, including northern California, have done well.

P. ponderosa, P. banksiana, and P. resinosa continue to do relatively well and, along with the mugho pines, are the best of the hard pines. However, they are not doing well enough to recommend them for planting as timber species in this climate. The mugho pines are among the hardiest of all species in the arboretum. Though they are slow growing and cannot be recommended as a timber species, they do well as ornamentals and may prove acceptable for use in watershed work. Some young lots of P. contorta show excellent growth rates.

With few exceptions, none of the Asiatic or European pines have done well enough to recommend them for planting as timber trees in this climate. The mugho pines and P. peuce have been mentioned. P. griffithii, though doing quite well, is still fairly young and no accurate statement can be made as to its suitability to the Wind River site. Most European pines are susceptible to sapsucker damage, and some groups have suffered from snowbreak. The Asiatic pines are damaged by snow and suffer occasional frost damage.

Of the 23 species of pine that have failed or are doing poorly, 7 are native to the Orient, 12 are from eastern or western North America below the 42nd parallel, 3 are from maritime climates, and 1 is believed to be European. Cold temperature has caused death in almost every case where the cause of failure has been recorded. Some species had done relatively well for 30 to 40 years before being killed by severe low temperatures (fig. 5).

Figure 5.--Adequate tests of introduced species require many years. Coulter and knobcone pine were promising species but were completely killed by frost in November 1955, after growing well for 39 and 43 years, respectively. Dead trees of the knobcone pine group are shown at right.

THE LARCHES (LARIX)

As a group the larches are one of the most successful of all genera in the arboretum. Eleven species have been tried at Wind River and only one may be listed as a failure. With the exception of L. leptolepis and L. occidentalis, the larches are resistant to frost damage. However, since 1946 the larches have suffered considerable snowbreak. Because of this tendency and their susceptibility to sap-sucker damage, they are not regarded suitable for introduction into this climate.

During its first 30 years, Larix is the only genus of all those tried at Wind River that equals the native Douglas-fir in height growth. The growth comparison becomes less favorable after 30 years, however. The lowest growth index of all the groups of larch under 30 years of age is 0.75. On the other hand, 7 of the 11 groups older than 30 years have a growth index of 0.59 or less.

In general, the larches from Europe are now doing better than those from Asia. L. decidua and L. decidua X leptolepis, both from Europe, are presently the best of all the larches and L. decidua var. polonica, another larch from Europe, is also doing very well. Many of the larches from Japan and continental Asia were once leading all arboretum groups in growth rate, but almost all have now proved very susceptible to snowbreak (fig. 6). L. leptolepis has also been damaged by frost.

Figure 6.--Siberian larch, which once outgrew Douglas-fir, has recently shown susceptibility to snow breakage.

The tamarack, or eastern larch, L. laricina, has done fairly well and has not suffered as much snow damage as other larches.

Both groups of western larch, L. occidentalis, are doing poorly. They have been damaged by snow and frost and earlier records indicate that they had a serious needle blight for many years. It should be pointed out that the seed for both groups in the arboretum came from east of the Cascade Range, where climate is more continental and humidities are therefore lower. In contrast to the poor showing of western larch groups in the arboretum, the western larch found native to the Wind River valley is a tree of excellent vigor.

L. lyallii has been the only failure of all species of larches. Only one group has done well enough in the nursery to warrant planting in the arboretum, and this group died over a period of 10 years.

THE SPRUCES (PICEA)

Although not generally rapid growing, most species of spruce have succeeded at Wind River. Of 20 species tried in the arboretum, 16 are doing fairly well, 3 are doing very poorly and may be classed as failures, and 1 has failed.

Though few of the spruces have done poorly, only P. abies has done well enough to warrant further trials in forest planting. So far this species has displayed excellent growth and vigor, though it shows evidence of light frost damage. To date it has not been attacked by Chermes cooleyi.

None of the other spruces show a growth index greater than 0.66, and P. glauca, P. engelmannii, and P. sitchensis are attacked by Chermes cooleyi. P. engelmannii is also damaged by sapsuckers.

The Asiatic spruces have not done well, and all of the failures are from the continent of Asia or from Japan. P. likiangensis gradually died out. P. bicolor, P. smithiana, and P. polita are also dying out, and P. smithiana and P. polita were repeatedly broken by snow.

THE HEMLOCKS (TSUGA)

All the hemlock species except two are thriving: T. sieboldii has suffered from frost damage, and occasional trees of the T. caroliniana group have been broken by snow. The two native species,

T. heterophylla and T. mertensiana are the best of all the Tsuga species. T. mertensiana, though slow growing, is the handsomest and hardiest. T. canadensis is doing fairly well but is growing considerably slower than the native T. heterophylla.

To date no species of hemlock may be listed as a failure at Wind River.

THE DOUGLAS-FIRS (PSEUDOTSUGA)

Only two species, P. menziesii and P. macrocarpa, have been tested at Wind River. P. macrocarpa has only one survivor after the low temperatures in 1955. This 30-year-old group has been of poor vigor and repeatedly broken by snow. The Rocky Mountain group of P. menziesii at 43 years of age had only three survivors. This group has been very severely and repeatedly attacked by needle diseases (Rhabdocline sp.) (fig. 7). Seed lots of the Asiatic species of Pseudotsuga have either failed to germinate or died in the nursery.

Figure 7.--Strains of native species introduced from more continental climates have performed poorly at Wind River. Douglas-fir from a Rocky Mountain seed source was planted at the arboretum more than 40 years ago; today, most of the trees are dead from repeated attacks by needle diseases, and adjacent natural Douglas-firs of about the same age as the survivors reach far over them (left). Similar poor performance has been shown by introduced strains of ponderosa pine, western larch, and lodgepole pine.

Ten lots of Douglas-fir, sown in 1948, were added to the arboretum in 1952. These lots are from various locations throughout the West and will be used to demonstrate racial variation within the species. So far the only differences observed have been in height growth, as shown in table 2.

THE FIRS (ABIES)

In all, 28 species and subspecies of Abies have been tried at Wind River. Of these, 24 are living, but only 11 have done well. Eight are only fairly successful, and 5 have been found not suited to the Wind River site.

Balsam woolly aphid (Chermes piceae) has become a serious threat among the firs since the last remeasurement in 1946. There is conclusive evidence that it appeared before 1949 in Fraser fir (A. fraseri), for tops of the Fraser firs that died in 1949 are heavily gouted from Chermes attack. At that time, Chermes was not known to be a serious problem in the Northwest, and extreme frost was reported as the agent responsible for damage (Steele, 1954). Because of the heavily gouted condition of all dead tops, it is certain that Chermes had reached the arboretum before this date, and it is now doubtful that cold played any role in the damage reported. Climatological records show the native climate of this group of Fraser fir (Mount Mitchell, N. C.) to be more severe than that at Wind River, and no frost damage was observed after the 1955 freeze.

Because a large number of fir species and varieties are established in the arboretum, there has been a good opportunity to observe relative resistance to Chermes attack. Six species and varieties are attacked: A. lasiocarpa var. arizonica and A. pinsapo show light infestation; A. balsamea has moderate infestation; and A. fraseri, A. lasiocarpa, and A. alba are heavily infested. (A. alba, though heavily infested, shows no apparent damage.) The remaining groups, including A. grandis, show no Chermes infestation to date.

As might be expected, species native to the Northwest and northern California have proved most successful at Wind River. Of the 11 species that are doing well, 8 are native to the Northwest, 1 to the Northeast, 1 to the Southwest, and 1 to northern Japan. It should be noted that the species from northern Japan, A. sachalinensis, is the only fir from outside the United States that has done well at Wind River. Although A. sachalinensis grows more slowly than native Douglas-fir, only A. grandis and A. procera are more rapid growing among the Abies.

A. grandis is the most rapid growing of all the balsam firs in the arboretum. The native species A. procera, A. amabilis, A. lasiocarpa, and a variety of A. grandis are also growing well but

considerably slower than A. grandis. A. balsamea and A. lasiocarpa var. arizonica are doing well, but the recent attack by Chermes has reduced their vigor.

Perhaps the handsomest of all the firs are A. magnifica and A. magnifica var. shastensis.

The greatest single factor causing failure among the firs is repeated freezeback. Many Asiatic and European firs suffer almost annual freezeback because they burst their buds quite early and are damaged by late spring frost.

No species of balsam fir from south of 42° latitude has shown good growth at Wind River, and many are listed as failures.

THE CEDARS (CEDRUS)

Of three species of Cedrus, none has failed at Wind River. However, C. deodara is not doing well, and C. atlantica and C. libani, though fairly vigorous, are both slow growing.

THE SEQUOIAS (SEQUOIA)

S. sempervirens is doing very poorly and is definitely not suited to the Wind River site. It is frozen back repeatedly. S. gigantea is displaying an excellent growth rate and some cones have been produced. One volunteer S. gigantea has been observed in the arboretum. This species occasionally suffers minor frost damage.

INCENSE-CEDAR (LIBOCEDRUS)

Two groups of Libocedrus have been tried at Wind River. Though some individuals of L. decurrens have been seriously damaged by frost, most trees of the species are doing very well.

L. formosana is the only incense-cedar that may be called a failure. It was killed by frost in the nursery.

THUJOPSIS (THUJOPSIS)

Only a single representative of this genus, T. dolabrata, has been included in the arboretum. Specimens of this species are growing well on a watered lawn near the headquarters building.

THE THUJAS (THUJA)

Six species of Thuja have been tried at Wind River, two of which failed to germinate. Of the four that did germinate, two are now living. The native T. plicata is doing very well, though one group has suffered freezeback. T. occidentalis has suffered light frost damage but is doing well.

Both T. standishii and T. orientalis were killed by frost in the arboretum.

THE WHITE-CEDARS (CHAMAECYPARIS)

C. lawsoniana and C. nootkatensis are the only species doing well. Both show occasional but not serious frost damage.

Other Chamaecyparis species are doing poorly. C. obtusa and C. pisifera were killed by repeated frost and winter damage. C. thyoides is frozen back repeatedly and, though living, is not suited to the Wind River site.

THE CYPRESSES (CUPRESSUS)

Of the eight species and subspecies of Cupressus tried, only C. macnabiana and C. bakeri are living. Some individuals have been damaged by frost, but all groups are doing very well.

Of the six Cupressus species that failed at Wind River, five were killed by frost or winter damage (table 6) and one died out in the Wind River nursery from unknown causes.

THE JUNIPERS (JUNIPERUS)

J. scopulorum has survived best of all the junipers, but it does not display good vigor. All the junipers show a tendency to snow and frost damage.

Four junipers have failed at Wind River, three as a result of frost damage. One lot died out in the arboretum over a period of 10 years.

THE YEWS (TAXUS)

None of the yews have been successful at Wind River. Attempts to establish T. brevifolia and T. baccata have failed because both species are heavily browsed by deer.

THE ARAUCARIAS (ARAUCARIA)

The two specimens of A. araucana are doing well after having been repeatedly frozen back for more than 30 years. The trees showed no damage from the severe early frosts of November 1955.

PERFORMANCE OF BROAD-LEAVED TREES

As mentioned earlier, no attempt has been made to establish hardwoods in the arboretum since 1928.

Major eastern hardwood species have done very poorly; only Quercus rubra and Tilia americana approach the size and form attained in their native habitat (table 4).

Of the maples, only Acer platanoides (Norway maple) has done well. Though it grows slowly, the single specimen of this species has developed fairly well and is an attractive tree. Both Acer macrophyllum var. kimballiae and Acer saccharum continue to do poorly.

The American chestnut, Castanea dentata, is the only species of the genus still surviving in the arboretum. The five living trees appear to have good vigor despite relatively slow growth; and some trees bore a heavy crop of chestnuts.

Golden chinkapin, Castanopsis chrysophylla, is the best hardwood group in the arboretum (fig. 8). The trees are tall and straight, of excellent vigor, and regularly bear fruit. These have produced a large number of natural seedlings throughout the arboretum.

All the Fraxinus species have done poorly, though the trees continue to survive. Green ash, F. pennsylvanica, has suffered from snowbreak.

Of the poplars, Populus X berolinensis is in fair condition and Populus X petrowskyana has been frozen back repeatedly.

Table 4.--Status of living broad-leaved species, Wind River Arboretum

Species		Lot number	Year sown	Number planted; number alive (1956)	Height in 1956 (feet)
Scientific name	Common name				
Acer platanoides L.	Norway maple[1/]	95	1913	8?/1	37.5
Castanea dentata (Marsh.) Borkh.	American chestnut	191	1924	6?/5	24.8
Castanopsis chrysophylla (Dougl.) A. DC.	golden chinkapin	54	1913	14/10	45.2
Fraxinus americana L.	white ash	72	1912	16/7	8.3
" latifolia Benth.	Oregon ash	74	1913	16/14	9.6
" pennsylvanica Marsh.	green ash	75	1912	15?/4	13.2
Liriodendron tulipifera L.	yellow-poplar	63	1911	17?/13	19.1
Lithocarpus densiflorus (Hook. & Arn.) Rehd.	tanoak	120	1925	9/2	2.5
Populus X berolinensis Dipp.	Berlin poplar	49	[2/]1916	3?/1	25.0
" X petrowskyana (Reg.) Schneid.	Petrowsky poplar	273	1926	18/13	3.1
Prunus serotina Ehrh.	black cherry	64	1913	15/11	1.5
" sp.[3/]	Patagonian cherry	283	[2/]1927	11/2	3.5
Quercus alba L.	white oak	188	1923	16/4	6.5
" chrysolepis Liebm.	canyon live oak	119	1925	12/8	6.0
" garryana Dougl.	Oregon white oak	55	1913	7/4	20.2
" kelloggii Newb.	California black oak	121	1925	16/7	20.7
" prinus L.	chestnut oak	187	1923?	14/7	14.0
" rubra L.	northern red oak	57	1912	16?/13	35.6
" velutina Lam.	black oak	56	1914	11/3	15.7
Rhamnus purshiana DC.	cascara buckthorn	239	1925	18/13	5.1
Tilia americana L.	American basswood	70	1912	6/4	28.2
Ulmus americana L.	American elm	62	1912	13/6	13.0

[1/] Planted on watered lawn.

[2/] Cuttings or plants set that year.

[3/] Identified by common name only.

Figure 8.--Broad-leaved species in general failed so consistently that the arboretum was devoted exclusively to conifers after 1928. The most successful broad-leaved group has been chinkapin, a native of southern Oregon, which attained a height of 45 feet in 43 years. Douglas-fir would be expected to grow 84 feet in the same length of time.

Tulip poplar, Liriodendron tulipifera, has grown very poorly at Wind River in comparison with growth in its native environment.

Northern red oak, Quercus rubra, is growing well, but all other surviving oaks are doing poorly.

Apparently the broad-leaved species have been very adversely affected by the hot, dry summers and porous soil. In earlier reports, the almost universal failure of these trees was attributed to the long, rainless period during July and August; low humidity; and porous, gravelly soil. Many species that failed in the arboretum have done well on watered lawns. Very little evidence of freezeback has been noted, even following the cold winter of 1949-50 and the early freeze of November 1955.

CONIFERS FOUND UNSUITED TO THE WIND RIVER SITE

Of 165 coniferous species tested at Wind River, 42 have died and another 17--although living--are obviously unsuited to the habitat (table 5). Some of these unsuccessful species were tried several times.

Cause of failure, though recorded, is difficult to evaluate; most lots died between examination dates, leaving questionable causal evidence. Winterkilling was listed for 29 percent of the lots, whereas a combination of causes was recorded for 57 percent--including winter damage, competition, drought, and disease. Often, several different causes were listed for individuals within the same lot. Fourteen percent had no cause of death listed.

Diseases or insects, though important killers of individual trees, have not yet been listed as causing the failure of any species. Although white pine blister rust has been present in the arboretum for several decades, it has not completely wiped out any white pine lot, even though all trees in some lots are infected. Likewise, the recent balsam woolly aphid attack on Abies has not completely killed any single species. In such outbreaks the arboretum has served to test the relative susceptibility of the species within a genus.

A number of species continue to live year after year, even though they are repeatedly damaged by frost, snow, or some other agency. These species also are considered unsuited to the Wind River site.

Table 5.--Conifers unsuited to Wind River

Species	Range	Seed source[1/]	Reason for unsuitability	Age at death
				Years
Dead:				
Abies firma Sieb. & Zucc.	Japan	Japan	Repeated winter damage	20
Abies veitchii Lindl.	Japan	Japan	Repeated winter damage	20
Abies bracteata D. Don	Calif.	S.Calif.	Repeated frost damage	?
Chamaecyparis obtusa (Sieb. & Zucc.) Endl.	Japan	Orient	Repeated winter damage	17
Chamaecyparis pisifera (Sieb. & Zucc.) Endl.	Japan	Orient	Frost killed and winter killed	30
Cephalotaxus harringtonia var. drupacea (Sieb. & Zucc.) Koidzumi	Japan	Austria	Frost killed	18
Cryptomeria japonica (L.f.) D. Don	Japan	Japan	Died gradually	15
Cupressus arizonica Greene	SW. U.S.	Arizona	Frost killed	18
Cupressus goveniana Gord.	Calif.	S.Calif.	Frost killed	18
Cupressus lusitanica Mill.	Mexico	Mexico	Stock died in nursery (see 1947 publication)	3
Cupressus macrocarpa Hartw.	SW. U.S.	S.Calif.	Winter damage	20
Cupressus sempervirens L.	S.Eur.,W.As.	Medit.	Winter killed	4
Cupressus duclouxiana Hickel	Himalayas	Austria	Winter killed	2
Ginkgo biloba L.	E. China	Japan	Repeatedly killed back	8
Juniperus ashei Buchholz	E.U.S.,Mex.	Not given	Frost killed	17
Juniperus excelsa Bieb.	Medit.	Austria	Frost killed	19
Juniperus monosperma (Engelm.) Sarg.	SW. U.S.	SW. U.S.	Died gradually	21

See footnote at end of table.

Table 5.--Conifers unsuited to Wind River (Continued)

Species	Range	Seed source[1/]	Reason for unsuitability	Age at death
				Years
Dead--Continued				
Juniperus semiglobosa	As. Min.	Russia	Frost killed	19
Larix lyallii Parl.	Pac. NW.	E. Wash.	Died in nursery and arboretum	13
Libocedrus formosana Florin.	Formosa	Japan	Frost killed	2
Picea likiangensis (Franch.) Pritz.	W. China	China	Died out in arboretum; probably frost	30
Pinus armandi Franch.	Cen.,W.China	China	Repeated freezeback	31
Pinus attenuata Lemm.	W. U.S.	Calif.	Frost killed	43
Pinus canariensis C. Smith	Canary I.	Canary I.	Winter killed, nursery	
Pinus elliottii Engelm.	SE. U.S.	SE. U.S.	Winter killed, nursery	4
Pinus coulteri D. Don	Mex.,Calif.	S. Calif.	Frost killed	39
Pinus edulis Engelm.	SW. U.S.	SW. U.S.	Frost and winter killed	20
Pinus gerardiana Wall.	Himalayas	India	Did poorly for several years; killed by rust disease	34
Pinus halepensis Mill.	Medit.	S.Cen.Eur.	Died out in nursery & arboretum	8
Pinus khasya Royle	N. Burma	India	Winter killed, nursery	1
Pinus leiophylla Schlech. & Cham.	SW. U.S., Mex.	Mexico?	Winter killed, nursery	5
Pinus roxburghii Sarg.	Himalayas	Himalayas	Winter killed, nursery	3
Pinus montezumae Lamb.	Mexico	Mexico	Winter killed, nursery	6
Pinus palustris Mill.	SE. U.S.	SE. U.S.	Winter killed, nursery	5
Pinus patula Schlech. & Cham.	Mexico	Mexico	Killed in nursery	5

See footnote at end of table.

Table 5.--Conifers unsuited to Wind River (Continued)

Species	Range	Seed source[1/]	Reason for unsuitability	Age at death
				Years
Dead--Continued				
Pinus pinaster Ait.	Medit.	Holland	Frost killed	27
Pinus radiata D. Don	Calif.	S. Calif.	Winter killed	12
Pinus taeda L.	SE. U.S.	SE. U.S.	Gradually died off; finally killed by frost	43
Pinus torreyana Parry	Calif.	S. Calif.	Winter killed, nursery	5
Taxodium distichum (L.) Rich.	S. U.S.	Louisiana	Died after few years	10
Thuja standishii (Gord.) Carr.	Japan	Japan	1 small lot failed after 5 years in arboretum	13
Thuja orientalis L.	N.,W.China	Japan	Frost and winter killed	20
Living, but in poor condition:				
Abies bracteata D. Don	Calif.	S. Calif.	Repeatedly frozen	--
Abies fabri (Mast.) Craib	W. China	China	Repeatedly frozen	--
Abies holophylla Maxim.	Manch.,Kor.	Japan	Repeatedly frozen	--
Abies sibirica Ledeb.	U.S.S.R.	Not given	Repeatedly frozen	--
Chamaecyparis thyoides (L.) B.S.P.	E. U.S.	N. J.	Repeatedly frozen	--
Picea bicolor (Maxim.) Mayr	Japan	Japan	Gradually dying off	--
Picea polita (Sieb. & Zucc.) Carr.	Japan	Japan	Repeatedly snowbroken	--
Picea smithiana Boiss.	Himalayas	India	Repeatedly snowbroken	--

See footnote at end of table.

Table 5.--Conifers unsuited to Wind River (Continued)

Species	Range	Seed source[1/]	Reason for unsuitability	Age at death
				Years
Living, but in poor condition--Continued				
Pinus bungeana Zucc.	NW. China	China	Repeatedly frozen back (2 alive but very poor)	--
Pinus densiflora Sieb. & Zucc.	Japan	Japan	Gradually dying off (snow-break; frost) 8 of 29 left in 2 lots	--
Pinus griffithii McClelland (?)	Himalayas	Himalayas	Frost--1 of 2 lots killed	--
Pinus sabiniana Dougl.	Calif.	N. Calif.	Frost	--
Pinus thunbergii Parl.	Japan	Japan	Frost; gradually dying off	--
Pinus virginiana Mill.	E. U.S.	N.C.	Frost; gradually dying off	--
Pseudotsuga macrocarpa (Vasey) Mayr	Calif.	S. Calif.	Gradually dying off (1 survivor)	--
Sequoia sempervirens (D. Don) Endl.	Calif.	S. Calif.	Repeatedly frozen	--
Taxus baccata L.	Euras., N. Af.	Austria	Repeatedly frozen	--

1/ Seed source as recorded in file record. Where source is outside species range, the seed may have come from arboreta, or may simply be the address of the collector.

GENERAL COMMENTS ON PERFORMANCE

Although tests of introduced trees at Wind River Arboretum are not statistically designed, it would be a disservice not to discuss those observations that seem to throw light on performance of introduced species in the Pacific Northwest. The Wind River area, being low site III, and at an elevation of 1,150 feet, certainly provides a conservative test of adaptability for plantings on forest land over much of the Pacific Northwest region. The risk of planting a species that does poorly at Wind River would be considerable, even in milder parts of the region.

With few exceptions, introduced trees have not attained growth rates equal to that of Douglas-fir native to the area. In this latest remeasurement, the average height of Douglas-fir dominants in the arboretum was determined for each year up to 45 years of age (table 3). These heights closely follow the curve for Douglas-fir site index 130. A growth index--the expression of performance of each lot--was provided by dividing the height of the tallest individual by the average height of Douglas-fir dominants of the same age. At first, this method for deriving the growth index seems overly favorable to the introduced tree. However, the tallest tree in a lot is probably a better expression than the average height in indicating how a species might perform if seed source were carefully selected to match the climate at Wind River. Even with such a favorable comparison, the growth index of almost all introduced trees falls below 1.00; hence it serves to focus attention on how few of the 215 living groups have possibilities for introduction as timber trees.

Practically all species that have grown at faster rates than Douglas-fir did so during early life and were eventually overtaken--mostly before reaching 20 years of age. This is particularly true of the pines. Several larches have continued to grow at high rates, but have been broken by snow. Even when comparisons are made within genera, instead of with native Douglas-fir, the Northwest representatives have usually shown the best growth rate.

Some introduced species seem to have promise, however. Better adapted strains of Sequoia gigantea, Picea excelsa, and several larches should be tested more exhaustively, for example, since the arboretum lots have shown good sustained performance.

Mention should also be made of patterns associated with growth and mortality. One of these patterns is the generally poor growth or

outright failure of introduced species and subspecies from the southern and southeastern United States, Mexico, southern Asia, China, Japan, and the southern hemisphere. Best performers in each genera have been native to the west slope of the Cascade Range and Sierra Nevada. Conifers from the northeastern United States have done fairly well, and those from western Europe have generally survived. This pattern is shown, species by species, for various climatic regions of the world (Heintzelman and Highsmith, 1955) in table 6. As shown in this table, the comparisons with height growth of native Douglas-fir (growth index) are fairly consistent by groups of species in each climatic region. In interpreting the table, however, the reader should recognize that the data used for evaluating any one species were very limited and that the classification is not a rigorous one.

The similar performance at Wind River of whole groups of species from climatic regions of the world supports the view long held by plant geographers (Gray, 1878; Gray and Hooker, 1881, p. 41) that climatic requirements of plant communities are highly restricted and probably have not changed much over millions of years.

Many tree species introduced at Wind River, now native to the Orient and southeastern United States, existed abundantly in the flora of the Pacific Northwest in the Miocene epoch (Beck, 1945; Chaney, 1948) but failed to survive as the climate became cooler and subject to more summer droughtiness. Their general unsuitability following reintroduction supports the idea of an inherently narrow ecological amplitude; these species have failed to develop a tolerance for the present climate of the Pacific Northwest, even after millions of years. This emphasizes the difficulty of finding species or strains from the Orient or southeastern United States that are adapted to Northwest conditions.

Another interesting pattern has been the poor performance of species native to the Northwest, but having origins from seed collected east of the Cascades. Growth rates are excellent for Douglas-fir, western larch, lodgepole pine, and ponderosa pine that are native to the Wind River valley, but strains of these species from areas having a more continental climate than at Wind River have usually done poorly at the arboretum. Likewise, better growth of trees from seed sources west of the Cascades is already apparent in the 10 lots of Douglas-fir sown in 1948 from various seed sources over its great range. Native needle diseases have undoubtedly played a major role in the poor performance of the Rocky Mountain form of Douglas-fir. Arboretum lots

Table 6.--Performance of species by climatic regions of the world

Species	Range	Seed source	Performance	Growth index
Dry-summer subtropics:				
Abies bracteata D. Don	Calif.	S. Calif.	Repeated frost damage	--
Cupressus goveniana Gord.	Calif.	S. Calif.	Frost killed	--
Cupressus lusitanica Miller	Mexico	Mexico	Died in nursery	--
Cupressus sempervirens L.	S.Eur.,N.As.	Palestine	Winter killed	--
Picea smithiana (Wall.) Boissier	Himalayas	Turkey	Repeated snow damage	--
Pinus coulteri D. Don	Calif.	S. Calif.	Frost killed	--
Pinus halepensis Mill.	Medit.	Italy and France	Died out in nursery & arboretum	--
Pinus muricata D. Don	Calif.	S. Calif.	Died in arboretum	--
Pinus radiata D. Don	Calif.	S. Calif.	Frost killed	--
Pinus torreyana Parry	Calif.	S. Calif.	Frost killed in nursery	--
Humid subtropics:				
Abies firma Sieb. & Zucc.	Japan	Japan	Repeated winter damage	--
Abies holophylla Maxim.	Manch.,Kor.	Japan	Repeatedly frozen back	.10
Abies sachalinensis Mast.	Japan	Japan	Good; light frost; crooked stems	.66
Araucaria araucana (Molina) K. Koch	Chile	Argentina	Repeatedly killed back; now good	.09
Chamaecyparis obtusa (Sieb. & Zucc.) Endl.	Japan	Japan	Repeated winter damage	.31
Larix gmelini var. principis-rupprechtii (Mayr) Pilger	E. Asia	Japan	Fair; extreme snowbreak	.47
Picea bicolor (Maxim.) Mayr	Japan	Japan	Poor; repeatedly snowbroken	.12
Picea polita (Sieb. & Zucc.) Carr.	Japan	India	Poor; snowbroken	.06
Pinus echinata Mill.	E. U.S.	N.C.	Suffers frost damage; poor to fair	.41

Table 6.--Performance of species by climatic regions of the world (Continued)

Species	Range	Seed source	Performance	Growth index
Humid subtropics--Continued				
Pinus elliottii Engelm.	SE. U.S.	Louisiana	Winter killed in nursery	--
Pinus koraiensis Sieb. & Zucc.	Jap.,Kor.	Japan	Good; evidence of root rot	.42
Pinus palustris Mill.	SE. U.S.	N.C.	Winter killed in nursery	--
Pinus rigida Mill.	E.,N.Amer.	Georgia	Good; badly snowbent	.46
Pinus rigida var. serotina (Michx.) Loud.	SE. U.S.	Florida	Died in nursery	--
Pinus taeda L.	SE. U.S.	Louisiana	Gradually died off; finally frost killed	--
Pinus thunbergii Parl.	Japan	Japan	Frost; gradually dying off	--
Pinus virginiana Mill.	E. U.S.	N.C.	Frost; gradually dying off	--
Sciadopitys verticillata (Thumb.) Sieb. & Zucc.	Japan	Japan	Died in nursery	--
Taxodium distichum (L.) Rich.	S. U.S.	Louisiana	Died after few years in arboretum	--
Thuja orientalis L.	N.,W.China	Japan	Frost and winter killed	--
Dry continentals:				
Cupressus arizonica Greene	SW. U.S.	Arizona	Frost killed	--
Juniperus monosperma (Engelm.) Sarg.	SW. U.S.	N. Mex.	Died off gradually	--
Juniperus occidentalis Hook.	W. U.S.	E. Oregon	Fair; snowbreak, twisted stems, extremely slow growth	.09
Juniperus scopulorum Sarg.	W. N.Amer.	E. Oregon	Good; some snowbreak, slow growing	.22
Juniperus semiglobosa Regel	As.Minor	U.S.S.R.	Frost killed	--
Pinus aristata Engelm.	W. U.S.	Arizona	Poor; snowbent	.14

Table 6.--Performance of species by climatic regions of the world (Continued)

Species	Range	Seed source	Performance	Growth index
Dry continentals--Continued				
Pinus contorta var. latifolia S. Wats.	W. N.Amer.	Montana	Poor; diseased, foliage damaged by east wind	.67
Pinus edulis Engelm.	SW. U.S.	N. Mex.	Frost and winter killed	--
Pinus engelmannii Carr.	SW. U.S.	Arizona	Good; tendency to snowbreak	.63
Pinus flexilis James	Mexico	N. Mex.	Good; blister rust; some crooked and forked	.82
Pinus leiophylla Schiede & Deppe ex. Schlech. & Cham.	SW. U.S., Mex.	Mexico	Winter killed in nursery	--
Pinus montezumae Lamb.	Mexico	Mexico	Winter killed in nursery	--
Pinus patula Schlech. & Cham.	Mexico	Mexico	Killed in nursery	--
Pinus ponderosa Laws.	W. U.S.	E. Wash.	Excellent; 4 best trees forked	.89
Pinus ponderosa Laws.	W. U.S.	Arizona	Fair to excellent; unidentified top disease, snowbreak	.63
Long-summer humid continentals:				
Chamaecyparis thyoides (L.) B.S.P.	E. U.S.	N. J.	Poor; repeated freezeback; very slow growth	.11
Juniperus virginiana L.	E. N.Amer.	Virginia	Fair to good; snowbreak; light frost; extremely slow growing	.17
Pinus echinata X rigida		Penn.	Good; fair growth	.57
Pinus nigra var. poiretiana (Ant.) Schneider	Medit.	Yugoslav.	Good; fair growth; sapsucker injury	.60
Pinus rigida Mill.	E. N.Amer.	N. J.	Good; snowbreak and snowbend	.42

Table 6.--Performance of species by climatic regions of the world (Continued)

Species	Range	Seed source	Performance	Growth index
Short-summer humid continentals:				
Larix gmelinii var. japonica (Reg.) Pilger	NE. As.	Kurile I.	Good; some snowbreak, sapsucker damage	.83
Larix laricina (Du Roi) K. Koch	Can.,N. U.S.		Good; some snowbend	.84
Picea glauca (Moench) Voss	Can.,N. U.S.	N. Minn.	Good; many galls	.49
Pinus banksiana Lamb.	Can.,N. U.S.	Minn.	Good; crooked boles	.66
Pinus strobus L.	NE. U.S.	Minn.	Good except for blister rust	.73
Pinus sylvestris L.	Eur.,NW.As.	Manchuria	Good; light sapsucker damage	.62
Pinus tabulaeformis Carr.	China, Kor.	Korea	Good; some snowbreak, sapsucker injury	.75
Thuja occidentalis L.	NE.U.S.,Can.		Good; slow growth	.68
Marine west coasts:				
Abies nordmanniana (Steven) Spach.	As.Minor	France	Died in arboretum	--
Cupressus macrocarpa Hartw.	SW. U.S.	Oregon	Winter killed	--
Cupressus duclouxiana Hickel	Himalaya	Austria	Frost killed in nursery	--
Larix eurolepis Henry	(hybrid)	England	Excellent; some crooked trees	1.00
Picea abies (L.) Karst.	N.Cen.Eur.	Prussia, Germany	Excellent; 1 tree snowbroken	1.33
Picea sitchensis (Bong.) Carr.	NW. U.S., Can.	Wash. and Oreg.	Fair to good; many spruce galls	.66
Pinus pinaster Ait.	Medit.	Holland	Frost killed	--
Sequoia sempervirens (D. Don) Endl.	Calif., Oreg.	Calif.	Repeatedly frozen back; very poor	.09

Table 6.--Performance of species by climatic regions of the world (Continued)

Species	Range	Seed source	Performance	Growth index
Middle-latitude highlands:				
High elevations--Europe and Asia:				
Abies alba Mill.	Europe	Switzerland	Fair	.40
Picea likiangensis (Franch.) Pritz.	N. China	China	Frost killed	--
Pinus mugo Turra.	Cen.& S.Eur.	Switzerland	Excellent	.36
High elevations--western America:				
Abies amabilis (Dougl.) Forbes	Pac. NW.	Wash.	Good; slow growth	.41
Abies lasiocarpa (Hook.) Nutt.	Pac. NW.	Wash.	Fair	.43
Abies magnifica A. Murr.	Calif.,Oreg.	Calif.	Excellent	.44
Abies magnifica var. shastensis Lemm.	Calif.,Oreg.	Oregon	Good	.40
Abies procera Rehd.	Oreg.,Wash.	Wash.	Good	.70
Cupressus macnabiana A. Murr.	Calif.	SW. Oreg.	Good; severe frost injury	.18
Larix lyallii Parl.	Pac. NW.	Wash.	Died out in arboretum	--
Larix occidentalis Nutt.	Pac. NW.	E. Wash.	Poor; severe snowbreak	.27
Picea engelmannii Parry	Pac. NW.	N. Idaho	Good; many galls, sapsucker injury	.51
Picea pungens Engelm.	W. U.S.	Utah	Excellent	.61
Pinus albicaulis Engelm.	W. N.Amer.	E. Oreg.	Fair; all have blister rust	.53
Pinus balfouriana Grev. & Balf.	Calif.	Calif.	Good; one killed by blister rust	.16

Table 6.--Performance of species by climatic regions of the world (Continued)

Species	Range	Seed source	Performance	Growth index
Middle-latitude highlands--Continued				
High elevations--western America--Continued				
Pinus flexilis James	SW. U.S.	Montana	Good; some snowbreak and blister rust	.70
Tsuga mertensiana (Bong.) Carr.	Pac. NW.	Wash.	Excellent	.41
Middle elevations west of Cascade Range and Sierra Nevada:				
Abies grandis (Dougl.) Lindl.	Pac. NW.	Wash.	Excellent	.81
Pinus jeffreyi Grev. & Balf.	Calif., Oreg.	Calif.	Fair; 1 tree damaged	.63
Pinus lambertiana Dougl.	NW. U.S.	Calif.	Excellent; 1 tree damaged by frost	.96
Sequoia gigantea (Lindl.) Decne.	Calif.	Calif.	Excellent	.89
Taxus brevifolia Nutt.	Pac. NW.	Wash.	Poor; repeated deer damage	.02
Thuja plicata Donn.	Pac. NW.	Wash.	Excellent	.68
Tsuga heterophylla (Raf.) Sarg.	Pac. NW.	Wash.	Excellent	.83

of western larch, ponderosa pine, and lodgepole pine have also suffered from disease as well as breakage from heavy, wet snows.

As previously mentioned, the known causes of mortality have been mostly climatic extremes--cold, heavy snows, and drought. Many species survived severe winters for 20 to 40 years until finally killed by some more extreme weather condition than previously encountered. Within the last 10 years, several lots--notably those of knobcone, cluster, and Coulter pine--were killed after growing well

Figure 9.--The major conclusion from testing introduced trees over a 44-year period is that native trees seem to be superior in both growth and vigor. At left, the bordering natural Douglas-fir stand towers above all lots in the arboretum. The area was logged about 1909, hence the Douglas-fir stand is about the same age as the oldest plantings.

in the Wind River climate for 41 years. Thus, the value of the arboretum as a test of adaptability increases with time.

The major conclusion from the arboretum testing is that no species has been found that seems presently suitable for introduction as a timber tree in the Pacific Northwest (fig. 9). Perhaps more careful choice of races better adapted to the Northwest climate will change the picture eventually.

Obviously, growth rate and mortality are only two of many criteria by which the performance of lots might be judged. The usefulness of some trees for watershed and ornamental plantings has been mentioned.

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