IMPROVED STRAINS OF DOUGLAS-FIR FOR THE NORTHEASTERN UNITED STATES

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ABSTRACT.--Provenances from the interior range of Douglas-fir were tested in Kalamazoo, Cass, and Osceola Counties, Michigan. Mortality, height growth, foliage color, spring frost damage, time of leafing out, and foliar moisture contents and drying rates were evaluated. Trees from Arizona and New Mexico (ARINEM race) grew fastest followed by trees from northern Idaho and northwestern Montana (INEMP). On good sites these provenances produced merchantable Christmas trees in 7-8 years. Trees from central Montana (CMON) and northern Colorado (NOROC) grew half as fast. NOCOL and SOCOL races suffered severe frost injury while ARINEM was moderately to heavily damaged. In contrast northern races (NOROC and INEMP) suffered relatively little damage. From the leafing-out data it was clear the correlation between leafing out and injury was significant. NOROC and INEMP races leaf out 2-3 weeks after the southern races and avoid frost damage. Also tall trees suffered relatively little damage. The Arizona provenance had the greatest foliar moisture content as well as the slowest rate of drying; and the ARINEM race was characterized by having the bluest needles of the material tested. Recommends ARINEM for Christmas trees where frost is no problem; where frost may occur provenances from northern Idaho may give better results. Using mixtures of the two races would reduce risk.

INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is one of the most widely distributed conifers in western United States and has great planting potential. It occurs naturally from Canada to Mexico and from the Pacific Cost to the eastern slopes of the Rocky Mountains. It has been successfully planted as an ornamental, Christmas tree or timber tree in many other parts of the United States.

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In the Pacific Northwest, Douglas-fir is recognized as one of the largest and most important timber trees. It towers up to heights as great as 300 ft and may reach 15 ft in diameter. In the northeastern United States it is planted mainly as an ornamental and Christmas tree. In Michigan over the past 25 years it has consistently commanded the highest prices in retail Christmas tree yards.

In most Christmas tree plantations established in Michigan in the early 1950's, the planting stock was grown from seed collected in northern Colorado and central Montana. Growth was so slow that 15 to 20 years were required for harvest. Early provenance tests in eastern United States (Baldwin and Murphy 1956; Gerhold 1966) showed that West Coast origins were not reliably hardy but that there was enough genetic variability with Rocky Mountain Douglas-fir to make possible appreciable improvement in planting stock for Michigan conditions.

This paper reports the results of a seed source experiment designed to result in dramatic increases in productivity of Douglas-fir planted in Michigan.

MATERIALS AND METHODS

In 1961 seeds were obtained from 129 natural stands of Douglas-fir (fig. 1) (Wright et al. 1971). The parental stands represented nearly the entire natural range of the species. The seeds were sown in an experimental nursery in East Lansing, Michigan in spring 1962. All the west coast seedlots suffered such severe winter damage while in the nursery, that they were discarded without field planting.

In spring of 1965, 68 seedlots from the interior portion of the range were field planted as 2 + 1 stock in 3 permanent test plantations in southern Michigan. In each plantation a randomized complete block design with 10 replications and 4-tree plots was used. Spacing was 6 by 6 ft. Weed control was achieved by the application of amino-triazole (2 gal/acre) the fall before planting and by simazine (4 lb/acre) immediately after planting. Details for individual plantations are as follows:

W. K. Kellogg Forest, Augusta, Kalamazoo County, Michigan, 65 miles southwest of East Lansing; site a level hilltop with good air drainage; soil sandy loam; 67 seedlots; mortality 8 percent by 1973.

Fred Russ Forest, Decatur, Cass County, Michigan, 110 miles southwest of East Lansing; site a level field with poor air drainage; soil sandy loam; 19 seedlots; mortality 21 percent by 1973.

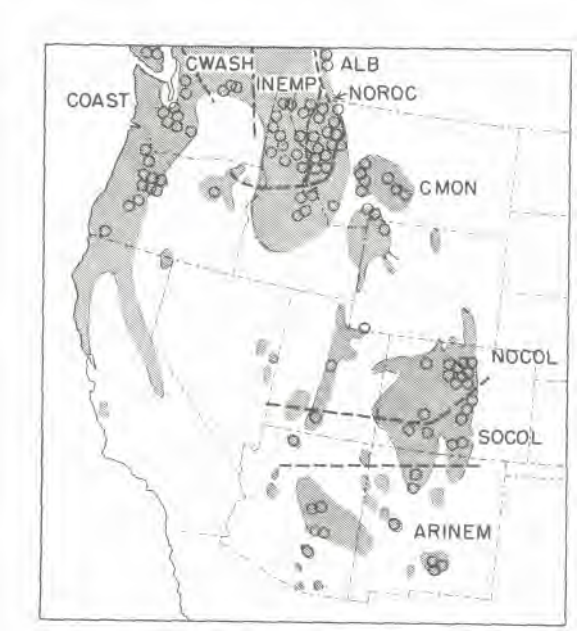

Figure 1.--Natural range of Douglas-fir (shaded area) and location of stands (dots) from which seed was collected and grown in Michigan. Douglas-fir races as recognized by Wright et al. (1971) are indicated.

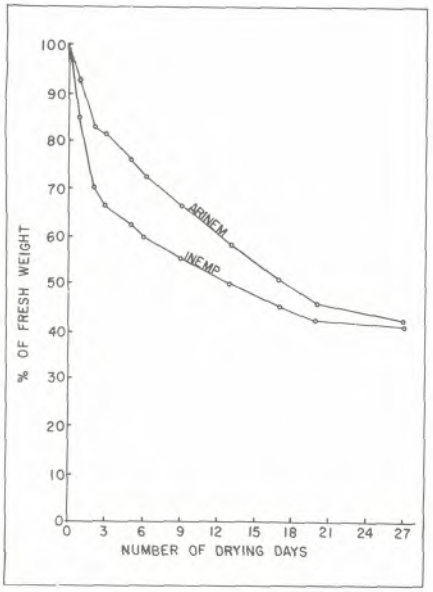

Figure 2.--Differences in rates of moisture loss of cut branches of Arizona-New Mexico (ARINEM) and northern Idaho (INEMP) Douglas-fir races growing at Kellogg Forest in southern Michigan.

Camp Kett (Kettunen Center), Tustin, Osceola County, Michigan, 150 miles northwest of East Lansing; site rolling with 5-20 percent north slopes and good air drainage, soil sandy loam; mortality 25 percent by 1973.

In all plantations, mortality, height, foliage color, and damage from late spring frosts were measured two or three times, the last time in the summer of 1973. Time of leafing out and rate of foliar drying were measured in the Kellogg Forest plantation in May and August 1973, respectively. Foliar moisture content was measured in the Kellogg Forest and Camp Kett plantations in August 1973.

Foliar moisture content was measured for both current-year and year-old foliage. Foliage samples (10 to 45 g/plot) were removed from all living trees in each plot. All material collected from a plot was combined and placed in a labelled, tared paper envelope and then sealed in a tared plastic bag to prevent moisture loss. Samples were returned to the laboratory for weighing within 24 hours and were subsequently oven dried at a temperature of 70°C. Dry weights were determined after the tissue reached a constant oven dry weight over a 24-hour period. Occasional technique checks indicated less than 0.1 percent error in fresh weight due to moisture loss prior to weighing.

Rate of foliage drying was determined by removing one 2-to-3-ft. branch per tree from each of two seedlots of Arizona and Northern Idaho origin. Samples were collected from 30 trees representing 2 replicates of the Kellogg Forest planation. Immediately after collection the branches were placed in sealed plastic bags and within 4 hours were brought to the laboratory where their fresh weights were determined. They were then spread out to dry in a laboratory kept at 22°C.

RESULTS

For the purpose of comparison and clear presentation, the 68 seedlots were divided into 8 geographical races and given code names according to the classification of Wright et al. (1971) (fig. 1). They divided the seedlots into races because they discovered that most genetic variation existed between groups of seedlots from different geographic locations. In other words, variation among seedlots within a race was very small whereas that between races was very large. The races and their distribution are as follows:

ALB ---------- Alberta

CMON --------- Central Montana, Wyoming

NOROC -------- Northern Rockies, West Central Montana

INEMP --------- Inland Empire, Northern Idaho and Northwestern Montana

CWASH --------- North Central Washington

NOCOL --------- Northern Colorado and adjacent Utah

SOCOL --------- Southern Colorado and adjacent Arizona

ARINEM -------- Central and Southern Arizona and New Mexico.

Mortality

By 1973 mortality averaged 8, 21, and 25 percent in the Kellogg, Russ, and Camp Kett plantations, respectively. The differences were presumably related to the effectiveness of weed control. Most deaths occurred during the first two years after field planting with only 1 to 2 percent additional mortality in the following 7 years. Mortality rates were similar for all races.

Height

At age 9 from planting, average heights were 7.4, 3.2, and 5.3 ft. in the Kellogg, Russ, and Camp Kett plantations, respectively. Slow growth in the Russ plantation is probably due to its location on a flat, open site subject to late spring frosts and strong westerly winds.

In all plantations trees grown from seed collected in Arizona and New Mexico (ARINEM race) grew fastest (table 1). They averaged 10.5, 4.3, and 6.8 ft tall at Kellogg Forest, Russ Forest, and Camp Kett, respectively at age 9 from planting. The INEMP race (northern Idaho and northwestern Montana) was second fastest growing, averaging 8.8, 3.8, and 5.6 ft tall, respectively, in the three plantations. Differences among individual seedlots within these races were not statistically significant.

Thus on good sites either of these races grew fast enough to produce merchantable Christmas trees on 7 or 8 year rotations. In sharp contrast, the CMON (central Montana) and NOCOL (northern Colorado) races grew only 50 to 60 percent as fast. Some trees of those races were still only 2 ft tall 9 years after planting.

Frost Susceptibility

Douglas-fir is subject to damage from late spring frosts. The amount of damage depends on the date and severity of the frost, and site conditions to which Douglas-fir is exposed. Killing frosts have occurred in Michigan when the temperature in the plantation falls below 28°F

Table 1.--Relative height of Douglas-fir (9 years old from planting) from different geographic origins growing at 3 test plantations in southern Michigan

Region of origin	Kellogg Forest	Russ Forest	Camp Kett
	Height Expressed as Percent of INEMP Trees		
Northern Races			
ALB	74	--	--
CMON	72	--	54
NOROC	91	92	89
CWASH	80	71	93
INEMP	100 (8.8 ft)[1/]	100 (3.8 ft)	100 (5.6 ft)
Southern Races			
NOCOL	59	63	73
SOCOL	88	63	88
ARINEM	119	113	120

1/ Figures in parenthesis are actual mean heights of INEMP trees.

(-2 C) after the trees have begun growing in the spring. Such frosts have occurred in our Douglas-fir plantations in 3 out of the 10 years since the trees have been field planted. Damage from late spring frosts results in killing of new foliage and causes unsightly damage to susceptible trees.

Killing late spring frosts occurred at Kellogg and Russ Forests in 1968, at Kellogg Forest and Camp Kett in 1969, and at all three places in 1973. The damage was worst at Russ Forest, where only the most resistant seedlots escaped serious injury.

Despite very large differences in incidence of frost damage at the three test sites, there were consistent differences in relative amounts of damage of the various races (table 2). Trees from the southern part of the range consistently suffered the most damage. Trees belonging to the NOCOL and SOCOL races were especially hard hit; the effects of the frost damage were compounded by their relatively small stature. Many of these trees were so heavily damaged that they had scarcely recovered by 1975 even though 1974 and 1975 were frost free. The ARINEM race suffered moderate to heavy damage but grew fast enough to show complete recovery the following year.

At the other extreme, the fastest growing northern races (NOROC and INEMP) experienced relatively little frost damage. Even at Russ Forest few trees of those races were injured enough to affect their merchantability at Christmas time.

Table 2.--Racial differences in susceptibility to frost damage and time of leafing out for Douglas-fir growing in Michigan plantations

Region of Origin	Frost Damage: Kellogg (3 yr avg.)	Frost Damage: Russ (2 yr avg.)	Frost Damage: Camp Kett (2 yr avg.)	Time of leafing out 1/: Kellogg only
	Range in Percent of Buds Killed			
Northern Races				
ALB	21-30	--	--	Intermediate
CMON	10-20	--	21-30	Late
NOROC	10-20	40-55	10-20	Very late
CWASH	21-30	56-70	21-30	Intermediate
INEMP	10-20	40-55	10-20	Very late
Southern Races				
NOCOL	31-45	71-85	21-30	Early
SOCOL	31-45	71-85	31-45	Early
ARINEM	21-30	71-85	21-30	Early
Average	25	65	21	

1/ Leafing out data applicable for May, 1973 (Steiner and Wright 1974).

Time of Leafing Out

The data on time of leafing out taken in the spring of 1973 furnished a very good clue as to the mechanisms of frost resistance. Growth started nearly three weeks later in the NOROC and INEMP varieties than in those from the southern part of the range. Since the frosts occurred 2 to 3 weeks after the first flush of growth, the frosts damaged the new growth on early trees but left the unopened buds on the later races unharmed (table 2). Therefore, the lesser amount of damage in the NOROC and INEMP varieties is a case of frost avoidance rather than frost resistance per se.

The correlation between earliness and susceptibility to frost damage was not perfect, however, as there was a confounding effect of height. Even in early-flushing seedlots tall trees suffered relatively small amounts of damage in their upper crowns.

Foliar Moisture Content

For all seedlots, moisture content averaged about 10 percent lower for year-old than for current-year foliage. This was probably due to an increase in cell wall thickness and cuticular waxes as the leaves matured.

For foliage of a given age, there were also genetic differences in foliar moisture content. Seedlots from Arizona and New Mexico (ARINEM race) had the most succulent foliage, averaging 58 and 68 percent moisture in year-old and current-year foliage, respectively. In contrast, the foliar moisture content was 54 to 55 percent and 64 to 65 percent, respectively, for year-old and current-year foliage of northern Idaho (INEMP race), central Washington (CWASH race), and northern Colorado (NOCOL race) trees.

Drying Rate of Fresh Branches

In the drying rate experiment, fresh branches were cut from 30 trees representing two seedlots each from Arizona and northern Idaho. The branches were spread out on a laboratory bench and weighed at intervals of 1 to 6 days.

After 2 days the Arizona branches lost 17 percent of their original fresh weight versus 30 percent for the northern Idaho branches (differences significant at the 1 percent level). This large difference in drying rate continued so that the Arizona branches were moister than the northern Idaho branches at all times until the experiment was concluded (fig. 2).

The differences in drying rate were clearly reflected in the appearance of the foliage. After 8 days all the Arizona branches appeared fresh and green whereas nearly half the northern Idaho branches had brown foliage (table 3.

Table 3.--Percent of branches turning brown after drying for various times

Origin	3 Days	8 Days	11 Days	20 Days	27 Days
Arizona	0	0	11	39	88
Idaho	8	42	50	75	100

Foliage Co

Foliage color was measured at the Kellogg Forest only in September 1973, using grades of 0 (= greenest) to 20 (= bluest).

Within some 4-tree plots there were all extremes from greenest to bluest. However, there was a great deal of consistency from plot to plot so that individual seedlots could be characterized as different from others. Most of the color differences are due to protective waxes on the needles rather than to differences in pigments. The races could be characterized as follows:

ALB----------moderately blue, uniform

INEMP, NOROC ----- uniformly among the greenest

CMON, CWASH ------ dark green with occasional moderately blue trees

NOCOL ---------- intermediate blue-green, uniform

SOCOL ---------- moderately blue, but variable; most seedlots were moderately blue but some were indistinguishable from northern races

ARINEM ---------- uniformly among the bluest

PRACTICAL APPLICATION

Of the interior races of Douglas-fir which can be considered reliably hardy in Michigan, only the ARINEM and INEMP races grow rapidly enough to be recommended for Christmas tree planting. With those races, rotations of 6 to 9 years are possible, versus rotations of 10 to 20 years for trees from other regions.

If frost is not apt to be a problem, the ARINEM race is superior in most respects (table 4). It grows fastest and has the foliage characteristics most desired by Christmas tree buyers. Its slower drying rate alone, if advertised, would make it a preferred tree.

Table 4.--Comparison of characteristics of the two fastest growing races

Race	Height age 9	Rotation	Frost damage	Foliage		
				Color	Moisture	Dry Rate
	ft	years				
ARINEM	10.5	7	Medium	Blue	High	Slow
INEMP	8.8	8	Light	Green	Low	Fast

However, the possibility of serious damage from late spring frosts cannot be ignored. Such frosts are apt to occur once every 3 or 4 years. When they occur, trees from northern Idaho are most likely to escape with such a small amount of damage that they are merchantable even in the year of the frost. Trees from Arizona and New Mexico will probably suffer enough damage to reduce their merchantability in the year of the frost but will probably recover well the following year.

Perhaps the best solution is to plant a mixture of these two races, thus obtaining the advantages of the ARINEM trees if frost damage is not serious while providing insurance against loss of a year's income if it is.

Throughout this paper we have treated the races as if they were genetically uniform and distinct from one another. That is undoubtedly not true, and there is probably a considerable amount of genetic variation within any one of the races. To date, however, it has not been possible to say which particular stands within a region produce the best seed. Thus for the present, we can only make general recommendations that the seed be collected in Arizona and New Mexico or in northern Idaho and northwestern Montana.

Since 1970 a growing number of eastern nurserymen have been aware of the advantages of Arizona-New Mexico trees and offer such stock for sale under the names "Coconino", "Apache", or "Kaibab", etc. A smaller number have stock of the INEMP race for sale, some of which is listed as "Shuswap Lake, B.C."; that origin seems similar to the seedlots from northern Idaho. One should avoid buying stock of unspecified origin, as some such stock is known to be grown from seed collected in parts of the range producing very slow-growing trees.

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