(3) The selection scheme for putative selfers was successful in the three areas tested. The stand trees generally did not perform as well as the isolated trees. Because of the possibility of parthenocarpy, the selection scheme could be improved by checking the full or even viable seed yield of isolated trees. Furthermore, it is reasonable to expect better results from applying the scheme in poor crop years than in good crop years.

(4) There were differences in the average selfing potential among the three areas. Compared with the results from other selfing studies, Cle Elum was above average and Olympia below average in selfing potential. Thus, in the search for good selfers, it would seem advisable to test trees in several populations.

(5) Five different mutants (presumably expressions of marker genes) were detected over a 2-month period; one was not detected until a general fertilizer treatment was given. Therefore, in the search for marker genes, frequent and critical seedling inspection is most necessary throughout the first few months following germination. Also, due to genotype/environment interactions, certain markers may become apparent only under certain conditions.

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Genetic Variation in Southern Rocky Mountain White Fir

By JONATHAN W. WRIGHT, WALTER A. LEMMIEN and JOHN N. BRIGHT[1])

White fir (**Abies** concolor [GORD. and GLEND.] LINDL.) is a high-elevation tree of the Sierra Nevada Mountains and southern Rocky Mountains. It is an important part of the landscape in the southern Rockies but of minor importance for timber because of the inaccessibility of most of the fir forests.

Although white fir has not been planted extensively within its native range, it is a common ornamental in eastern United States and Europe. Its regular crown and soft blue foliage are much admired in private gardens and parks. The same traits make it a desirable Christmas tree and many eastern growers have experimented with it with varying degrees of success. Up to 20 years have been needed to produce salable Christmas trees in Michigan. The present work was undertaken to discover seed sources which could grow much faster than those used in the past.

There are several reports of natural hybrids between white fir and another western species, grand fir (*A.* grandis [DOUGL.] LINDL.). Intermediates are common where the ranges of the two overlap in northern California and southern Oregon and such hybrids have also been reported from Europe. But, until recently, such reports comprised the sum total of genetic knowledge of these two species.

The Sierra Nevada and Rocky Mountains populations of white fir have occasionally been recognized as distinct varieties, var. *lowiana* and var. concolor respectively. In several other species, the Sierra-Cascade forms have proven less suitable to the harsh winters of the Northeast than the Rocky Mountain forms. Therefore the present study was confined to interior sources. A study of the Sierra-Cascade populations, similar to the one reported here, was undertaken at the University of California and has been reported by CONKLE, LIBBY and HAMRICK.[2])

Through the courtesy of the U.S. Forest Service and other agencies seeds were obtained from natural stands in Utah, Colorado, Arizona and New Mexico in the autumn of 1961. Although we desired cones from several trees per

[1]) Professor of Forestry, Resident Forester of the W. K. Kellogg Forest and Resident Forester of the Fred Russ Forest of Michigan State University, respectively. This work is part of the NC-51 project "Improvement of Forest Trees through Selection and Breeding" supported in part by regional research funds from the U. S. Department of Agriculture. Approved for publication as Journal Article Number 5034 of the Michigan Agricultural Experiment Station.

[2]) CONKLE, M, T., W. J. LIBBY and J. L. HAMRICK. 1967. Winter injury among white fir seedlings. Pacific Southwest Forest and Range Experiment Station Res. Note 138. Dr. LIBBY shared most of his seedlots with us and theg were sown in Michigan in 1964, two years later than the present study. All suffered repeated severe winter injury if they grew above the snow cover. Therefore they have not been field planted. The only direct comparison possible is between those trees and four Rocky Mountain seedlots retained as windbreaks in the nursery. In foliage characteristics the trees from southern California resemble Rocky Mountain white fir but those from northern California and Oregon do not. The northern Sierra trees have much greener foliage which is 2-ranked. The differences seem large enough to warrant continued separation of var. lowiana and var. concolor.

Table 1. — Place of origin, relative height and foliage color of white fir from 18 localities in the southern Rocky Mountains.

No. and state of origin	N. Lat.	W. Long.	Elev.	No. of parent trees	Relative height at Nurs. age 1	Kellogg Forest age 8	Russ Forest age 8	Camp Kett age 8	Foliage color
	°	°	feet	number	percent of plantation or nursery mean				grade (1=green) (5=blue)
2409 Utah	111.3	39.8	8,800	8	86	55	—	—	3.5
2407 Utah	112.1	38.8	8,000	5	89	59	—	—	3.0
2429 Utah	112.2	37.7	8,200	—	68	79	53	80	3.8
2432 Utah	112.7	37.5	8,500	10	95	64	—	—	4.2
2406 Colo.	105.8	37.5	8,500	10	98	92	—	—	3.4
2431 Colo.	105.0	38.8	10,000	5	68	95	—	100	3.2
2430 Colo.	105.0	37.5	8,000	10	114	92	—	—	3.7
2405 Colo.	105.0	37.5	8,000	6	89	113	—	131	4.6
2421 N. Mex.	105.4	36.0	8,700	—	114	135	113	—	3.6
2416 N. Mex.	105.9	35.2	10,500	1	101	87	59	96	3.8
2417 N. Mex.	107.5	33.8	9,300	1	104	95	—	125	2.0
2415 N. Mex.	105.8	33.4	9,000	10	101	87	—	123	1.0
2426 N. Mex.	105.9	33.0	8,700	5	123	111	—	88	1.5
2428 N. Mex.	105.4	32.9	8-9,000	100	104	116	178	148	1.4
2412 Ariz.	111.2	34.4	6,500	3	120	109	118	114	3.9
2413 Ariz.	111.0	33.4	7,500	1	142	144	—	—	4.0
2423 Ariz.	110.8	33.4	7,800	10	78	111	69	—	2.6
2427 Ariz.	110.8	32.4	8,400	10	155	120	105	86	3.6
Actual mean height, centimeters					8	72	56	53	

stand, this was not always possible. The actual number of parental trees per stand is included as a pertinent part of the seed origin data in *table 1* but does not help to explain any of the vagaries of performance. The cones were allowed to dry and shatter. Then seeds and chaff were sown in a research nursery in East Lansing, Michigan in late October 1961. They germinated early the following spring, before other species. Germination was nil to poor if the cones had been collected prior to September 15; moderate to good if the cones had been collected between September 15 and October 15. The location of parental stands is shown in *figure 1.*

The seedlings were grown one year at East Lansing, transferred to a nursery 40 miles distant in 1963, and field planted at four locations in 1965. The first-year nursery experiment was replicated four times, with 1.2-m row plots 30 cm apart containing up to 34 trees per row; excess seed was sown in large rectangular plots in a fifth replicate. There was no replication in the transplant beds. Each permanent plantation contained up to ten 4-tree plots per origin; spacing was 2 × 2 m. Due to shortages, some seedlots could be included in one or two plantations only.

The descriptions of the permanent plantations are as follows.

W. K. Kellogg Forest near Battle Creek, southwestern Michigan. Upper part of a steep slope facing south with a gravelly clay soil and a dense sod cover; trees planted in furrows and sprayed with simazine immediately after planting.

Fred Russ Forest near Niles, southwestern Michigan. Low lying level area with a sandy loam soil and a dense sod cover; trees planted in 2-foot strips sprayed 6 months previously with amino-triazole and sprayed with simazine immediately after planting.

Camp Kett, central part of Michigan's Lower Peninsula. Upper part of a gentle north-facing slope with a gravelly sandy loam soil and a sparse sod cover; weed control as at Russ Forest.

Tree Research Center, East Lansing, south-central part of Michigan's Lower Peninsula. Nearly level low lying site with a sandy soil and a dense sod cover; weed control as at Russ Forest.

Several dozen seedlings of some sources remained after the plantations were established. These were planted as portions of windbreaks in the university's Tree Research Center. All have been maintained weed-free and some received irrigation during the summer. These supply some information on within-population variability and on growth potential under near-ideal conditions.

Several variables, described sufficiently in the tables and text, were measured, some of them several times. Each set of nursery or plantation measurement data was subjected to analysis of variance from which an F value and a standard error of a provenance mean were calculated. The last-named statistic was multiplied by 3.2 (5 percent level) or 4.2 (1 percent level) to obtain an approximate "least significant difference" among individual seedlots. Such "least significant differences" applied strictly only to seedlots represented in all blocks of a plantation; separate "t" tests were made for a few critical comparisons between sparsely represented seedlots.

Perusal of the data showed some obvious interactions. The reality of these was determined by Chi-square analyses.

Mortality

Mortality was as follows at the end of 1969, 5 years after planting.

Kellogg Forest — 27 percent
Russ Forest — 47 percent
Camp Kett — 32 percent
Tree Research Center (weed-free windbreaks) — 2 percent.

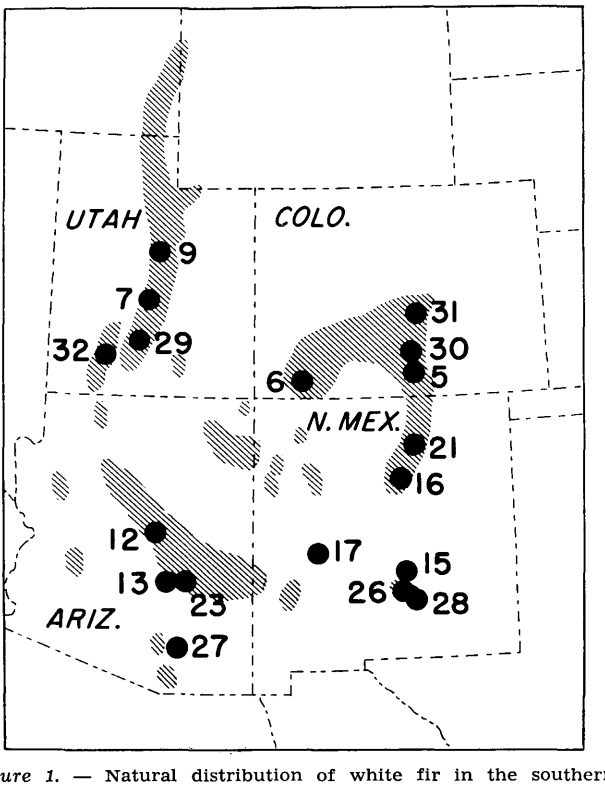

Figure 1. — Natural distribution of white fir in the southern Rocky Mountains (shaded) and location of the seed sources used in the present experiment (numbered dots).

Approximately two-thirds of the mortality occurred within a year after planting.

The contrast between the nursery and planting data indicate that transplanting shock plus moisture stress were responsible for most deaths, and that better weed control could have reduced the death rate to a negligible amount.

The mortality rate was approximately the same for all seedlots.

Height

For convenience, the seedlots were divided into four geographic groups. Trees from Utah and southeastern Colorado were the slowest growing at all ages *(table 1)* Even under the favorable conditions found in the Tree Research Center, the tallest tree at age 8 was only 75 cm tall, a height greatly exceeded by trees of other origins in all plantations.

Next tallest was the group from south-central Colorado and northern New Mexico. These varied from slow to moderately fast growing.

The separation of southern New Mexico trees from southern Arizona trees is arbitrary and perhaps wrong. Two origins from southern Arizona were outstanding in the nursery whereas the New Mexico trees were generally taller than those from Arizona. However, one Arizona origin (No. 2427) which was outstanding the first year has continued excellent growth as a windbreak-hedge in the Tree Research Center. The trees averaged 150 cm (5 feet) in height at age 8 (from seed, age 5 from planting) and will produce trees of Christmas tree size by age 9.

The same factors which caused mortality caused variation in growth rate among the survivors and there was a very large amount of within-seedlot variability in the plantations. The well kept windbreak hedges in the Research Center provide a better measure of the amount of genetic variation among the parents in a single stand. The windbreak plots were much more uniform, and the standard deviation of a single tree was between 5 and 10 percent of the mean. With that amount of variation, intensive within-stand selection might result in a 1 to 3 percent gain.

There were some statistically significant (5 percent level) differences among trees originating from stands within the same region. Certainly the between-stand differences were appreciable and there are possibly many more such differences which were not detectable statistically. These between-stand differences were as great if the stands were located a few miles apart as when they were located on different mountain ranges.

Color

There was a striking difference between the California-Oregon-Nevada collection supplied by Prof. Libby and the Rocky Mountain origins. A few trees from southern Califorina were as blue as any Rocky Mountain trees, but the remainder of Prof. Libby's trees were much greener.[3])

[3]) The color contrast between the very green *Abies concolor* × *grandis* collections from the northern Sierras and the greenest Rocky Mountain trees was 3 to 4 times as great as among extremes in the Rocky Mountain collection.

Among the Rocky Mountain origins, seedlot 2405 from southern Colorado was exceptionally blue; most trees were rated 5 (bluest) on a 1- to 5 scale. At the other extreme were the four seedlots from southern New Mexico; most trees were rated green (1 and 2) on the same scale. Seedlots from Arizona, Utah and other parts of Colorado and New Mexico did not differ greatly from each other; most were rated medium to bluish (grades 3 to 4).

Some seedlots were nearly uniform in color. Others were variable enough that adjacent vigorous trees might differ by two or three color grades. This indicates that parental selection for color might be productive in some stands; it would be unnecessary in others.

Hardiness

Except for the very smallest trees which were protected by snow, the trees in Prof. Libby's collection have suffered repeated winter injury in Michigan. This took the form of needle browning. Generally the cambium was not hurt and the trees looked thrifty as soon as they formed new leaves, only to suffer again the next winter.

The Rocky Mountain origins escaped such damage while in the nursery. During the first two years after field planting, however, the tips of the needles of most trees became brown. Except at Russ Forest, where the plantation has little protection from wind, such damage became negligible as the trees became established.

All Rocky Mountain origins continued to suffer varying degrees of bud mortality, mainly on lateral branches. Well-watered trees such as those in the Tree Research Center windbreak-hedges responded by abundant new growth from the undamaged buds or by the formation of new buds. Crown deformities developed in less vigorous trees. Such crown deformities were most frequent in Arizona and New Mexico trees but between-source differences were not significant statistically.

Abstract

White fir seed from 18 natural stands in the southern Rocky Mountains was sown in a East Lansing, Michigan nursery in autumn 1961. Four permanent test plantations were established in southern Michigan in 1965. Trees from Utah and southwestern Colorado grew most slowly in the nursery as well as at all test sites. In the plantation with the mildest climate, trees from Arizona grew twice as fast, averaging 1.5 m tall at age 8 from seed. Trees from southern New Mexico grew most rapidly (twice as fast as Utah origins) at the coldest test sites. Needle length was also about twice as great in Arizona and southern New Mexico trees as in Utah trees. All trees from the Rocky Mountains were very blue in comparison with a few seedlots from the Sierras of northern California and Oregon but there were differences among the Rocky Mountain origins, trees from southern New Mexico being the greenest. All the Rocky Mountain seedlots suffered slight to medium injury from winter cold on the most exposed test site; between-origin differences were not significant statistically.