Variation in Specific Gravity and Tracheid Length for Several Species of Mexican Pine[1])

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Introduction

The pines of Mexico are of interest because of the large number of species growing over a wide range of habitats. Both within Mexico and outside of it there is widespread interest in utilizing this natural variation, and demand for trials in other forested areas is great. Interest in adaptability and growth rates is naturally high, but of equal concern should be the kind of wood produced by different species as well as by an individual species when grown under a range of environmental conditions.

In general, the wood characteristics of the Mexican pines are not well known, although various researchers have studied and reported on several species. Knowledge of wood quality is essential to sound forestry and should be properly evaluated when determining which species to use either within Mexico or when used as introductions. It is recognized that a species or provenance may produce wood with somewhat different characteristics when grown outside its native habitat; nevertheless, the native trees can be used as indicators of expected variation in wood characteristics when the species is grown as an exotic.

This paper reports on variability in the wood of several species of Mexican pines determined from 11-mm. increment cores extracted at the breast height position (4.5 feet above ground). The wood samples were obtained on the Mexican pine collection trip, described by SAYLOR and MCELWEE (1963), organized by six of the pulp and paper industries that are members of the North Carolina State-Industry Tree Improvement Program[3]); men participating in the trip and its organization, along with cooperating Mexican agencies and personnel, are listed in the 1962 report.

The assessment of the wood properties reported in this paper are not the result of an exacting study but represent a survey to obtain an idea of variations within individual trees, among trees of a species growing in the same habitat, among stands of a species growing on different habitats, and to some extent, among species. Therefore, the reported gross differences should be considered indicative rather than exact; their exact magnitude can be determined only by more intensive sampling and analytical methods. This paper will also compare results of the current survey with other published data on the wood of the Mexican pines.

Obtaining Wood Specimens

Wood specimens were obtained from each tree for which seed was available. Collections were made from individual trees from 21 species or varieties of Mexican pines. Species, elevations, number of trees sampled, growth rates, and other data are listed in *Table* 1. When possible, samples were collected for each species from five trees per stand, and an attempt was made to collect from several stands each growing in different habitats. This objective was not always attained because of time and travel limitations and because of the very poor cone crop in 1962, limiting choice of trees to sample. Especially in Chihuahua and Durango it was rarely possible to sample five trees of a species in a single stand because of the lack of cones. Further studies on wood will be possible because the seed obtained was plantod in about 20 locations on company lands in the southeastern United States, as well as at several locations in Hawaii and in Brazil. All plantings are by progenies of individual mother trees, making it possible to compare the wood of each mother tree in its native habitat in Mexico with that of its progeny grown under a variety of different environments.

Two large 11-mm. diameter increment cores were obtained from opposite sides of each tree at the breast height position of 4.5 feet. Each core was then divided into 10-year segments, *i. e.*, pith through 10th ring, 11th through 20th, 21st through 30th, and 31st through 40th ring.

Cores were separated into 10-ring segments to show the change in extractive free specific gravity and tracheid length with age from the pith. The rapidity and extent of this change has practical as well as theoretical interest in that rotation ages and other management decisions are influenced by such information.

Although some of the plots had trees less than 40 years of age, most were older than 40. In the older cores no further divisions were made but the last section was analyzed in a single segment labelled 40+. The forty year division was chosen because in plantations most interest is in wood from the younger trees. Also, it was found that the variability in wood characteristics within a tree was small beyond the 40th annual ring.

Some collections included trees over 100 years old, but most were younger than 70 years. Among the older trees of the slower growing species, heart rot made it impossible to assess either specific gravity or tracheid lengths of the first 10, and, in some cases, in the first 20 rings from the pith.

There is a question as to the meaning of breast height values and their relation to the trees. Although a relationship of breast height values to whole tree values for specific gravity and tracheid length has not yet been determined for the Mexican pines, there are numerous studies for pines from other areas, showing that specific gravity values at breast height reflect whole tree values (cf., EINSPAHR, *et al.*, 1962; HIETT, *et al.*, 1960; MILLER, 1959; STERN, 1963; WALGREN and FASSNACHT, 1959; and ZOBEL, *et al.*, 1960, 1964). All these authors report a fairly close relationship between breast height and total tree values, with correlation coefficients ranging from 0.6 to 0.9. This relationship may change with tree age, site and species, but the published data in all instances indicate breast height specific

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Table 1. — Location and description of trees sampled.

Species	State	Elevation *(feet)*	Nr. of Trees per plot	Collection Nr.	Ave. Age Yrs.	Ave. DBH *In.*	Ave. Ht. *Feet*	Growth Rate *Ring/In.*
Group Montezumae								
P. montezumae	Puebla	8900	5	6 through 10	56	18.3	90	6.1
P. montezumae	Puebla	8100	5	36 through 40	73	18.7	87	7.8
P. montezumae	Michoacan	7500	5	56 through 60	36	21.5	64	1.7
P. montezumae	Mexico	8400	5	76 through 80	74	22.8	120	3.3
P. montezumae var. *macrocarpa*	Michoacan	6900	2	538 through 539	30	19.1	79	1.5
P. michoacana	Michoacan	4600	5	71 through 75	68	25.8	98	2.7
P. michoacana								
var. *cornutu*	Jalisco	7600	5	513 through 515	26	15.7	40	1.6
var. *cornutu*	Michoacan	6900	5	536 through 542	47	23.0	89	2.4
var. *cornutu*	Michoacan	5000	5	543 through 548	35	22.6	85	1.5
P. hartwegii	Mexico	12000	5	1 through 5	50	14.7	47	3.4
P. rudis	Tlaxcala	9000	5	26 through 30	56	17.6	73	3.2
P. lutea	Durango	7200	1	511	57	—	—	—
Group Serotines								
P. oocarpa	Michoacan	4800	5	66 through 70	52	19.8	59	2.6
P. oocarpa	Michoacan	5500	5	551 through 555	72	26.2	66	2.7
P. patula	Tlaxcala	8800	5	21 through 25	45	20.6	91	2.1
P. patula	Puebla	6700	5	46 through 50	45	19.6	96	2.3
Group Pseudostrobus								
P. pseudostrobus	Puebla	6700	5	41 through 45	38	21.5	73	1.7
P. pseudostrobus	Michoacan	7600	5	531 through 535	32	21.4	100	1.4
P. pseudostrobus or *tenuifolia*[1])	Michoacan	8000	5	51 through 55	52	26.2	105	1.9
P. tenuifolia	Michoacan	6900	6	516 through 520, 517 a	48	30.9	80	1.5
Group Teocote								
P. teocote	Puebla	9300	5	11 through 15	81	20.8	87	3.9
P. teocote	Tlaxcala	8700	5	31 through 35	64	17.6	81	3.6
P. lawsoni	Michoacan	6400	5	61 through 65	33	19.5	58	1.7
P. lawsoni	Michoacan	5600	5	526 through 530	62	23.1	80	2.7
P. hererai	Chihuahua	—	5	505—1, 505—2, 505—3 and 507	150	16.1	65	9.3
Group Leiophylla								
P. leiophylla	Puebla	8100	5	16 through 20	34	16.1	53	2.1
P. leiophylla	Michoacan	6900	5	521 through 525	32	17.3	63	1.8
P. leiophylla	Durango	7300	1	512	49	—	—	—
P. leiophylla	Jalisco	8300	1	514	25	16.0	50	1.5
P. chihuahuana	Chihuahua	8000	1	504	175	26.6	80	6.1
P. lumholtzii	Durango	7300	2	509 through 510	85	—	—	—
Group Ponderosa								
P. arizonica	Chihuahua	8200	5	503—1 through 503—5	105	17.0	87	6.2
P. durangensis	Durango	9000	3	506—1 through 506—3	90	19.7	76	4.5
P. engelmanii	Chihuahua	7400	3	502—1 through 502—3	75	21.2	72	3.5

[1]) Positive identification of these trees was not made, though they tended to resemble *P. pseudostrobus*.

gravities as reflecting whole tree values fairly well. If more precise estimates are desired, regression equations need to be developed for each species and condition being investigated.

A relationship of whole tree tracheid length values to breast height values has not been well established; the few studies from which data are available show this relationship to be only moderately strong (Einspahr, *et al.*, 1962; Nicholls and Dadswell, 1962; van Buijtenen, 1962; Zobel, 1964). In a study on loblolly pine *(P. taeda)* estimation of average stand whole tree tracheid length values from breast height lengths appears to be quite good (Zobel, 1964). Published information, however, suggests the need for more caution in the interpretation of whole tree values obtained by breast height sampling for tracheid lengths than for specific gravities.

No statistical treatment has been applied to the data from this study because of the method of sampling and because the main objective was to obtain comparisons among trees, sites, and species rather than exact values. Furthermore, each plot consisted of only five trees, and the large amount of individual tree variation makes meaningful statistical analysis of such a small sample difficult. Additionally, all reported values for specific gravity and tracheid length are arithmetic averages which have not been weighted for the proportion of wood which they represent. Since in nearly every instance the values for both specific gravity and tracheid length increased from the tree center outward, the average tree values reported at breast height are lower than they actually would be if weighted, the values near the center of the tree obviously representing a smaller proportion of the total cross-sectional area at breast height than those nearer the bark. However, since straight arithmetic averages serve well for

10-year segments, meaningful comparisons are obtained for the average of the first 40 annual rings which are reported as representative tree values.

Despite the above-mentioned restrictions in sampling and analysis, some very valuable results have emerged and should prove most helpful in determining sample size and design for future studies of wood qualities of Mexican pines. Additionally, the data to be obtained from the many progeny of individual mother trees will give a good estimate of the quality of wood that can be produced by various species of the Mexican pines when grown in various habitats under different growth conditions.

Results

General:

Several factors must be considered in evaluating the results of this study. The data on specific gravity are more reliable than those for tracheid lengths. Sampling at breast height restricts generalization of results to whole trees. The use of two large increment cores from each tree, divided into 10-ring segments, enabled assessment of wood of equal ages, making comparisons possible at a standard sampling point among individual trees, habitats, and species. Some difficulties were caused by compression wood resulting from various causes. Compression wood often has specific gravity and tracheid lengths different from those produced in normal wood and was avoided whenever possible; nevertheless, a considerable amount was found in the trees which were growing, for the most part, in unmanaged stands.

Variation Within the Tree:

In any given cross section of a tree, wood of the same annual ring may not be uniform, either for specific gravity or tracheid length. In addition, wood formed near the pith is usually different from that formed nearer the bark. Such variability within a tree is evident for all characteristics studied and always causes concern as to the adequacy of the sample whether in the form of increment cores or of wedge segments. Numerous studies on *Pinus taeda, P. elliottii,* and other species have shown that, although within-tree variability is always present, it is usually less than the variation among trees of a species of the same age growing in similar environments. Two increment cores were obtained, one each from opposite sides of the tree. Previous studies have shown that one increment core per tree was satisfactory for a population analysis of specific gravity, but assessment of individual trees requires two or more cores for best results. Specific gravity was determined for each of the two cores obtained from each tree in this study; results for three species are shown in *Table 2.* The A and B sides shown in the table represent opposite sides of the tree, with the point on the girth at breast height being chosen at random. In most instances the results obtained for the 10-ring segments of each pair of cores are in acceptably close agreement. They seldom differed by more than .02 units of specific gravity, regardless of age *(Table 2).* However, notable exceptions do occur; for example, in the 21—30 segment of tree no. 5 of *P. hartwegii* the sides differed by .04 and some segments in several *P. patula* trees differed by as much as .04 and .05.

The tree average in the last column shows what the differences would be if specific gravity of the tree were based on only one rather than two cores; the difference per tree would normally be .02 or less. From this it appears that one core would have been sufficient to assess specific gravity for a group of trees, but using two cores naturally helped to strengthen the data for each tree.

For tracheid length, within-tree variation is very noticeable in some trees and species, practically absent in others. To categorize a stand on the basis of tracheid lengths, one core per sample tree appears sufficient; however, it is not adequate to properly classify any individual tree. In testing tracheid length differences between opposite

Table 2. — Comparison of specific gravity for paired 10-ring segments on cores from opposite sides of the tree.

Species and Tree No.	Ten-ring segments from pith outward								Tree Ave.		Sides A and B
	0-10		11-20		21-30		31-40				
	Side A	Side B	Side A	Side B	Side A	Side B	Side A	Side B	Side A	Side B	
P. hartwegii (Mexico)											
1	.35	.34	.35	.34	.39	.37	.41	.41	.37	.36	.370
2	.29	.30	.32	.32	.37	.36	.41	.42	.35	.35	.348
3	.34	.31	.33	.31	.34	.33	.33	.35	.33	.32	.330
4	.35	.36	.37	.38	.40	.38	.40	.38	.38	.37	.377
5	.34	.34	.32	.33	.36	.40	.38	.40	.35	.37	.358
P. patula (Puebla)											
46	.39	.34	.42	.38	.45	.43	.43	.45	.42	.40	.411
47	.41	.39	.43	.43	.46	.47	.47	.48	.44	.44	.442
48	.40	.39	.40	.39	.49	.46	.48	.43	.44	.42	.430
49	.38	.42	.41	.38	.44	.43	.46	.49	.42	.43	.426
50	.36	.36	.42	.45	.46	.50	—	—	.41*	.44*	.425
P. montezumae (Mexico)											
76	[1]	—	.41	.43	.43	.45	.44	.44	.43*	.44*	.433
77	—	—	—	0	.48	.45	.47	.46	.48*	.46*	.465
78	—	—	—	—	.38	.38	.39	.40	.39*	.39*	.387
79	—	—	.41	.42	.42	.41	.42	.39	.42*	.41*	.411
80	.40	.43	.44	.47	.48	.42	.49	.47	.45	.45	.450

[1]) Values missing because of rot or excessive pitch.
* Tree means with incomplete 10-ring segments.

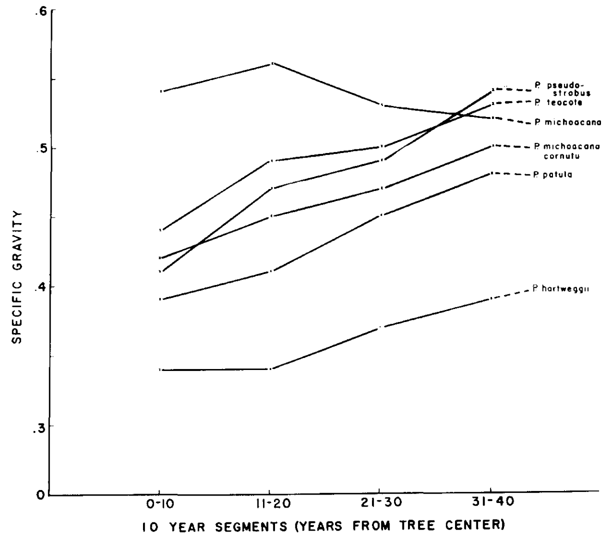

Fig. 1. — Specific gravity of several species of Mexican pines by 10-ring segments from tree center. Note that the species illustrated show the normal trend of low gravity near the tree center, except *P. michoacana*. The dotted lines indicate the specific gravity of the 40+ segments.

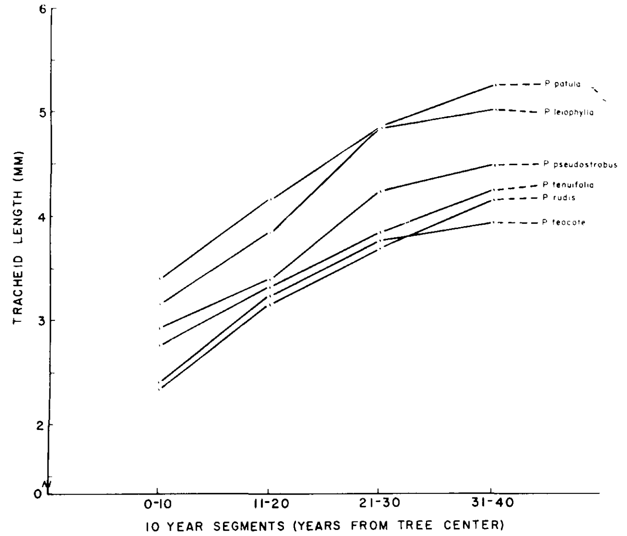

Fig. 2. — Tracheid length of several species of Mexican pines by 10-ring segments from tree center. Note that all species shown follow the general pattern of low tracheid length near tree centeı and longer tracheids outward.

sides of *P. montezumae* (Mexico) and *P. hartwegii* (Mexico) sample trees it was found that the two opposing side values for any individual age-class segments of *P. montezumae* were essentially identical; for example, the 11- to 20-year segment had values of 3.75 mm. and 3.78 mm., and in the 31- to 40-year segment the values were 4.85 mm. and 4.81 mm., respectively. Less consistency was found in *P. hartwegii* in which plot values for the 11- to 20-year segment averaged 2.94 mm. using one core, compared with 3.13 for two cores, or in the 31- to 40-year age segment, one core yielding an average of 1.67 mm. compared with 1.79 mm. for two cores.

Since tracheid lengths in this study were sampled only from one side of each tree, the values are most meaningful as plot averages. Even though the sampling error may be sizeable in some instances, the plot and species differences occurred with values so large and consistent that there can be no doubt that real differences exist.

For most trees, the largest differences were found in the 0- to 10-year segment. This can be attributed to any one of several factors such as compression wood, incipient rot, or in a few instances because the increment boring missed the center of the tree. *P. montezumae* (Mexico) is an example in which the sections near the center of some trees were not usable because of heart rot.

Change in wood qualities with age from tree center:

In most pine species, wood qualities change in a radial direction from the center of the tree outward. For the Mexican pines an estimate of this change for specific gravity and tracheid lengths by 10-ring segments is shown in *Tables 3 and 4*. Most species in this study exhibited the usual pattern of low specific gravity and short tracheids near the center of the tree *(Fig. 1 and 2)*. Surprisingly, this pattern was not evident for specific gravity in *P. oocarpa* and *P. michoacana* (See *Fig. 1 and 3)*. Trees of these two

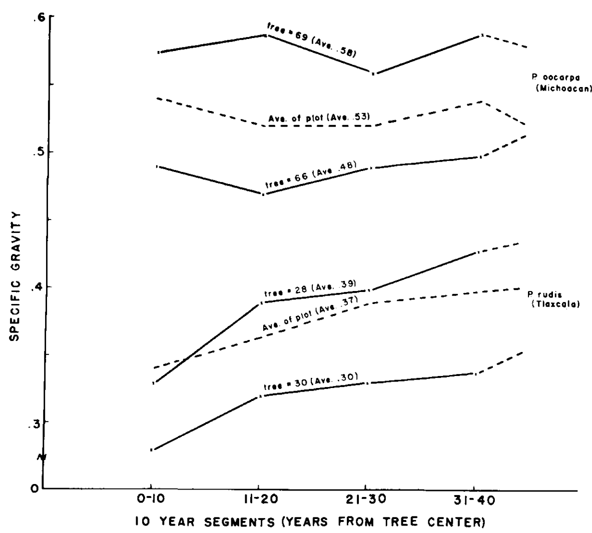

Fig. 3. — Specific gravities of the highest, lowest and average tree per 5-tree plot for two species. These illustrate the large tree-to-tree differences among trees of essentially the same age growing under relatively similar environmental conditions.

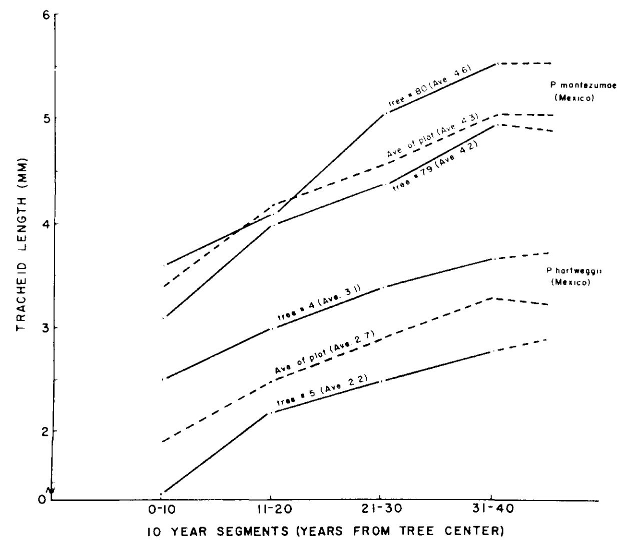

Fig. 4. — Tracheid lengths of the longest, shortest and average tree per 5-tree plot for two species. These illustrate the very large tree-to-tree differences in tracheid length among trees of the same age growing under similar environments.

Table 3. — Specific gravity at breast height.

Group and Species	State	Sample Trees No.	Growth Periods by 10-yr. segments 0-10	11-20	21-30	31-40	Ave.	Sample Trees No.	40+ Sp. Gr.
			Specific Gravity						
Group Montezumae									
P. montezumae	Puebla	5	.39	.43	.47	.48	.44	4	.49
P. montezumae	Puebla	5	.44	.45	.47	.50	.47	5	.49
P. montezumae	Michoacan	5	.39	.42	.45	.45	.42	1	.44
P. montezumae	Mexico	5	.39	.44	.43	.44	.43	5	.46
	Average		.40	.44	.46	.47	.44		
P. montezumae var. *macrocarpa*	Michoacan	2	.41	.52	.55	—	—	—	—
P. michoacana	Michoacan	5	.54	.56	.53	.52	.54	5	.51
P. michoacana var. *cornutu*	Jalisco	5	.39	.43	.46	—	—	—	—
P. cornutu	Michoacan	5	.42	.45	.46	.50	.46	2	.49
P. cornutu	Michoacan	5	.46	.46	.47	.45	.46	1	.46
	Average		.42	.45	.46	.47	.46		
P. hartwegii	Mexico	5	.34	.34	.37	.39	.36	4	.44
P. rudis	Tlaxcala	5	.34	.36	.39	.40	.37	5	.41
P. lutea	Durango	1	.34	.40	.41	.45	.40	1	.44
Group Serotines									
P. oocarpa	Michoacan	5	.54	.52	.53	.51	.53	4	.51
P. oocarpa	Michoacan	5	.44	.47	.46	.43	.45	4	.47
	Average		.49	.49	.49	.47	.49		
P. patula	Tlaxcala	5	.39	.41	.45	.48	.43	4	.45
P. patula	Puebla	5	.39	.41	.47	.47	.44	3	.48
	Average		.39	.41	.46	.47	.43		
Group Pseudostrobus									
P. pseudostrobus	Puebla	5	.39	.44	.47	.49	.45	1	.53
P. pseudostrobus	Michoacan	5	.41	.47	.49	.54	.48	—	—
	Average		.40	.45	.48	.51	.46		
P. tenuifolia or *pseudostrobus*	Michoacan	5	.38	.44	.47	.50	.45	5	.50
P. tenuifolia	Michoacan	5	.42	.42	.45	.45	.44	3	.43
Group Teocote									
P. teocote	Puebla	5	.44	.49	.50	.53	.49	5	.55
P. teocote	Tlaxcala	5	.42	.46	.51	.53	.48	5	.51
	Average		.43	.47	.50	.53	.48		
P. lawsoni	Michoacan	5	.49	.48	.49	.45	.48	—	—
P. lawsoni	Michoacan	5	.51	.53	.55	.55	.53	5	.56
	Average		.50	.50	.52	.50	.50		
P. herrerai	Chihuahua	5	—	—	—	.48	—	3	.49
Group Leiophylla									
P. leiophylla	Puebla	5	.38	.42	.44	.45	.42	—	—
P. leiophylla	Michoacan	5	.36	.41	.44	.42	.41	1	.35
P. leiophylla	Durango	1	.38	.42	.45	.44	.42	1	.43
P. leiophylla	Jalisco	1	.36	.42	.43	—	—	—	—
	Average		.37	.42	.44	.44	.41		
P. chihuahuana	Chihuahua	1	—	.43	.40	.46	—	1	.43
P. lumholtzii	Durango	1	.39	.41	.45	.43	.42	1	.46
Group Ponderosa									
P arizonica	Chihuahua	5	—	.37	.38	.39	—	5	.42
P. durangensis	Durango	1	—	.43	.43	.42	—	1	.43
P. engelmanii	Chihuahua	3	.39	.43	.44	.48	.43	2	.47

species had wood of high specific gravity near the tree center and it remained nearly constant to the bark. For some species, the specific gravity continues to increase to age 40, but others tend to increase rapidly to 20 or 30 years of age, after which they taper off.

Similar comparisons from tree center to bark for tracheid length are shown by the curves in *Fig. 2 and 4.* Almost without exception tracheid lengths increased at least through the 20- to 30-year segments. One species, *P. oocarpa*, however, (not shown in the figure) levelled off at year 30 and did not increase thereafter.

Although the results are based upon data to ring 40, many trees were over 100 years old; on these older trees determination of specific gravity and tracheid length were made and designated as 40+ segments (Last column, *Table 3 and 4).* The specific gravity of the older segments is nearly the same as the 31—40 segment, although examples were found where the values either descreased or increased

Table 4. — Tracheid length at breast height.

Group and Species	State	Sample Trees No.	Growth Periods by 10 yr. segments Tracheid Length 0-10	11-20	21-30	31-40	Ave.	Sample Trees No.	40+
Group Montezumae									
P. montezumae	Puebla	5	2.25	3.13	3.80	4.11	3.32	4	4.41
P. montezumae	Puebla	5	2.30	3.47	4.07	4.38	3.55	5	4.78
P. montezumae	Michoacana	5	3.13	3.90	4.62	5.04	4.18	1	5.56
P. montezumae	Mexico	5	3.44	4.43	4.47	4.85	4.27	5	4.88
	Average		2.78	3.73	4.24	4.59	3.84		
P. montezumae var. *macrocarpa*	Michoacan	2	4.31	4.62	5.09	—	—	—	—
P. michoacana	Michoacan	5	2.61	3.17	3.80	4.32	3.48	3	4.25
P. michoacana var. *cornutu*	Jalisco	5	3.30	4.13	4.39	—	—	—	—
P. cornutu	Michoacan	5	3.18	3.90	4.66	4.44	4.04	2	4.29
P. cornutu	Michoacan	5	3.20	3.77	4.15	4.22	3.83	—	—
	Average		3.13	3.93	4.40	4.33	3.92		
P. hartwegii	Mexico	5	1.92	2.48	2.93	3.33	2.67	3	3.40
P. rudis	Tlaxcala	5	2.42	3.29	3.92	4.23	3.47	5	4.19
P. lutea	Durango	1	2.19	3.13	3.81	3.82	3.24	1	3.77
Group Serotines									
P. oocarpa	Michoacan	5	3.49	4.47	4.55	5.07	4.39	4	5.29
P. oocarpa	Michoacan	5	3.71	4.37	4.56	4.59	4.31	2	4.75
	Average		3.60	4.41	4.55	4.83	4.35		
P. patula	Tlaxcala	5	2.89	3.53	4.26	4.29	3.74	3	4.71
P. patula	Puebla	5	3.32	4.24	4.84	5.25	4.41	3	5.50
	Average		3.10	3.88	4.55	4.77	4.07		
Group Pseudostrobus									
P. pseudostrobus	Puebla	5	2.88	3.53	4.33	4.55	3.81	1	4.87
P. pseudostrobus	Michoacan	5	3.15	4.71	4.71	5.00	4.39	—	—
	Average		3.01	4.12	4.52	4.77	4.11		
P. tenuifolia or *pseudostrobus*[1])	Michoacan	5	3.02	4.36	4.50	4.69	4.14	4	4.38
P. tenuifolia	Michoacan	5	2.68	3.43	3.80	4.44	3.59	3	4.50
Group Teocote									
P. teocote	Puebla	5	3.70	4.07	4.34	4.25	4.09	3	4.26
P. teocote	Tlaxcala	5	2.52	3.43	3.69	3.86	3.37	3	3.72
	Average		3.11	3.75	4.01	4.05	3.73		
P. lawsoni	Michoacan	5	2.44	3.10	3.82	4.58	3.48	—	—
P. lawsoni	Michoacan	5	3.74	4.77	5.31	4.58	4.60	3	5.14
	Average		3.09	3.93	4.56	4.58	4.04		
P. herrerai	Chihuahua	5	—	—	—	4.42	—	4	4.81
Group Leiophylla									
P. leiophylla	Puebla	5	3.00	3.81	4.47	4.15	3.86	—	—
P. leiophylla	Michoacan	5	3.27	3.85	4.82	4.99	4.23	1	4.47
P. leiophylla	Durango	1	2.38	2.76	2.87	2.97	2.75	1	3.42
P. leiophylla	Jalisco	1	3.08	3.94	4.73	—	—	1	—
	Average[2])		3.06	3.75	4.50	4.42	3.92		
P. chihuahuana	Chihuahua	1	—	3.43	3.44	3.48	—	1	3.96
P. lumholtzii	Durango	2	2.85	2.68	4.27	4.92	3.68	1	4.94
Group Ponderosa									
P. arizonica	Chihuahua	5	2.83	3.16	3.63	3.94	3.40	1	4.31
P. durangensis	Durango	3	2.55	3.42	4.05	4.33	3.59	2	4.57
P. engelmanii	Chihuahua	3	3.25	3.61	4.06	4.30	3.80	2	4.53

[1]) Positive identification of these trees was not made although they tended to resemble *P. pseudostrobus*.
[2]) Weighted by nr. of trees.

slightly, being on the average .01 higher than the 31—40 segments. This similarity in values suggests that after 30 to 40 years for most species the specific gravity changes very little.

Tracheid length followed a similar trend, although there was some tendency for a more pronounced increase in the 40+-age segment. Although the over-all tracheid length increase for the older wood was about 0.15 mm., there were, nevertheless, some trees that exhibited a definite decrease. In general, such a small increase makes it appear safe to use the 31- to 40-year segment for most species as a good indication of tracheid length of older wood.

Variation among trees on the same site:

Past study of wood qualities in pines almost always has shown large variations from tree to tree. In this respect, the Mexican pines were found to be no different. The highest and lowest values of specific gravity and tracheid length from the five trees in two plots are presented in *Figures 3 and 4*. This shows that both specific gravity and tracheid length of the most different trees are either high or low in each of the 10-year segments sampled, and their relative magnitude appears to be maintained at all sections throughout the life of the tree. Differences as large as .10 in specific gravity and 1 mm. in tracheid length among trees on a plot are not unusual; on the other hand, an occasional plot with quite uniform trees can be found. For example, in the five-tree sample of *P. tenuifolia* specific gravity values ranged only from .42 to .46, and in a similar sample of *P. rudis* tracheid length varied only from 3.30 mm. to 3.66 mm. Occasionally, as many as four of the five sample trees would turn up to be uniform, but the fifth one greatly different, as, for example, in our sample of *P. teocote*, in which four trees averaged 3.10 mm., one tree, 4.26 mm.

The large variation encountered among individual Mexican pines growing on the same site is not an unexpected finding, but it appears especially prominent in certain species. Although it is recognized that undoubtedly some of the differences observed are not inherent but caused by different micro-sites in which the trees are growing, this variability is most encouraging because, without it, individual tree selection for wood qualities obviously would not be possible.

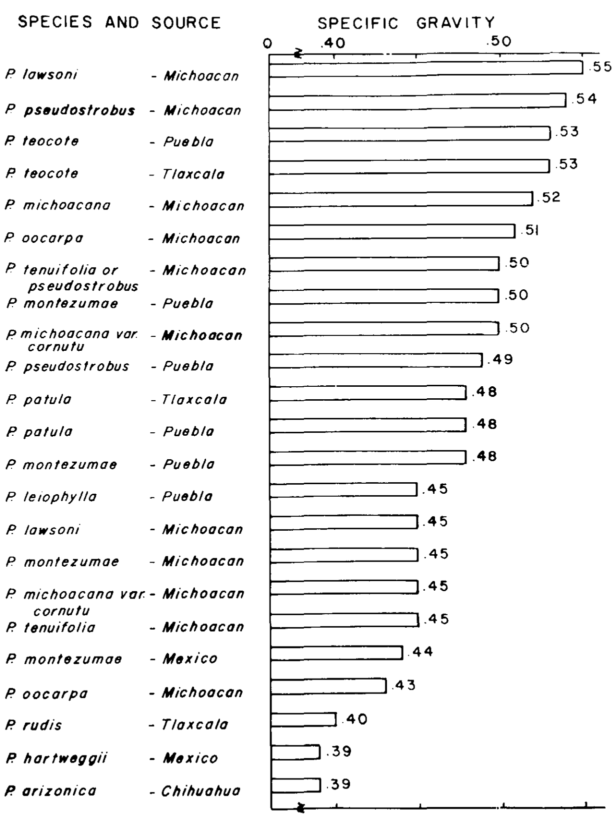

Fig. 5. — Specific gravity of a number of Mexican pine species (growth rings 31—40) are shown graphically in descending order. Note that sometimes the species from different sources are very different (example, *P. pseudostrobus, P. oocarpa*), sometimes the same species from different sources are very similar (example, *P. teocote, P. patula*). Note also the spread among species studied — from .55 to .39, a really large spread.

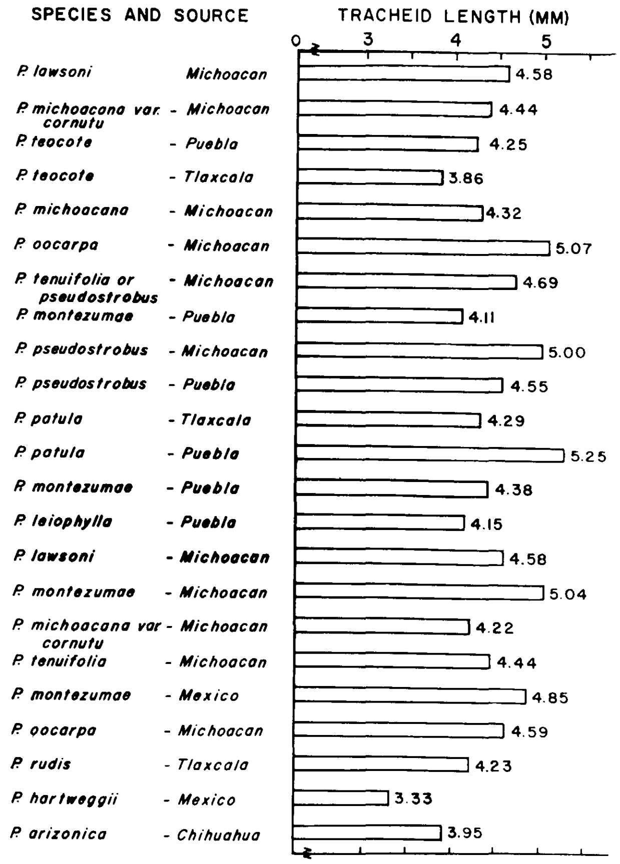

Fig. 6. — Variation in tracheid lengths for rings 31—40 are shown. Trees are arranged in the same order as for *Fig. 5* (descending order of specific gravity). Note that there appears to be little relationship between specific gravity and tracheid length. Note also the very large spread in values of 3.33 to 5.25.

Variation within a species from different sites:

A major contribution of this study, and indeed perhaps the most important one, is the clear evidence of variability within a species when grown on different sites or geographic areas. This evidence gainsays statements in the literature that a certain species has certain wood qualities, statements that not only have little meaning but that may actually be misleading. Without defining the habitat where the sample of the species was obtained, a proper interpretation of its value cannot be made. Frequently, two different species of Mexican pines from the same area are found to have wood more similar than the same species from different areas (see *Fig. 5*). Thus, specific gravity of *P. montezumae* from Puebla favors *P. patula* from Puebla definitely more than *P. montezumae* from Mexico *(Table 3)*. But the reverse may also occur, as is illustrated by *P. patula* in which specific gravity from the Puebla source is very similar to that from the Tlaxcala source, and by *P. montezumae* which is essentially the same from Puebla as from Michoacan.

Among sources within a species, differences of similar magnitude exist for tracheid length as for specific gravity, although the pattern may be different *(Fig. 6)*. For example, in *P. patula* from both Tlaxcala and Puebla specific gravities are identical but their tracheid lengths differ considerably. Conversely, tracheid lengths in *P. oocarpa* from

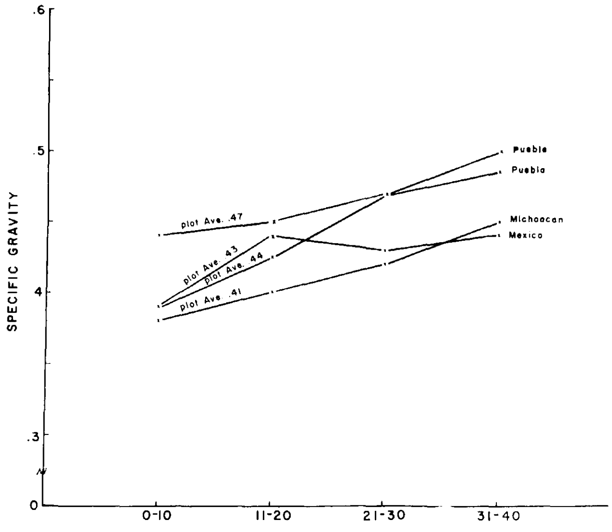

Fig. 7. — Specific gravity of *Pinus montezumae* grown in four different areas, showing the variation within a species when grown in different areas. It is also of special interest that the specific gravity of this species obtained from the state of Mexico did not show an increase in specific gravity beyond the 20th annual ring from tree center, while the others increased through the 40th ring.

two areas in Michoacan are quite similar but their specific gravities are greatly different. To emphasize these differences, the specific gravity and the tracheid length are shown for *P. montezumae* growing at four different locations *(Figs. 7 and 8)*.

Neither specific gravity nor tracheid length appear strongly related to altitude of site or to growth rate. It is difficult to make any definitive statement about the effect of elevation or growth rate because of confounding of effects.

Variation among species:

It has been a common assumption that any major differences in wood qualities are ascribable to species. Often

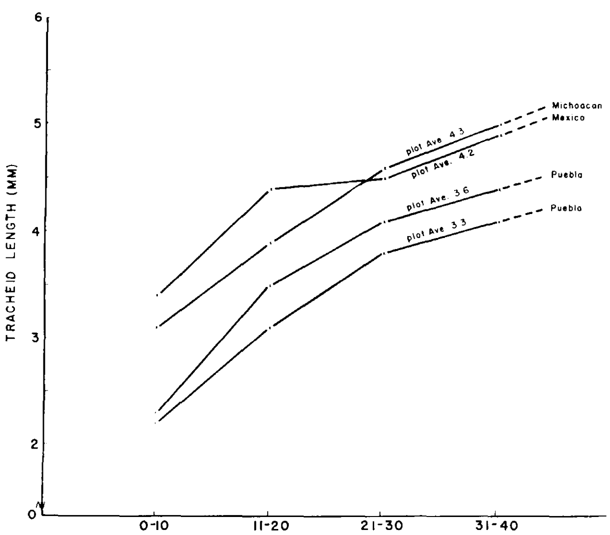

Fig. 8. — Tracheid length of *Pinus montezumae* grown in four different areas, showing the variation within a species when grown in different areas. Note that the short tracheid trees remained short throughout their whole life. The dotted lines represent tracheid lengths of the 40+ segments.

this assumption does not hold true; it is quite possible to find more tree-to-tree differences within a species on a given site and more differences among stands of the same species from different areas than there are between species *per se.* This within species variability makes assessment of species differences based on only one or two trees relatively meaningless. To illustrate, had we sampled only tree no. 78 of *P. montezumae* (Mexico), we might have concluded that this species has a specific gravity of 0.36; but if by chance we had sampled only no. 80 from the same plot, we might have judged the specific gravity of this species to be 0.45. Similarly, we might have classed *P. tenuifolia* as a long-fibered species (4.20 mm.) basing our judgment on a sample from tree no. 517, but a short-fibered tree (3.10 mm.) if based on tree no. 519 from the same plot. Meager sampling will almost certainly lead to such errors, yet over and over again it is possible to find in published data species categorization based on only one or, at best, very few individual trees. In the pines we have studied, a sample of 20 to 30 individuals appears necessary to categorize a stand with respect to specific gravity. Within species differences in the Mexican pines are similar to those encountered in our southern pines and are shown graphically in *Fig. 5 and 6.* This emphasis on the variation within species is not meant for down-grading the importance of real species differences but merely to call attention to the fact that often species differences may actually be a reflection of sampling position in the tree or of the site quality on which the trees were growing.

An even more common error in species classification is to sample trees from only one habitat or greographic area, then assume that the results apply to the species wherever it may occur. *P. montezumae (Fig. 7 and 8)* clearly illustrates stand differences that can lead to erroneous conclusions where stand sampling is too limited. Stand-to-stand differences in tracheid lengths are similarly evident for *P. lawsoni* in Michoacan, where in one stand the tracheid length averaged 4.60 mm. but in another one only 3.48 mm. Additional evidence of stand variation is dramatically shown by *P. oocarpa* from Michoacan, for which one plot averaged 0.53 in specific gravity but another in the same province only 0.45.

High specific gravity or long tracheids in a species in its native habitat provide no assurance that these characteristics will be retained when the same species is introduceo to another area. A delicately balanced genotype-environment interaction occurring with the change in environment may alter the quality of the wood produced in the new habitat. Such interactions make use of non-native sources not so simple as has been often supposed. Mere choosing of a species with desired wood and assuming that the desired qualities will be retained in the new habitat can lead to disappointing results; only progeny tests can give the final answer, yet in countless instances the bases on which exotic species have been introduced have rested on such tenuous assumptions. It is only when the new habitat is as similar as possible to the native one that the chances grow larger for the wood produced by the exotic to be similar to that at its source.

Neither previously reported research on Mexican pines nor this study provides any basis for making blanket statements about the quality of the wood of any one species as an entity. In fact, in any area such as Mexico with its very diverse habitats it may never be possible to do so except for a few species. To be valid, any statement on the wood qualities of a species must be accompanied by a description of the location on which the stand is growing.

Wood Qualities of the Mexican Pines

Another major objective of this study was to obtain a preliminary estimate of the wood qualities of the Mexican pines for comparison with other pines. Although specific gravities had a wide range, the highest values still were found to be considerably lower than for certain pines of the Southeastern United States and in the Caribbean. On the other hand, tracheid lengths of several sources were on the long end of the scale, with occasional trees such as no. 528 *(P. lawsoni)* averaging 5.25 mm. and having individual tracheids as long as 8 mm. In one *P. oocarpa* tree (no. 68) the tracheids in all measured 10-year age segments averaged longer than 5.1 mm. with some as long as 8.5 mm. (See *Fig. 9*). On comparable sections the tracheids in tree no. 70 in the same plot averaged less than 3.5 mm. in length. The majority of the samples from *Pinus patula* had only moderately long tracheids, but one tree had unusually long tracheids, some being nearly 7.0 mm. in length. Samples from certain plots of several species, especially *P. hartwegii*, had very short tracheids.

Comparison of results with other studies:

Search of literature for data on specific gravity and tracheid lengths failed to yield more than rough comparisons with results of this study. In most instances the age of sample trees, the condition of the tracheids whether whole or cut, the nature of the averages whether weighted or simple arithmetic, were not revealed in the published papers. Usually the source of the species was not indicated nor the number of trees on which the estimate was based.

Since published data was most abundant for *P. patula*, values from literature are listed in *Table 5* below to provide a rough basis for comparison with present results.

Considering the large differences both in age and in habitat that probably existed among sample trees in these determinations, the specific gravity of *P. patula* is not too different whether grown in Mexico or Africa. Although the exact source of seed for the African plantations was not given, Scott and Stephens state:

"The strain is infinitely more important a factor than either site or rate of growth....." By this, the authors apparently imply *individual variation,* and they go on to say "One of the main reasons why difficulty has been experienced...... has been the considerable difference that exists in any one plantation even between trees of the same size and age when growing under identical conditions." Their reported individual tree values ranged from 27 to 35 lbs. per cu. ft.

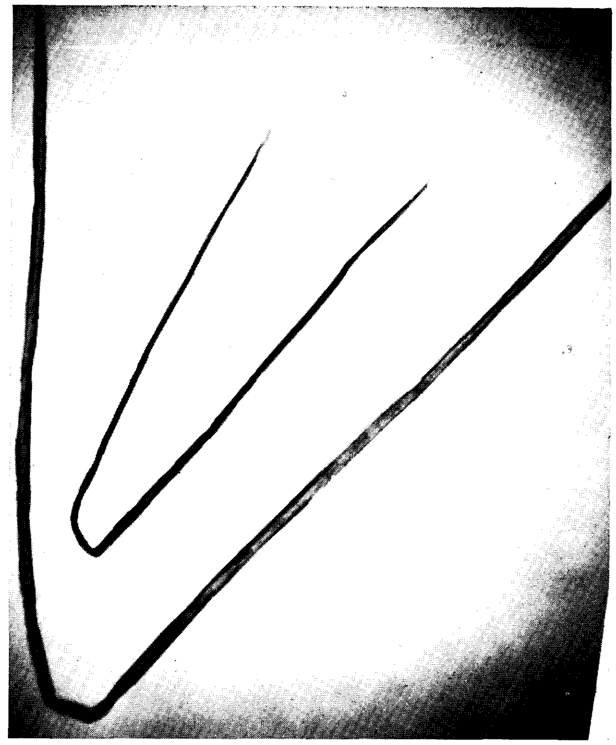

Fig. 9. — Tracheids from tree no. 68 *(P. oocarpa)* were long, being nearly 8.5 mm. in length. Here a long tracheid is compared with a tracheid from a *P. taeda* of the southeastern United States. Over-all, tracheids of the Mexican pines were rather long, although *P. hartwegii*, for example, had short tracheids.

Quite recently Schafer and Chidester (1961) reported on wood qualities and pulp and papermaking potentials of nine Mexican pine species. Their data are based on 15 logs per species, but they did not report position of samples in the trees. Later, Villasenor (1962) summarized specific gravities of several species investigated during the Latin American Conifer Seminar and Study Tour. His results are tabulated below, along with results from the courrent study and those of Schafer and Chidester (1961) *(Table 6)*.

In a special investigation on *P. oocarpa* in the Republic of Honduras (Schafer and Chidester, 1961), wood qualities were obtained for trees of different ages from two different geographic locations. These data are compared with the species from Mexico as shown in *Table 7* below.

Data from the current study are all from samples extracted at 4.5' and averaged. Specific gravity was determined on extractive free samples. In some of the other

Table 5. — Specific gravity of *Pinus patula* wood grown in several locations.

Source of Information	Specific Gravity	Location	Sample Trees	Age of Trees
			No.	*Yrs.*
Current Study	.43	Tlaxcala (Mexico)	5	40
Current Study	.44	Puebla (Mexico)	5	40
Villasenor	Less than .45	(Mexico)	—	—
Eckbo	.34	Cedara (South Africa)	—	10
Eckbo	.38	Belfast (South Africa)	—	10
Scott and Stephens	.36 (calculated)	East Transvaal (South Africa)	20—30	30
Scott and Stephens	.38 (calculated)	East Transvaal (South Africa)	20—30	30
Scott and Stephens	.42 (calculated)	East Transvaal (South Africa)	20—30	30
Fry and Chalk	.37 earlywood			
	.47 latewood			
	.40 (approx.)	Kenya	23	13
Banks and Schwegmann	range .36—.50	South Africa	—	19 and 23

Table 6. — Specific gravity comparisons of several species of Mexican pines.

Species	Location	Specific Gravity		
		Current Study (1963)	SCHAFER and CHIDESTER (1961)	VILLASENOR (1962)
P. tenuifolia	Michoacan	.45	.44	less than .45
P. montezumae	Puebla	.44 and .47	—	—
P. montezumae	Michoacan	.42	.40	less than .45
P. montezumae	Mexico	.43	—	—
P. leiophylla	Puebla	.42	—	—
P. leiophylla	Michoacan	.41	.45	"heavy"
P. teocote	Puebla	.49	—	—
P. teocote	Tlaxcala	.48	—	—
P. teocote	Michoacan	—	.45	"hard"
P. pseudostrobus	Puebla	.45	—	—
P. pseudostrobus	Michoacan	.48	.38	less than .45
P. michoacana	Michoacan	.54	.49	more than .45
P. lawsoni	Michoacan	.48 and .53	.49	more than .45

Table 7. — Specific gravity and tracheid length of *P. oocarpa* from Honduras and Michoacan, Mexico.

Location	Age of Log	Rings/ Inch	Specific Gravity	Tracheid Length
	Yrs.	No.		
Gualco, Honduras	22.1	7.8	.45	—
La Union, Hond.	24.6	5.1	.47	4.81
Michoacan[1])	41	7.8	.49	—
Gualco, Hond.	43.8	7.4	.52	4.59
Michoacan[2])	52	2.6	.53	4.39
La Union, Hond.	53.5	10.7	.48	—
Michoacan[2])	72	2.7	.45	4.31
?[3])	—	—	.46—.52	5.70
?[4])	—	—	.45—.52	—

[1]) SCHAFER and CHIDESTER
[2]) Current Study
[3]) VILLASENOR
[4]) PRATS-LLAURADO

studies, resins may not have been extracted; in addition, their data are based on whole-tree composites or on individual logs of unknown age or position from the tree. At any rate, for proper interpretation in all of the above tables, differences in age and method of obtaining samples must be kept in mind.

In most instances, the comparisons cited here show rather good relationships when differences in basic sources or methods of sampling are considered. The results from *P. patula* from South Africa showed this species (source unknown) to have quite usable wood. Similar results from known provenances grown in different habitats are needed as a further guide in selection of the proper area from which seed should be obtained.

Summary

In 1962, two large increment core wood samples were obtained from 145 individual trees representing approximately 20 species or subspecies of Mexican pine. Five tree plots of each species were obtained, and in a number of instances several plots were taken to represent a species growing in different habitats.

Two wood properties, specific gravity (or basic density) and tracheid length, were measured. Each increment core was divided into 10-ring segments up to 40 rings, beyond which the wood was handled as a unit. Only whole tracheids were measured, and specific gravity was determined on extractive free (by use of alcohol-benzene) wood.

Tree-to-tree variation was large — larger than in most species of pines. It was not unusual to find as much as 1 mm. difference in tracheid lengths among trees of the same plot or specific gravity differences as large as 0.10 among the 5 trees. Considerable plot-to-plot differences were found. No pattern was evident — in some instances plots of the same species from distant areas were similar, while in other instances there was more uniformity between plots of different species growing together than between plots of the same species. These studies clearly showed the danger of assuming that any value represents a species and point up the necessity of defining location as well as species.

Specific gravity of the Mexican pines varied greatly but did not approach as high values as those in the southeastern United States or in the Caribbean. Conversely, tracheid lengths were often very great, and tracheids 8 mm. in length were found in trees of several species. However, species such as *P. hartwegii* had relatively short tracheids.

Most species showed the same trend with age from pith common in pines from other areas. There were exceptions, however, in which specific gravity was as high in the 0—10 segment as at greater distance from tree center, a pattern rather unique in pine. Conversely, tracheid length was always low at tree center and increased to the 31—40 segment. Here, some species levelled off.

An attempt was made to compare results of this study, with those of other published data on wood of the Mexican pines, including species grown in Africa. Although differences were evident, quite good comparisons were obtained when one considers the different ages and growth conditions of the trees being compared.

The Mexican pines show a remarkable variation in wood properties, among trees, among stands, among sites within species, and among species. Wood with nearly any desired qualities for softwoods can be found among the Mexican pines.

Résumé

Titre de l'article: *Variation de la densité et de la longueur des trachéïdes pour plusieurs espèces de pins mexicains.*

En 1962, on a prélevé sur 145 arbres représentant environ 20 espèces ou sous-espèces, 2 carottes à la tarière de fort diamètre. Pour chaque espèce, on a choisi 5 placeaux, et dans un certain nombre de ces plusieurs placeaux ont été pris pour représenter une espèce poussant dans différents habitats.

On a mesuré caractères du bois: densité et longueur des trachéïdes. Chaque carotte était divisée en segments de 10 à 40 accroissements, avec un seul segment pour la partie restante. On a mesuré seulement les trachéïdes entières et

la densité a été déterminée sur le bois après extraction à l'alcool benzène.

La variation individuelle est élevée, plus que dans la plupart des autres espèces de pins. On a trouvé de façon courante des différences jusqu'à 1 mm pour la longueur des trachéïdes entre les arbres d'un même placeau et des différences jusqu'à 0,10 pour la densité. On a également trouvé des différences considérables d'un placeau à l'autre. Il ne semble pas qu'il existe un type de variation régulière: dans certains cas, les placeaux de la même espèce mais de régions différentes ont donné des résultats analogues, tandis que dans d'autres cas les placeaux de différentes espèces poussant ensemble ont été plus uniformes que les divers placeaux d'une même espèce. Ces études montrent clairement qu'il est imprudent d'attribuer une valeur pour les caractères mesurés à une espèce et qu'il est nécessaire de définir le lieu d'origine aussi bien que l'espèce.

La densité des pins mexicains varie beaucoup et n'atteint pas les valeurs élevées que présentent les pins du sud-est des Etats-Unis ou de la zone caraïbe. Par contre, les longueurs des trachéïdes sont souvent très élevées et on a pu trouver des trachéïdes de 8 mm pour plusieurs espèces. Cependant, des espèces telles que *P. hartwegii* ont des trachéïdes relativement courtes.

La plupart des espèces montrent, comme les pins des autres régions, un gradient dans les caractères des accroissements suivant leur âge. Il y a cependant des exceptions: densité aussi élevée dans le segment 0 — 10 que plus loin du centre, type de variation presque unique chez les pins. Par contre, la longueur des trachéïdes est toujours faible près du centre de l'arbre et augmente jusqu'au segment 31 — 40.

On a essayé de comparer les résultats de cette étude avec ceux des autres travaux publiés sur le bois des pins mexicains, y compris les espèce introduites en Afrique. Bien qu'il existe des différences manifestes, on a pu obtenir un certain parallélisme pour des âges et des conditions de croissance comparables.

Les pins mexicains manifestent une variation remarquable des propriétés du bois suivant les arbres, suivant les peuplements, suivant les stations et suivant les espèces. On peut trouver chez ces pins des bois qui présentent presque toutes les qualités requises pour les bois tendres.

Zusammenfassung

Titel der Arbeit: *Variation im spezifischen Gewicht und in der Tracheidenlänge bei mehreren mexikanischen Kiefern.*

1962 wurden von 145 Einzelbäumen, die zu etwa 20 Arten oder Unterarten gehörten, 2 große Bohrspäne genommen. 5 Bäume je Art wurden als Proben verwendet, und bei einer Reihe von Beispielen kamen die Proben von mehreren Plätzen, die dann verschiedene Standorte repräsentierten.

2 Holzeigenschaften, spezifisches Gewicht und Tracheidenlänge wurden festgestellt. Jeder Bohrspan wurde in 10-Ring-Segmente eingeteilt bis zu 40 Ringen, über die hinaus das Holz als Einheit behandelt worden ist. Nur ganze Tracheiden wurden gemessen, und das spezifische Gewicht wurde an extraktfreiem Holz bestimmt.

Die Variation von Baum zu Baum war groß; größer als bei den meisten Kiefernarten. Es war nicht ungewöhnlich, Unterschiede in den Tracheidenlängen von 1 mm bei den Bäumen derselben Probe zu finden oder Unterschiede im spez. Gewicht von 0,10 bei den 5 Bäumen. Beachtliche Unterschiede wurden auch zwischen den Proben gefunden. Bei manchen Beispielen waren die Proben derselben Species aus entfernten Gebieten ähnlich, bei anderen war mehr Uniformität bei Proben verschiedener, zusammen erwachsener Arten, als bei Proben der gleichen Species. Diese Untersuchung zeigt deutlich, wie gefährlich es ist anzunehmen, daß jeder Wert schon die Species repräsentiert, und weist auf die Notwendigkeit hin, sowohl den Standort wie die Species genau zu bestimmen.

Das spez. Gewicht der mexikanischen Kiefern variiert stark, es erreicht aber nicht die Werte der Kiefern der SO-Staaten oder der karibischen Kiefern. Umgekehrt waren oft die Tracheidenlängen sehr groß; 8 mm Länge wurde bei mehreren Arten gefunden. Arten, wie *Pinus hartwegii,* hatten aber nur relativ kurze Tracheiden.

Die meisten Arten zeigten den bei Kiefern allgemeinen Alterstrend. Es gab auch Ausnahmen davon, bei denen das spez. Gewicht in den ersten 10 Segmenten genau so groß gewesen ist wie bei den späteren. Im anderen Fall war die Tracheidenlänge stets im Zentrum niedrig und stieg zum 31.—40. Segment hin an.

Versucht wurde, diese Ergebnisse mit anderen an mexikanischen Kiefern gewonnenen zu vergleichen, ebenso mit solchen, die von in Afrika gewachsenen stammten. Obwohl die Unterschiede evident waren, ließen sich doch gute Vergleiche erzielen, wenn man die zu vergleichenden verschiedenen Altersstufen und Wachstumsbedingungen der Bäume in Rechnung gestellt hat.

Die mexikanischen Kiefern zeigen eine bemerkenswerte Vielfalt in ihren Holzeigenschaften bei Einzelbäumen, bei Beständen, bei unterschiedlichen Standorten und bei den Species. Holz mit beinahe jeder erwünschten Weichholzqualität kann unter den mexikanischen Kiefern gefunden werden.

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Effects of Inbreeding in Red Pine, Pinus resinosa Ait.

II. Pollination Studies[1])

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Introduction

The effect of inbreeding in normally cross-fertilized organisms is to increase the homozygosity of such organisms. Most organisms carry within their genomes recessive genes, many of which are deleterious when present in a homozygous condition. Inbreeding of such organisms considerably increases the frequency of individuals homozygous in respect to rare deleterious genes.

Recessive genes are, of course, not all deleterious although under "normal conditions" many of them are. These same genes are the building blocks of evolution. A deleterious gene may actually become advantageous in improving an organism's utilization of a changed environment. A species is considered to have a better evolutionary potential when it carries a large amount of genetic variability. Such a species is plastic and able to survive with, or even to capitalize on environmental change.

The genus *Pinus*, in general, is composed of species depending on cross-fertilization for the production of normal progenies. Abundant support for this statement has been obtained from self-pollination studies with *Pinus* species (AUSTIN, 1937; BINGHAM and SQUILLACE, 1955; DENGLER, 1932, 1939; DUFFIELD and STOCKWELL, 1949; EHRENBERG and SIMAK, 1957; JOHNSON, 1945; KOLESNIKOFF, 1929; MAGINI, 1956; MERGEN, 1954; PERRY, 1960; PETERS and GODDARD, 1961; PLYM FORSHELL, 1953; RIGHTER, 1958; SARVAS, 1962; SQUILLACE and BINGHAM, 1954; TOYAMA, 1950; WETTSTEIN, 1940; and WRIGHT and GABRIEL, 1958). All of the *Pinus* species studied have proven to be partially self-fertile and self-compatible, although some authorities have reported instances of apparently completely self-sterile trees. Individual trees of several of the species studied have actually been found to be highly self-fertile and self-compatible (BINGHAM and SQUILLACE, 1955; DENGLER, 1932; EHRENBERG and SIMAK, 1957; MAGINI, 1956; PLYM FORSHELL, 1953; SQUILLACE and BINGHAM, 1954; TOYAMA, 1950).

Studies of the effects of inbreeding in red pine are almost non-existent. JOHNSON (1945), on the basis of self- and cross-pollination on a single tree, reported that self-pollination resulted in a reduced seed set. Seed lots from four isolated red pine trees, which probably resulted from natural self-pollination, were included among the 37 provenances studied by RUDOLF (1947). Although RUDOLF did not single out the "selfed" progenies for comparisons, it is quite evident from his data that these progenies did not differ appreciably from progenies of the other, presumably cross-pollinated trees. Two of the former seed lots were included among the 50 lots tested at Kane, Pennsylvania (HOUGH, 1952).

Table II — 1 shows the ranking of the four "selfed" progenies among the 37 provenances studied by RUDOLF (1947) as well as the ranking of two of these seed sources in relation to the 46 to 49 seed sources studied by HOUGH (1952).

Inbreeding, especially self-pollination, is a useful method of determining the genetic variability of an individual and has been suggested as a method of testing selected trees (AUSTIN, 1927, 1937; HEITMÜLLER, 1957; KOLESNIKOFF, 1929; LANGNER, 1951; MERGEN, 1954; SCHREINER, 1953; and SCHRÖCK, 1957).

[1]) Contribution 64 — 6. Ontario Department of Lands and Forests. This paper is the second in a series based on a dissertation submitted to the Graduate School of Yale University as partial fulfillment of the requirements of the PhD degree in 1963.

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Table II — 1. — Ranking of Red Pine Progenies. — Presumably Resulting from Self-pollination.

Collection Number	Climatic Region	Survival	Height	Diam. b. h.	Basal Area/ Acre	Unpeeled Volume/ Acre	Good Form	Better Dom. and Codom. Trees	Premium Trees
Rank out of 37 Progenies — Trees 16 years old — RUDOLF (1947)									
24	Head of Lake	6	23	28	14	19	4	18	3
74	Brainerd Cameron	3	6	5	11	3 or 4	15	16	21
75	Brainerd Cameron	8	19	23	15	17	17	6	2
82	Lower Michigan	34	21	24	32	31	19	20	19

Rank out of 49 or 46 Progenies — Trees 10 years old — HOUGH (1952)

		Germination 49 Provenances	Survival 46 Provenances	Height 46 Provenances
74	Brainerd Cameron	6—8	38	25
75	Brainerd Cameron	19—20	31—34	8