PERFORMANCE OF EASTERN WHITE PINE FROM THE SOUTHERN APPALACHIANS IN EASTERN UNITED STATES, NEW ZEALAND, AND AUSTRALIA

by

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ABSTRACT -- Seeds of eastern white pine were obtained from 177 native trees located in 49 stands scattered from Maryland south to Georgia. The resulting seedlings were planted in 15 replicated plantations located in six eastern or midwestern states and two foreign countries. The trees were measured at ages 7 to 11 from seed. In most plantations mortality varied from 1 to 25%, reaching 43% in two places. At every place except central Michigan and Victoria, Australia, growth was rapid, many trees growing 1 m per year after their sixth year. Although average temperature during the coldest month varied from -7° C to +8° C at the 15 test sites, results were remarkably similar. Trees from Georgia, parts of North Carolina and Tennessee grew most rapidly and trees from Virginia, West Virginia and Maryland grew most slowly wherever they were tested. In other words, the same seedlots as recommended for southern Michigan or Nebraska would be the best ones to plant in New Zealand. There was so little pest damage at any test site that possible differences in pest resistance were not evaluated. Through the 11th year, cone production was light or nil. The experiments can be converted into seedling seed orchards by removal of the poorest half-sib families.

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In 1957 the U. S. Forest Service started a large cooperative provenance test of eastern white pine *(Pinus strobus)* in which trees grown from seed collected in all parts of the range were planted at many different locations in northeastern United States and adjacent Canada (1, 4, 16). In 1961 a new experiment, including more seedlots but fewer plantations, was started by Genys of the University of Maryland (5, 6). Early results from both experiments showed trees from part of the southern Appalachians to be especially rapid growing.

Those early results prompted the undertaking of the present experiment, in which southern Appalachian white pine was sampled much more intensively than before. Briefly, the present experiment consists of a series of combined half-sib progeny and provenance tests which include the offspring of 177 different wild parent trees located in 49 stands from Maryland south. The test plantations are limited to areas in southern Michigan and southward because earlier experience (2, 7) had shown southern Appalachian trees not to be winter hardly under sever winter conditions.

MATERIAL AND METHODS

Seeds were collected from natural stands in the southern Appalachian mountains from 1964 to 1966. In all, 177 seedlots were collected. Of these, 28 represent collections from several (usually 10) trees in a stand. The remaining 149 represent single trees in 21 other stands. Thus, a total of 49 stands are represented. In all but two of the stands, the seeds were collected from average trees. The location of the parental stands is given in Table 1 and Fig. 1.

In 1965, portions of many seedlots were sent to cooperators in West Virginia, Tennessee, New Zealand and Australia. These cooperators raised their own nursery stock *and* established *test plantations at various* dates. The remaining seeds were sown in an experimental nursery in East Lansing, Michigan in autumn 1966 and germinated spring 1967. The sowing density was such as to result in about 50 trees per square foot. The nursery experiment followed a randomized complete block design with four replications, with each seedlot represented by one 1.2 m row in each block.

In 1969, seedlings were lifted from the East Lansing nursery and used to establish two test plantations in Michigan or shipped to cooperators in Ohio, Indiana, Illinois and Nebraska. Most cooperators lined the stock out for additional year and planted it as 2+1 stock. In 1970, two more plantations were established with 3+0 stock in Michigan.

Table 1. Origin data for the eastern white pine seedlots represented in the southern Appalachian provenance test.

Map no.	Original numbers, MSFG-	State and county of origin		North latitude		West longitude		Elevation (ft)
				°	′	°	′	
1	3513-3521	Georgia	Fannin	34	35	84	10	1500
2	3542-3544	Georgia	Fannin	34	44	84	09	2000
3	3545	Georgia	Union	34	43	84	06	2400
4	3546	Georgia	Rabun	34	52	83	19	1800
5	3547	Georgia	Rabun	34	49	83	31	—
6	3548	Georgia	Rabun	34	54	83	30	—
7	3421	North Carolina	Macon	35	06	83	12	4000
8	3522-3531	North Carolina	Cherokee	35	10	84	10	1500
9	3438-3443	North Carolina	Henderson	35	10	82	50	—
10	3452	North Carolina	Graham	35	20	83	52	2000
11	3436-3437	North Carolina	Buncombe	35	20	82	50	—
12	3409-3418	North Carolina	Buncombe	35	30	82	30	—
13	3428-3435	North Carolina	Yancey	35	45	82	25	1800
14	3551	North Carolina	Madison	35	50	82	40	2000
15	3552	North Carolina	Burke	35	50	81	30	1200
16	3422	North Carolina	Burke	35	57	81	51	—
17	3423	North Carolina	Caldwell	36	00	81	46	—
18	3483-3492	North Carolina	Burke	35	52	81	46	1200
19	3493-3502	Tennessee	Polk	35	00	84	25	1500
20	3503-3512	Tennessee	Monroe	35	20	84	10	1800
21	3532-3541	Tennessee	Anderson	36	00	84	10	900
22	3420	Tennessee	Carter	36	20	82	04	—
23	3597	Virginia	Carroll	36	30	80	30	1800
24	3596	Virginia	Amherst	37	30	79	00	1800
25	3407	Virginia	Montgomery	37	14	80	27	—
26	3419	Virginia	Craig	37	35	80	09	2700
27	3470	Virginia	Botetourt	37	31	79	37	1500
28	3550	Virginia	Alleghany	37	48	79	43	1500
29	3471	Virginia	Augusta	38	20	79	20	2000
30	3475-3476	Virginia	Rockingham	38	40	79	00	1500
31	3447-3450	Kentucky	Whitley	36	45	84	15	900
32	3479	West Virginia	Greenbrier	37	48	80	03	2500
33	3408, 3425	West Virginia	Greenbrier	37	50	80	00	2100
34	3480	West Virginia	Greenbrier	37	54	80	08	2300
35	3460-3464	West Virginia	Greenbrier	37	58	80	08	2000
36	3465-3469	West Virginia	Greenbrier	37	59	80	01	2700
37	3564-3569	West Virginia	Greenbrier	38	00	80	14	—
38	3427	West Virginia	Mercer	37	50	81	02	2500
39	3477	West Virginia	Pocahontas	38	07	80	02	2700
40	3478	West Virginia	Pocahontas	38	08	80	00	2500
41	3549	West Virginia	Pocahontas	38	10	80	00	2000
42	3590-3595	West Virginia	Pocahontas	38	20	79	53	—
43	3453-3459	West Virginia	Pocahontas	38	28	79	48	2800
44	3424-3426	West Virginia	Tucker	39	05	79	50	1600
45	3580-3589	West Virginia	Braxton	38	45	80	30	—
46	3554-3563	West Virginia	Pleasants	39	25	81	07	—
47	3570-3579	West Virginia	Wetzel	39	30	80	45	—
48	3482	Maryland	Garrett	39	30	79	25	2300
49	3553	Ohio	Monroe	40	00	81	00	400

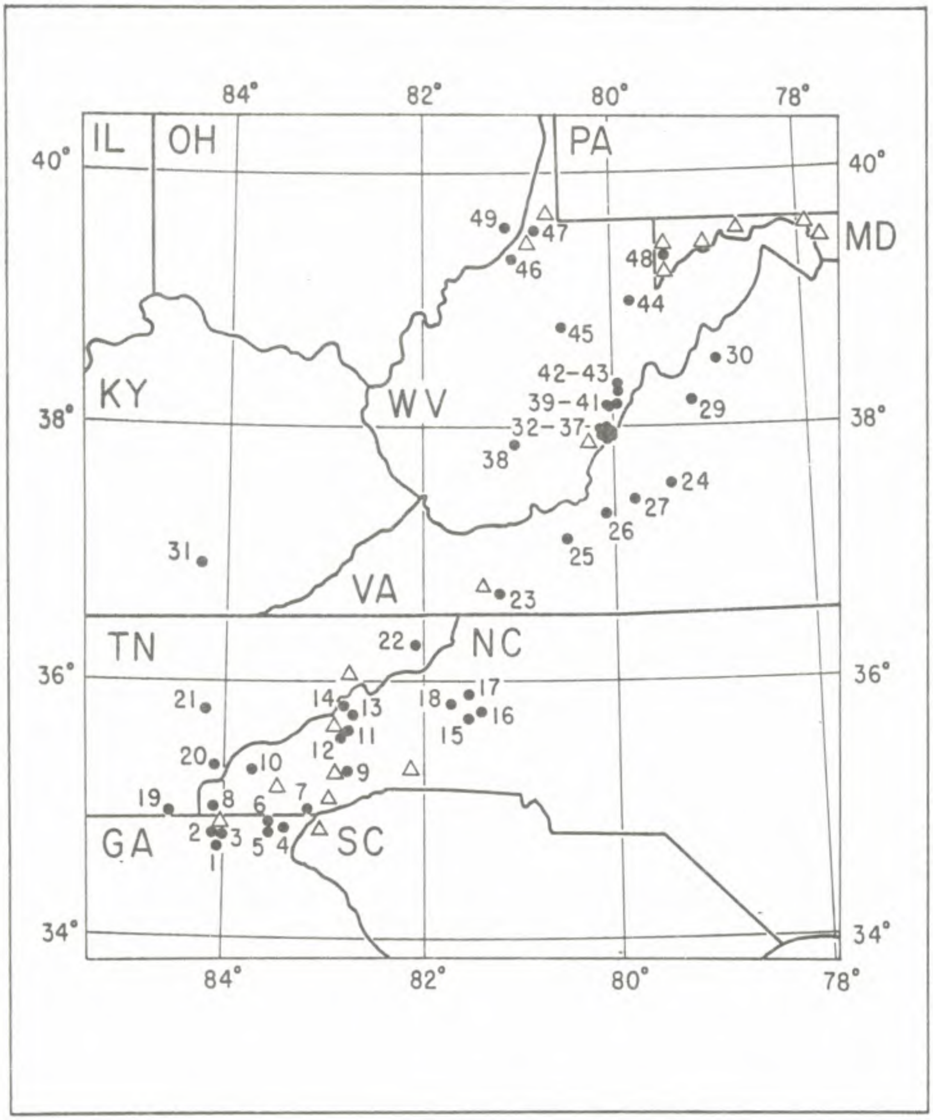

Figure 1. Location of eastern white pine parental stands whose offspring were tested in the present experiment (numbered dots) and previous experiments (triangles).

All the test plantations follow randomized complete block designs with 3-10 replications and 2-10 tree plots. In the New Zealand and Australian plantations all seedlots were bulked by stand of origin. At the other locations the identity of many seedlots was maintained by tree as well as stand or origin. Weed control varied from moderate to excellent. Further details of the plantations are given below and in Table 2.

W.K. KELLOGG FOREST near KALAMAZOO, KALAMAZOO COUNTY, MICHIGAN. Lat. 42.2 N, Long. 45.2 W, elev. 270 m. Temperature: ave. Jan. -4°C, ave. July 23°C, absolute minimum -32° C. Prec. 860 mm, lowest in winter. Weeds controlled by spraying 60-cm strips with amino-triazole (10 liter/ha) prior to planting and simazine (4.5 kg/ha) after planting. An old field with a gentle south slope and a sandy loam soil, previously in grass up to 1 m tall. Spacing 2.4 X 2.4 m.

FREDRUSS FOREST near DOWAGIAC, CASS COUNTY, MICHIGAN. Lat. 42.0° N. long. 86.0° W, elev. 280 m. Temperature: ave. Jan. -4° C, ave. July 23° C, absolute minimum -30° C. Prec. 880 mm, lightest in winter. North and south slopes of 10-15%, previously in mixed hardwood forest of the beech-maple type, soil sandy loam. Weed control and spacing as at Kellogg Forest.

HIDDEN LAKE GARDENS near TIPTON, LENAWEE COUNTY, MICHIGAN. Lat. 42.0°N, long. 84.2°W, elev. 200 m. Temperature: ave. Jan. -4°C, ave. July 23°C, absolute minimum -32° C. Prec. 790 mm, evenly distributed. Nearly level old field with a sandy loam soil and occasional poorly drained patches of clay soil. Weed control and spacing as at Kellogg Forest.

Roscommon , ROSCOMMON COUNTY, MICHIGAN. Lat. 44.5° N, long. 84.6° W, elev. 300 m. Temperature: ave. January -7° C, ave. July 20° C, absolute minimum -39° C. Prec. 700 mm. Gentle south facing slope with loamy sand, acidic soil, previously in grass and ericaceous shrubs. Weed control and spacing as at Kellogg Forest but the weed control was relatively ineffective in the shrubs and occasional patches of sedge.

MOHICAN STATE FOREST near LOUDONVILLE, OHIO. Lat. 40.6° N long. 82.3° W, elev. 378 m. Temperature: ave. Jan. -1° C, ave. July 22° C, absolute minimum -30° C. Prec. 980 mm, evenly distributed. Gentle south-facing slope; soil silt loam derived from sandstone; native white pines in nearby forests. Weeds controlled by spraying 2-m bands with simazine and atrazine (2.2 kg/ha) the first 2 years, mowing between bands. Spacing 3.2 X 3.2 m.

HIGHLAND RIM FOREST near TULLAHOMA, TENNESSEE Lat. 35.4°N, long. 86.3° W, elev. 300 m. Temperature ave. Jan. 5° C, ave. July 25° C, absolute minimum -30°C. Prec. 1380 mm, evenly distributed. Site poorly drained in winter due to a fragipan at 50 cm depth. Converted oak forest, now mostly in grass. Weeds controlled by mowing. Spacing 2.4 X 2.4 m.

Near W. LAFAYETTE, INDIANA, Lat. 40.4° N, long. 86.8° W. elev. 180 m. Temperature: ave. Jan. -3°C, ave. July 25° C, absolute minimum -36° C. Prec. 970 mm.

DIXON SPRINGS RECREATIONAL AREA, POPE COUNTY, ILLINOIS. Lat. 37.3° N, long. 88.7°W. elev. 120 m. Temperature: ave. Jan. 2°C, July ave. 26°C, absolute minimum -26°. Prec. 1200 mm.

Near CARBONDALE, JACKSON COUNTY, ILLINOIS. Lat. 37.7°N, long. 89.3° W. elev. 150 m. Temperature ave. Jan. 2° C, ave. July 27° C, absolute minimum -31° C. Prec. 1100 mm. Soil a Hosmer silt loam with 2-18% slopes facing northwest. Spacing 3.0 X 3.7 m, with filler rows to result in a 1.5 X 3.7 m spacing.

FERNOW EXPERIMENTAL FOREST, near PARSONS, WEST VIRGINIA. Lat. 37.1° N, long. 29.7° W. elev. 700m. Temperature: ave, Jan. 1° C, ave. July 21° C, absolute minimum -33° C. Prec. 1220 mm, evenly distributed. Steep, cutover south-facing slope, site index of 20 m (age 50) for oak. Clearcut and sprayed with 2,4,5-T before planting and again in summer of 1969. Spacing 2.4 X 2.4 m.

HORNING STATE FARM, PLATTSMOUTH, NEBRASKA. Lat. 41.0° N long. 95.9° W, 335 m. elev. Temperature: ave. Jan. -5° C, ave. July 25° C, absolute minimum -37° C. Prec. 760 mm, heaviest in summer. Gentle north-facing slope of silt loam derived from loess, prairie vegetation, 170-day growing season. Weeds controlled by annual spraying of 50-cm strips with simazine (4.5 kg/ha) and dalapon (11 kg/ha) and by mowing between strips. Planted with 1+1 container stock, containers not removed. Spacing 3.4 X 2.4 m.

GWAVAS, NORTH ISLAND, NEW ZEALAND. Lat. 39.7° S, long. 176.3° E, elev. 270 m. Temperature: ave. July 8° C. ave. Jan. 18° C. Prec. 1300 mm, evenly distributed. Abondoned farm land with a dense cover of manuka, crushed and burned in 1960. Present vegetation grass, disked before planting. 0-3% northwest facing slope. Spacing 1.8 X 2.8 m.

ROTOEHU, NORTH ISLAND, NEW ZEALAND. Lat. 37.9° S long. 176.5° E. elev. 80 m. Temperature: ave. July 8° C, ave. Jan. 18° C. Prec. 1620, evenly distributed. Vegetation bracken fern and manuka, disked before planting. Spacing 1.8 X 2.8 m.

GOLDEN DON, SOUTH ISLAND, NEW ZEALAND. Lat. 41.5° S long. 172.8°C, elev. 390 m. Temperature: ave. July 7° C, ave. Jan. 15°C. Prec. 1280 mm, evenly distributed. Originally beech forest, reverted to farm land and covered with bracken and gorse at time of planting. 0-25 west facing slope. Spacing 1.8 X 2.8 m.

TOOMBULLUP, near MANSFIELD, VICTORIA, AUSTRALIA. Lat. 37°S, long. 146.1° E, elev. 910 m. Temperature: July 0-10° C, Jan. 10-30° C. Prec. 680 mm, mostly in winter. Uniform northeast facing slope. Soil a deep red-brown loam, covered with bracken and grass. Plowed and fenced, chipped, fertilized around each tree. Spacing 2.75 X 2.75 m.

Height was measured one to three times in each plantation, at the end of the growing season. The dates of the most recent measurements are given in Table 2. Most data sets were subjected to analysis of variance, one analysis for each plantation (or a combined 3-plantation analysis for New Zealand). In these analyses, the F values and coefficients or correlation apply to single seedlots, whether those represent single trees or stands. The coefficients of variation were calculated according to the formula: Coefficient of variation = [Error mean square/Mean

Other traits, including stem diameter, cone number, needle length and pest damage were measured at one or more plantations.

RESULTS

Survival and general vigor. Survival was generally high, averaging 75% or more at most place. Only at Roscommon, Michigan and Toombullup, Australia was survival less than 60% (Table 2). Those two plantations are the ones with the poorest growing conditions. Most of the mostality occurred soon after planting.

In the United States, growth was generally good and most American cooperators felt that their experimental plantations could serve as models for commercial practice in their areas. In Nebraska, one seedlot averaged 0.8 m height growth per year for a 5-year period. In southern

Table 2. Relative rates of height growth of southern Appalachian white pines in 15 American and southern hemisphere test plantations.

Map No.	State & County	MSFG Nos.	MICHIGAN Kel	MICHIGAN Rus	MICHIGAN Hid Lak	MICHIGAN Ros com	OHI	TEN	IND	ILLINOIS Dix Spr	ILLINOIS Car bon	WVA	NEB	NEW ZEALAND Gwa vas	NEW ZEALAND Rot	NEW ZEALAND Gol den	AUS	Ave.
1	GA Fannin	3513-21	108	110	92	117	121	--	115	115	120	115	103	110	112	112	126	111
2	GA Fannin	3542-44	112	99	92	114	107	137	105	107	110	110	91	111	118	110	116	110
3	GA Union	3545	104	109	--	100	98	125	105	--	100	114	110	110	103	112	125	110
4	GA Rabun	3546	--	117	106	--	98	106	--	91	--	--	101	108	105	103	117	107
5	GA Rabun	3547	--	91	--	--	--	95	--	106	--	--	107	100	110	102	116	103
6	*GA Rabun*	*3548*	*96*	--	--	*102*	*95*	*118*	--	--	--	*97*	*83*	*109*	*111*	*116*	*82*	*106*
7	NC Macon	3421	104	98	82	90	80	87	97	--	73	--	98	--	--	--	--	92
8	NC Cherokee	3522-31	100	98	93	96	86	--	96	94	104	89	85	107	109	--	--	94
9	NC Henderson	3438-43	106	115	--	95	111	125	101	--	118	106	106	101	48	83	111	105
10	NC Graham	3452	110	--	--	112	--	123	89	107	--	110	93	111	--	--	--	108
11	NC Buncombe	3436-37	106	--	--	126	129	116	88	--	97	--	114	114	115	104	105	111
12	NC Buncombe	3409-18	108	108	99	105	112	133	100	116	108	98	101	112	--	--	104	109
13	NC Yancey	3428-35	108	110	94	108	107	117	102	126	78	--	101	103	--	--	--	110
14	NC Madison	3551	102	94	91	--	--	119	--	--	85	111	103	108	100	96	128	105
15	NC Burke	3552	104	91	--	--	106	114	--	--	--	94	92	102	106	103	115	105
16	NC Burke	3422	90	87	100	94	--	93	92	--	--	95	105	101	101	--	95	97
17	NC Burke	3423	102	108	--	72	--	--	--	--	--	103	--	--	--	--	--	97
18	NC Burke	3483-92	98	115	103	84	110	95	82	--	81	119	95	--	--	--	--	103
	NC Chatham	--	--	--	--	--	--	--	--	--	--	--	--	90	93	91	--	91
	SC Pickens	--	--	--	--	--	--	--	--	--	--	--	--	118	126	121	100	118
19	TN Polk	3493-3502	117	115	111	116	115	--	115	141	124	112	113	112	122	117	145	118
20	TN Monroe	3503-12	106	104	114	118	108	--	106	108	115	108	101	118	--	--	72	108
21	TN Anderson	3532-41	112	118	113	107	136	--	116	--	107	122	113	109	116	--	128	115
22	TN Carter	3420	120	102	111	104	93	115	82	--	--	98	116	103	--	--	114	107
23	VA Carroll	3597	104	95	--	--	79	--	--	--	--	--	--	--	--	--	--	96
24	VA Amherst	3596	104	98	--	--	93	--	--	--	106	--	--	--	--	--	--	100
25	VA Montgomery	3407	104	85	95	69	--	80	--	--	--	94	--	85	--	--	--	87
26	VA Craig	3419, 3473-74	92	--	--	78	--	--	--	--	--	--	--	--	--	--	--	88
27	VA Botetourt	3470	94	98	--	--	--	99	84	85	--	75	96	92	81	--	--	89
28	VA Alleghany	3550	--	103	92	--	91	74	--	--	--	--	--	96	94	--	--	91
29	VA Augusta	3471	110	--	--	--	77	74	--	--	--	--	--	--	--	--	--	86
30	VA Rockingham	3475-76	94	93	102	105	101	91	80	100	67	--	99	93	--	--	100	96
	VA Bath	3472	100	--	--	--	--	105	--	--	--	--	--	--	--	--	120	111
	VA Wythe	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	69	69
31	KY Whitley	3447-50	104	92	--	100	--	107	92	--	--	101	--	104	104	106	106	103
32	WV Greenbrier	3479	104	89	97	139	71	82	85	--	--	--	100	--	--	--	114	99
33	WV Greenbrier	3408-25	98	--	--	--	--	84	--	--	--	--	--	--	--	--	--	91
34	WV Greenbrier	3480	90	89	94	104	67	70	65	--	63	--	90	93	77	--	102	93
35	WV Greenbrier	3460-64	92	74	96	108	83	87	74	80	80	70	96	87	76	--	87	85
36	WV Greenbrier	3465-69	98	--	--	96	97	--	--	--	--	--	112	--	--	--	--	102
37	WV Greenbrier	3564-69	80	91	98	83	83	82	82	87	79	91	95	--	--	--	--	87
38	WV Mercer	3427	100	--	--	86	--	--	--	--	--	--	89	95	--	--	--	93
39	WV Pocahontas	3477	98	--	--	104	78	74	77	--	--	--	98	90	--	--	87	89
40	WV Pocahontas	3478	108	--	--	94	--	74	--	--	--	--	107	--	--	--	--	90
41	WV Pocahontas	3549	100	101	98	--	--	96	--	--	--	--	--	95	88	--	--	95
Year planted			'69	'70	'70	'69	'70	'68	'69	'70	'70	'68	'69	'70	'70	'70	'68	
Age at planting			2+0	3+0	3+0	2+0	2+1	2+0	2+1	2+1	1+2	2+0	1+1	4	4	4	2+0	
Year measured last			'76	'75	'76	'74	'74	'72	'75	'77	'75	'73	'75	'75	'75	'75	'74	
Age when measured, years			10	9	10	8	8	7	9	11	9	8	9	10	10	10	9	
Average height, cm			374	296	259	80	195	114	268	275	231	195	297	272	252	237	110	
Mortality, %			14	20	8	33	5	42	11	23	15	16	25	6	7	1	43	
Coeff, of variation			15	12	17	27	14	29	11	25	16	--	--	--	11	--	26	
F Value, seedlot			3.2	2.6	1.6	2.6	4.8	4.5	6.3	3.1	6.8	--	--	--	15.0	--	3.0	
Number of blocks			5	5	5	5	3	10	4	5	5	7	7	5	5	5	4	
Trees per plot, number			4	4	4	4	4	4	4	4	4	4	2	10	10	10	9	

Michigan, one tree grew 3.3 m in 3 years and several others in the same plantation grew 2.5-3 m in 3 years. In West Virginia, overall vigor was good.

Results were less promising in the southern hemisphere. By any standards the Australian plantation grew poorly, being only a little over 1 m tall at age 9 from seed. In New Zealand, growth was almost as good as at several places in the U. S. but that is not enough to excite New Zealand foresters who are accustomed to growth of 2-3 m per year.

Differences in growth rate. In range-wide provenance tests, as reported by previous authors (1, 2, 3, 4, 5, 6, 7, 10, 17), the fastest growing seedlots have commonly grown 70-80% faster than the slowest growing ones. In the present experiment, differences were much less pronounced, being limited to 40%. Even the 40% differences in rate of height growth are important, however, as they translate into 2-to-1 or greater differences in rate of volume growth.

Relative heights for all stand-progenies at all test sites are given in Table 2. In that table it is possible to detect examples of interaction, where one seedlot grows much faster than another at lone location but slower than the other at a second test site. Some of these interactions are undoubtedly real but others are probably due to the vagaries of nursery treatment.

The sameness of results at all test sites is much more important to stress than the interactions. Seedlots 19-TN and 21-TN were tallest and next-to-tallest on the average at all test sites. One or the other of those seedlots was tallest or next-to-tallest at all but two of the test sites considered individually. If white pine were to be planted in New Zealand, it would be just as well to use data from Nebraska or Australia as from local test plantations when deciding where to obtain seed.

This absence of interaction even extends to West Virginia, the home of some of the slowest growing seedlots. One might have expected the West Virginia trees to grow a little better, relative to the others, when planted closest to their place or origin. That did not happen. As a matter of fact, seedlots 35-WV and 43-WV grew more slowly (relative to others) in their native state than in any other place.

Of special interest in the New Zealand plantations are 10 half-sib progenies grown from seed collected in a Chatham County, North Carolina stand. This particular stand is a relict in the Piedmont zone, close to Raleigh and Durham. It is a considerable distance from and at a lower elevation than the bulk of the eastern white pine found in the southern Appalachian. Chatham trees were not represented in American plantations, so our only data are from New Zealand. There the half-sib progenies considerably but few were as fast growing as any other seedlots from North Carolina. On the average, they grew almost as slowly as trees from West Virginia.

Also of interest in the New Zealand and Australian plantations are the Pickens County, South Carolina trees, which were not represented in American plantations. They grew exceptionally rapidly and should be tested in the United States.

Of the seedlots which were tested at several localities, 1-GA, 2-GA, 3-GA, 4-GA, 10-NC, 11-NC, 12-NC, 13-NC, 19-TN, 20-TN, 21-TN and 22-TN grew fastest on the average and at most plantations considered individually. To them should be added the Pickens County, South Carolina trees which grew so well in New Zealand. These 13 seedlots are from a narrow zone in northern Georgia and South Carolina and from another zone about 100 km wide and 250 km long extending northeast-southwest along the Tennessee North Carolina boarder but extending only a short distance east into North Carolina.

In most cases, seeds were obtained from average trees. Thomas F. Zarger of Tennessee Valley Authority collected cones only from carefully selected plus trees in the two North Carolina stands which he sampled (Nos. 9-NC and 11-NC). Offspring of these stands ranked 14th and 3rd, respectively in average growth rate at all sites. No firm conclusion can be reached as to the efficiency of the plus tree selection.

Winter injury. Following the 1971-1972 winter severe needle burning was visible on 75% of the trees in Nebraska (12). Recovery was good, however, and none of the trees suffered permanent injury.

In Michigan, where the northernmost plantations are located, winter injury has been noted only at Roscommon, in the north-central part of the Lower Peninsula. Average January temperatures there are -7° C, a few degrees colder than at any other test site. During the winters of 1970-71 and 1978-74, 10-20% of the trees from Georgia, North Carolina and Tennessee had brown needles but none suffered cambial injury.

At the other tree test locations in southern Michigan the winters of 1976-77 and 1977-78 were among the coldest on record. Absolute minimums were not as low as recorded in some previous years but the duration of the cold was exceptional. In both years more than 50 consecutive below-freezing days were recorded. Winter cold damage was especially severe on such things as flowering dogwood *(Cornus florida)* and some types of ponderosa pine *(Pinus ponderosa).* However, the southern Appalachian white pines suffered no noticeable damage.

Here, reference should be made to previous range-wide provenance tests, now 20 years old from seed. In them, trees from Tennessee, North Carolina and Georgia have suffered cold damage and grown slowly when planted in New England, New York, the northern Lake States or Ontario (1, 2, 4, 7). The southern trees have, however, held up well when planted in Pennsylvania, Maryland, southern Michigan and the central states (1, 3, 4, 5, 6, 10, 17).

Flower production. A few cones where observed in the Kellogg Forest plantation in southern Michigan after 1973. There was no evident relation between flowering and place of origin or growth rate.

In Nebraska, 20 trees had produced female flowers by 1974. Of these, 15 were from the two northernmost stands in West Virginia. These results agree with observations made on the older, range-wide test plantations. In them, the bulk of the flowering through age 10 was limited to slow-growing northern (i.e., Minnesota, Canada) seedlots (17). Even through age 20 in southern Michigan, flowering has been considerable on slow growing northern origins but very light on fast growing ones from the southern Appalachians.

Pest damage. Deer rubbing was noted on a few of the border trees in Nebraska (12). There was no particular preference for any seedlot. A small percentage of the trees at Kellogg Forest, Michigan suffered attacks by the white-pine shoot borer *(Eucosma gloriola),* an insect which feeds in new lateral shoots or sometimes leaders, At this and other Michigan test sites less than 1% of the trees were attacked by white-pine weevil *(Pissodes strobi),* usually considered to be the most important pest of eastern white pine. All in all, the damage was too little to be evaluated genetically or to have an influence on growth traits.

Within-stand variation, In New Zealand there were statistically significant differences among the 10 half-sib progenies from the Chatham County, North Carolina stand which were tested at all three New Zealand sites (11). However, none of the Chatham half-sib progenies approached the better stand-progenies in growth rate.

In West Virginia and Tennessee there were statistically significant differences among families from the same stand in some cases and not in others (13, 14, 15). Overall, the variation attributable to differences within stands was small compared with that attributable to difference among stands.

On Nebraska, the variation within stands 8-NC and 19-TN was studied in some detail. For those half-sib families represented in four or more replications there were 15% differences in growth rate among families from the same stand (12). There was no correlation between average annual growth rate of the parent tree and growth rate of the offspring.

In Michigan, an analysis of variance was performed on the combined data for three plantations and for each of the three plantations separately. At only one of the three plantations considered separately were the differences among half-sib progenies from the same stand significant statistically. In the combined analysis, differences among half-sib progenies from the same stand were not significant.

DISCUSSION

<u>What of the future?</u> Growth rate of the southern Appalachian white pines has been impressive but one must remember that the trees are now (1978) only 12 years old from seed. Will the early growth trends continue throughout a rotation? Two types of papers written about the older, range-wide provenance tests may help answer this question.

One such paper is that on cold hardiness by Maronek and Flint (8). They collected branches of many different seedlots from a southern Michigan test planting at various times during the winter and subjected this material to artificial freezing tests in their laboratory in Indiana. Trees from all parts of the range withstood lower temperatures in midwinter than at other times of the year. There were also differences among seedlots at each test time. Trees from the north withstood temperatures of -50° to -60° C without damage when tested in midwinter. Tennessee and Georgia trees tested in midwinter suffered detectable leaf injury at temperatures varying from -31 to -42° C.

The 40-year minimums recorded by the U. S. Weather Service are -36° C for W. Lafayette, Indiana and -39° C for Roscommon, Michigan. It is likely that Tennessee trees planted at those places will suffer noticeable winter injury during the next few decades, as they already have at Roscommon.

The 40-year minimums are -32° $_{o}$C or above at the other test sites and vary from -29° to -32°C at towns in Tennessee close to native white pine stands. Southern Michigan test plantations have already experienced temperatures of -31° C without damage. These facts and Maronek and Flint's data indicate that fast-growing trees from Tennessee will probably escape serious winter injury for a full rotation at many places from West Virginia and southern Michigan southward.

The other pertinent papers are those comparing, growth rates at different ages for test plantations of the U. S. Forest Service range-wide provenance test started in 1957. At several plantations in the central states, the ranking of different seedlots did not change appreciably between ages 7 and 15, those from the southern Appalachians continuing to be the tallest (3). However, the percentage superiority of the southern Appalachian trees decreased with age. Similar results were obtained for test plantations located in eastern United States (1, 4). Between ages 10 and 16 the absolute differences between fast-growing southern and slow growing northern seedlots increased but the relative differences decreased. According to unpublished data from southern Michigan, the size of the growth rate advantage of southern Appalachian trees over slow growing northern ones has decreased from about 80% at age 6 to 30% at age 18. At all places the decrease has been greater for height than for diameter growth.

From such results, it seems likely that the southern Appalachian test plantations studies for the present paper will continue to perform well but that their degree of superiority over other plantations established with northern trees may decrease with age. Until the southern Appalachian trees have been tested for at least half a rotation, it will be difficult to estimate just how much faster they can produce sawlogs than can the trees which have been planted in the past.

<u>Conversion of the test plantations to seed orchards.</u> Ordinarily a provenance test does not make a good seed orchard if thinned to leave only the best seedlots. Usually, if there was a high selection differential, such thinning would leave relatively few trees. Also, in many cases such thinnings might leave trees of diverse genotypes which would produce variable progeny.

It so happens that in establishing the present experiment, many seedlots which turned out to be among the leaders in growth rate are considerably overrepresented. Seedlots 1-GA, 2-GA, 12-NC, 13-NC, 19-TN, and 21-TN are among the leaders in growth rate and account for over 25% or the trees in most plantations. Removal of 50-75% of the trees could result in a plantation consisting mostly of fast growing types. Presumably, conversion to a seed orchard will involve selecting the best trees in the best half-sib families from the best stands.

Lack of cone production at early ages promises to be a difficulty encountered in treating these plantations as seed orchards. So far, flowering has been inconsequential and the fruiting record of southern Appalachian trees in older, range-wide provenance tests has not been good.

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