SCOTCH PINE FOR THE NORTHERN GREAT PLAINS

Richard A. Cunningham

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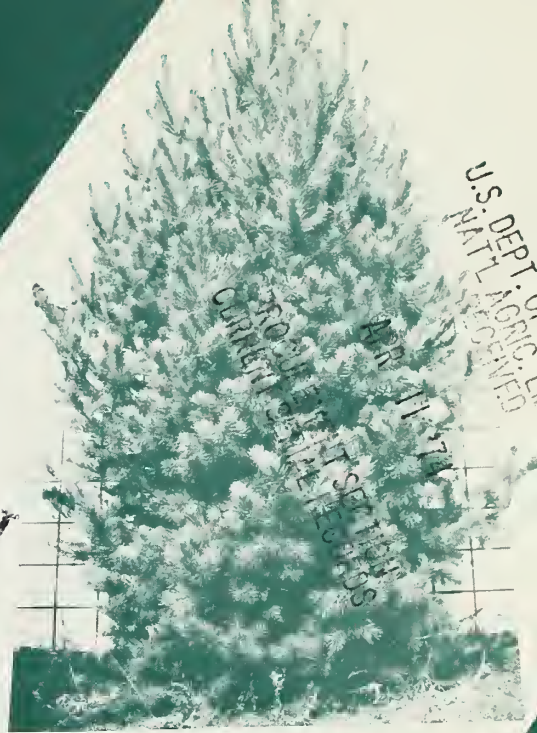
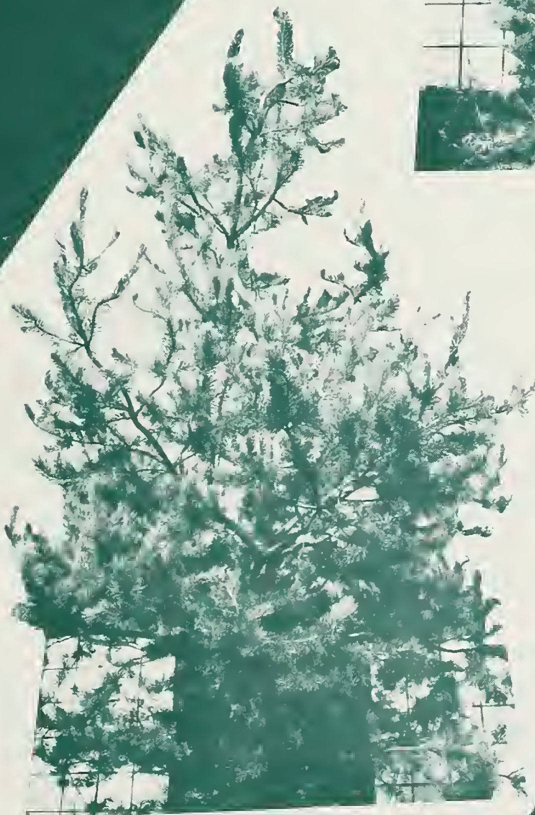
Rocky Mountain Forest and
Range Experiment Station





Forest Service
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Fort Collins. Colorado 80521

Abstract

A provenance test of 49 origins of Scotch pine (Pinus sylvestris L.) from eastern Europe, Russia, and Siberia was established at three locations in North Dakota and one in Nebraska. After 10 years (7 in Nebraska), trees from 50° to 55° latitude and 20° to 40° longitude survived best, were taller, and had greener winter foliage. Several provenances appear to be well suited for planting in shelterbelts and for Christmas tree culture.

Oxford: 232.12:165.52. **Keywords:** Geographic variation, provenance trials, *Pinus sylvestris*.

PREFACE

The cooperation of many individuals made this provenance study possible. Robert B. Hill, Institute of Forest Genetics at Rhinelander, Wisconsin, and Paul O. Rudolf, Lake States Forest Experiment Station, initiated the study. Some of the planting stock was provided by Mark Holst of the Petawawa Forest Experiment Station, Ontario, Canada, and by Jonathan W. Wright, Professor of Forestry, Michigan State University. David H. Dawson and Paul E. Slabaugh of the Shelterbelt Laboratory, Bottineau, were primarily responsible for the planting, maintenance, and measurements of the North Dakota plantings. Walter T. Bagley, Associate Professor of Horticulture and Forestry, University of Nebraska, made the Nebraska planting, and Ralph A. Read, Rocky Mountain Forest and Range Experiment Station, Lincoln, maintained and measured it.

Studies of this type are conducted by the USDA Forest Service through its Rocky Mountain Forest and Range Experiment Station Research Work Unit at Bottineau, North Dakota, to identify and develop, through selection and breeding, better adapted and more useful trees and shrubs for planting in the Great Plains.

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Scotch Pine for the Northern Great Plains

by

Richard A. Cunningham, Associate Plant Geneticist

Rocky Mountain Forest and Range Experiment Station[1]

[1] *Central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at the Station's Shelterbelt Laboratory at Bottineau, in cooperation with North Dakota State University-Bottineau Branch and Institute of Forestry.*

Contents

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Introduction

A wider variety of pine species is needed for planting in shelterbelts and windbreaks in the northern Great Plains. Ponderosa pine (Pinus ponderosa Laws.), the only species of pine that has been widely planted in this region, has poor initial survival, slow initial growth, and is susceptible to winter injury.

Although Scotch pine (Pinus sylvestris L.) has not been planted very extensively, limited trials suggest it is well suited for shelterbelt plantings. These early trials indicated the importance of obtaining trees from the proper geographic region, however.

During the period 1956-61, seed and seedlings of known provenances from the U.S.S.R. became available to the Lake States (now North Central) Forest Experiment Station (fig. 1). Since these provenances represented northern latitudes and climatic conditions similar to those in the northern Great Plains, their availability provided an excellent opportunity to test a wide range of provenances for adaptability and growth in the northern Great Plains. This Paper summarizes 10 years of observations of growth survival, and winter foliage color of provenance trials in North Dakota and Nebraska.

Past Work

George (1953) reported the results of extensive trials, in the northern Great Plains, of many tree and shrub species. Of two Scotch pine origins, a provenance from Russia was more hardy than one of unknown origin obtained from a commercial dealer. At 10 years of age, 75 percent of the Russian origin had survived and averaged 12.5 feet in height. In 1950, 20 years after planting, survival was still 75 percent and the trees averaged 28.5 feet tall. Winter injury was rated none or minor.

Species trials at the Denbigh Experimental Forest indicated that, in north-central North Dakota, Scotch pine from Latvia and Finland survived best and grew moderately fast.[2]

[2] *Stoeckeler, J. H., and E. J. Dortignac. 1939. Report of work at Denbigh Station. Unpublished report on file at USDA Forest Service Shelterbelt Laboratory, Bottineau, N. D.*

Cram and Brack (1953) studied vigor and seed crops of trees representing six geographic races of Scotch pine growing in a prairie-plains environment. Survival and growth seemed to be two distinct characteristics of the geographic races studied. Some seeds from Russian sources apparently were frost-hardy during the reproductive process (anthesis stage of the flowers and the initial enlargement of the embryonic cones). The Russian provenance suffered no winter injury in 1951 when all but one other provenance did. A Scottish provenance showed greatest vigor, while the Finnish and Russian provenances survived best. The Russian provenance had the best combination (relative vigor x survival) of these two characteristics at the test site.

Stoeckeler and Rudolf (1949) reported on winter injury and recovery of conifers in the Lake States following unusual weather conditions in 1946 through 1948. In north-central North Dakota, Scotch pine of Finnish origin showed no browning of foliage while other pines suffered varying degrees of needle discoloration. Similar results were reported from plantations of Scotch pine on the Chippewa National Forest in Minnesota. Generally the trees representing the more northerly sources had less damage than those from farther south. Scotch pine of Manchurian and northern European origin suffered less foliage injury than local red pine (Pinus resinosa Arr.).

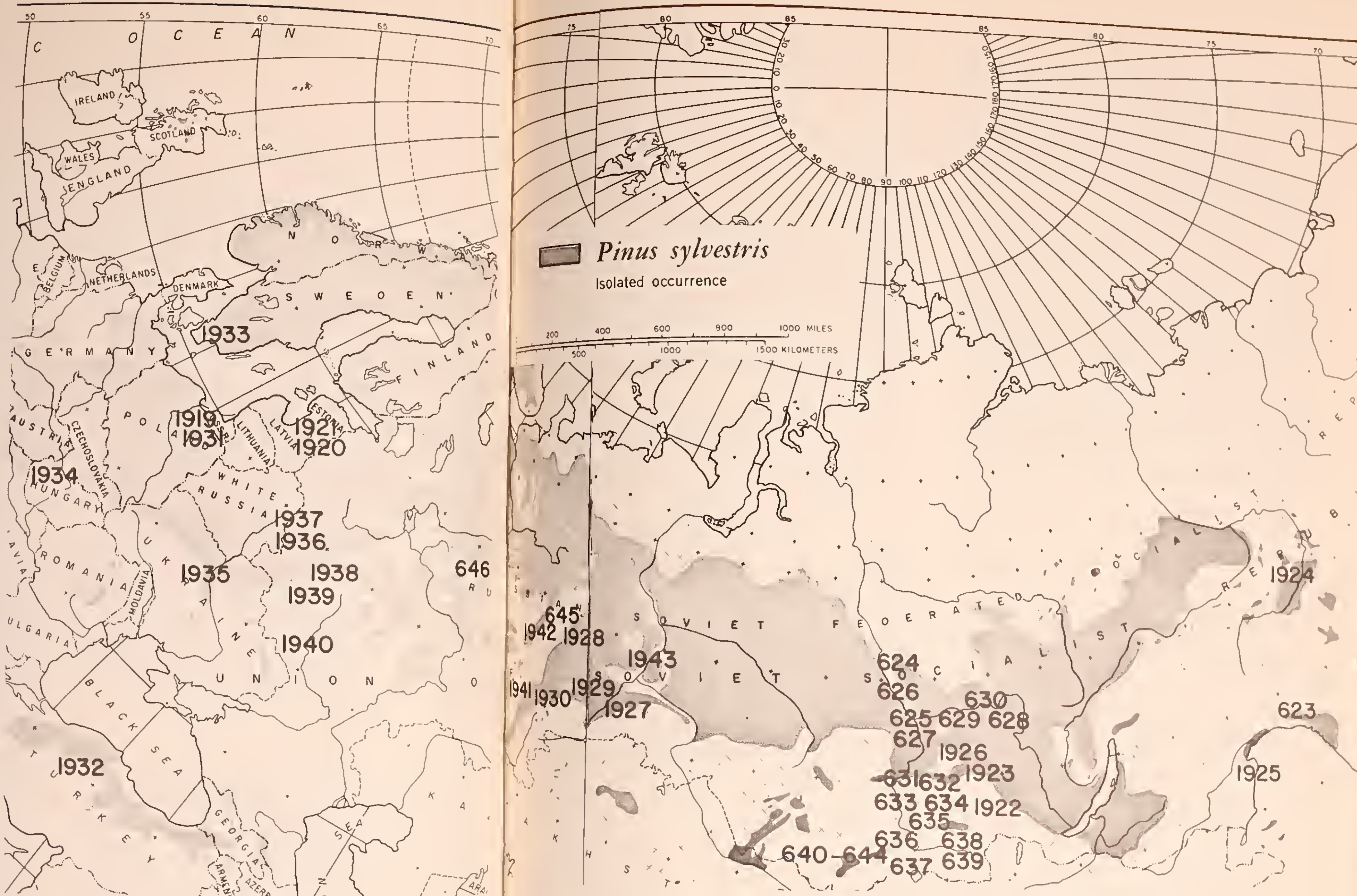
Winter injury following a severe winter was observed by Rudolf (1948) on Scotch pine planted in northern Minnesota. Trees grown from seed collected in the same climatic zone as Cass Lake (Minnesota) suffered very little foliage injury. Trees from seed originating in a milder climate suffered greater foliage loss.

Read (1971) reported on a field test of 36 provenances of Scotch pine in eastern Nebraska. Results after 8 years revealed that (1) southern origins bordering the Mediterranean grow slowly to moderately fast and remain dark green in winter, (2) central European origins grow very fast and turn yellowish green in winter, and (3) northern origins grow slowly and turn very yellow in winter. Southern origins were recommended for Christmas trees, fast growing central European origins were recommended for windbreaks, and the northern origins were recommended as special-purpose ornamentals.

Figure 1.—Natural distribution of Scotch pine, and location of origins tested.

(see Map 32, Critchfield and Little 1966)

Origin number	Latitude °N	Longitude °E	Geographic variety
U.S.S.R.--FAR EASTERN SIBERIA			
623	54.00	124.00	*mongolica*[1]
1924	60.75	131.67	*mongolica*
1925	52.33	117.67	*mongolica*
U.S.S.R.--NORTHERN SIBERIA[2]			
624	60.25	90.00	*lapponica*[1] *orientalis*[3]
626	60.25	90.00	*lapponica orientalis*
U.S.S.R.--CENTRAL SIBERIA, MIDDLE YENESEI RIVER			
625	58.50	92.00	*eniseensis*[3]
627	57.50	92.00	*eniseensis*
628	57.00	95.00	*eniseensis*
629	57.00	93.00	*eniseensis*
630	58.50	96.00	*eniseensis*
631	56.00	91.00	*eniseensis*
632	55.25	92.00	*eniseensis*
1923	56.00	95.00	*eniseensis*
1926	56.67	96.36	*eniseensis*
U.S.S.R.--SOUTH CENTRAL SIBERIA, SOUTHERN YENESEI RIVER			
1922	54.03	94.03	*eniseensis*
633	54.25	91.00	*eniseensis*
634	54.25	93.00	*eniseensis*
635	53.75	92.00	*eniseensis*
636	53.00	90.50	*eniseensis*
637	52.75	90.00	*eniseensis*
638	52.00	93.75	*eniseensis*
639	51.50	93.00	*eniseensis*
U.S.S.R.--SOUTHERN SIBERIA, ALTAI MOUNTAINS[2]			
640	52.00	84.00	*altaica*[1]
641	52.00	84.00	*altaica*
642	52.00	84.00	*altaica*
643	52.00	84.00	*altaica*
644	52.00	84.00	*altaica*
U.S.S.R.--EAST URAL MOUNTAINS			
1927	56.83	65.02	*uralensis*[1]
1928	58.83	60.83	*uralensis*
1929	56.92	63.25	*uralensis*
1930	56.85	61.38	*uralensis*
1943	58.00	68.00	*uralensis*
U.S.S.R.--WEST URAL MOUNTAINS			
645	59.50	57.50	*uralensis*
646	58.00	45.00	*uralensis*
1941	55.00	57.00	*uralensis*
1942	58.00	57.00	*uralensis*



Origin number	Latitude °N	Longitude °E	Geographic variety
U.S.S.R.--CENTRAL RUSSIA			
1935	50.00	30.00	*balcanica*[3]
1936	54.00	32.00	*balcanica*
1937	54.50	32.00	*balcanica*
1938	54.00	36.00	*balcanica*
1939	53.00	37.00	*balcanica*
1940	52.00	39.00	*balcanica*

Origin number	Latitude °N	Longitude °E	Geographic variety
U.S.S.R.--LATVIA			
1920	57.50	25.83	*rigensis*[1]
1921	57.67	26.33	*rigensis*
NORTHERN POLAND			
1919	53.83	20.45	*polonica*[1]
1931	53.72	20.45	*polonica*
SOUTHERN SWEDEN			
1933	55.87	14.08	*septentrionalis*[1]

Origin number	Latitude °N	Longitude °E	Geographic variety
WESTERN HUNGARY			
1934	47.68	16.58	*pannonica*[1]
TURKEY			
1932	40.50	32.67	*armena*[1]

[1]Wright et al. (1966).
[2]From different sites and age classes.
[3]Pravdin (1969).

Materials and Methods

Seed from 24 Russian and Siberian provenances was received by the Lake States Forest Experiment Station in 1956. Part of this seed was sown in the Hugo Sauer Nursery, Rhinelander, Wisconsin, in 1957. After 2 years in the seedbed, the stock was lifted and shipped to North Dakota where it was lined out in transplant beds at the Towner Nursery.

In addition to the 24 sources grown from seed, the Petawawa Forest Experiment Station, Chalk River, Ontario, supplied 9 different seed sources of Russian origin as 2-1 stock. These seedlings were lined out in transplant beds at the Towner Nursery in 1960. In the spring of 1961 both groups of seedlings were field planted.

A randomized complete block design was used in all field plantings. Single tree plots were arranged in 24 replications. Three outplantings were made in North Dakota and one in Nebraska (fig. 2, table 1). An additional outplanting at Indian Head, Saskatchewan, was a complete failure, primarily due to drought-induced mortality.

A block planting was made at Denbigh Experimental Forest in central North Dakota (Denbigh-1). The soil on this site is a loamy fine sand. Each test tree was separated by filler trees of ponderosa pine from a Black Hills seed source. Spacing was 7 feet by 7 feet.

Plantings in Richland and Ransom counties in southeastern North Dakota were in the form of a shelterbelt in which two center pine rows were flanked by a shrub (Caragana aborescens Lam.) row and a hardwood (Fraxinus pennsylvanica Marsh.) row. The Richland planting was oriented east-west; the Ransom planting, north-south. Tree rows were spaced 10 feet apart, and trees within the rows about 6.5 feet apart.

Figure 2.—Location of test sites in North Dakota and Nebraska.

At Ransom, the site is an alluvial bottomland with soils ranging from silty clay loam to fine sandy loam. Soil at the Richland site varies from loamy fine sand to loam.

All three locations were planted by hand. Site preparation consisted of plowing and disking a year prior to, as well as immediately before, planting.

Table 1.--Test site locations and climatic data[1]

Site location	County	Latitude	Longitude	Elevation	Average temperature		Freeze-free days	Average precipitation		Period of record
					Jan.	July		April-Sept.	Annual	
		°N	°W	Feet	°F		No.	Inches		
Denbigh, N.D.	McHenry	48°17'	100°39'	1486	4.8	69.7	114	13.30	15.92	1961-70
Ransom, N.D.	Ransom	46°31'	97°19'	1080	4.6	71.1	120	15.60	19.16	1961-70
Richland, N.D.	Richland	46°23'	97°14'	1080	4.6	71.1	120	15.60	19.16	1961-70
Horning, Nebr.	Cass	41°00'	95°54'	1100	22.2	77.2	163	24.54	31.92	1961-65

[1]Nearest U.S. Weather Bureau used: Denbigh--Granville, N.D.
Ransom and Richland--McLeod, N.D.
Horning--precipitation, Plattsmouth, Nebr.; temperature, Weeping Water, Nebr.

Plantation failures were replanted with extra line-out stock in the spring of 1962.

Weeds were controlled by rototilling at the Ransom and Richland sites annually for the first 7 years after planting, and at Denbigh for the first 5 years.

Low-lying portions of the Richland planting were inundated for an extended period in the spring of 1962, which resulted in higher than normal mortality.

The outplanting in Nebraska was on the University of Nebraska Horning State Farm near Plattsmouth. The soil is a silty clay loam derived from loess. A block planting design was used, with single tree plots and 24 replications per seed source. Eastern redcedar (Juniperus virginiana L.) filler trees were planted to give a final spacing of 7 feet by 7 feet. The soil was disked the fall of 1960, and the trees were machine planted in mid-April 1961. Plantation failures (except origins 624 and 626) were replanted with extra line-out stock in the springs of 1962 and 1963. Weeds were controlled by rototilling the first year after planting, and with chemicals thereafter (simazine, 4 lbs/acre).

In April 1968, a wildfire completely destroyed the plantation at Horning Farm.

In the spring of 1963 the original study was enlarged by the acquisition of 16 additional Scotch pine provenances from western Europe and eastern Asia. In 1961, Jonathan Wright, Michigan State University, sent 2-0 seedlings from 16 provenances to the Institute of Forest Genetics at Rhinelander, Wisconsin. The seedlings were lined out in transplant beds until April 1963 when they were lifted and sent to the Shelterbelt Laboratory, Bottineau, North Dakota.

A block planting of these additional provenances was made in the spring of 1963 on the Denbigh Experimental Forest (Denbigh-2). Ten replications of square four-tree plots were hand planted at a spacing of 7 feet by 7 feet. The soil is a loamy fine sand. Plantation failures were replanted with extra line-out stock in the spring of 1964. Weeds were rototilled the first 5 years after planting.

Survival, total height, and current leader growth were measured in the North Dakota plantings at the end of the first, second, fifth, and tenth years after planting. These variables were measured annually in the Nebraska planting until the spring of 1968 when the planting burned.

Winter foliage color was scored after 6 growing seasons in Nebraska and after 10 growing seasons in the North Dakota plantings.

Crown density was scored after 10 growing seasons in the four North Dakota plantings.

Results

Survival

Relative survivals summarized by variety are listed in table 2; detailed information on each origin at each test site is in table 3.

Table 2.--Relative performance of Scotch pine varieties in the northern and central Great Plains (percent of all-plantation mean)

Geographic area	Variety	Survival	Total height	Crown density	Winter foliage color
Far eastern Siberia	*mongolica*	91	84	95	67
Central Siberia	*lapponica*	36	58	78	68
	eniseensis	103	94	104	83
	altaica	107	116	94	97
Eastern Russia	*uralensis*	103	105	102	102
Central Russia	*balcanica*	108	122	103	151
Eastern Europe	*rigensis*	104	111	97	114
	polonica	102	119	97	112
	septentrionalis	102	109	100	119
	pannonica	80	92	89	118
Turkey	*armena*	93	64	94	140
		Percent	*Meters*	*Scale*[1]	*Scale*[2]
Average, all test sites		79	3.47	1.95	2.56

[1]Ranked on a scale of 1 = sparse, 3 = dense.
[2]Ranked on a scale of 1 = yellowest, 5 = darkest green.

Table 3.--Seed origin[1] locations and geographic varieties of Scotch pine (*Pinus sylvestris*) tested in the Great Plains, with measurements[2] of relative survival, total height, crown density, and winter foliage color at the test sites (in percent of plantation mean)

Seed origin number	Latitude °N	Longitude °E	Geographic variety	Survival: Oenbigh 1	Survival: Oenbigh 2	Survival: Ransom	Survival: Richland	Survival: Horning	Survival: Average	Total height: Oenbigh 1	Total height: Oenbigh 2	Total height: Ransom	Total height: Richland	Total height: Horning	Total height: Average	Crown density: Oenbigh 1	Crown density: Oenbigh 2	Crown density: Ransom	Crown density: Richland	Crown density: Average	Winter foliage color: Oenbigh 1	Winter foliage color: Oenbigh 2	Winter foliage color: Horning	Winter foliage color: Average
U.S.S.R.-- FAR EASTERN SIBERIA																								
623	54.00	124.00	*mongolica*[3]	98		69	99	106	93	86		91	103	89	92	95		85	89	90	76		49	62
1924	60.75	131.67	*mongolica*		72				72		47				47		89			89		55		55
1925	52.33	117.67	*mongolica*		104				104		91				91		105			105		89		89
			Average	98	88	69	99	106	91	86	69	91	103	89	84	95	97	85	89	93	76	72	49	67
U.S.S.R.-- NORTHERN SIBERIA[4]																								
624	60.25	90.00	*lapponica*[3] *orientalis*[5]	67		21	31	53	43	40		58	87	34	55	76		55	79	70	54		62	58
626	60.25	90.00	*lapponica orientalis*	67		14	15	18	28	70		59	65	48	60	86		90	79	85	77		77	77
			Average	67		18	23	36	36	55		58	76	41	58	81		72	79	78	66		70	68
U.S.S.R.-- CENTRAL SIBERIA, MIDOLE YENESEI RIVER																								
625	58.50	92.00	*eniseensis*[5]	107		69	114	106	99	89		66	92	77	81	100		110	89	100	78		49	64
627	57.50	92.00	*eniseensis*	94		104	84	102	89	86		76	85	78	81	95		95	84	91	78		54	66
628	57.00	95.00	*eniseensis*	107		83	99	106	99	87		93	91	85	89	105		100	84	96	76		49	62
629	57.00	93.00	*eniseensis*	103		132	91	102	107	97		100	96	90	96	100		95	116	104	73		64	68
630	58.50	96.00	*eniseensis*	103		90	99	106	100	85		86	90	86	87	105		90	95	97	98		49	74
631	56.00	91.00	*eniseensis*	89		97	84	102	93	75		86	83	77	80	105		115	95	105	82		67	74
632	55.25	92.00	*eniseensis*	103		104	122	106	109	99		105	89	95	97	119		120	105	115	92		90	91
1923	56.00	95.00	*eniseensis*		104				104		109				109		105			105		94		94
1926	56.67	96.36	*eniseensis*		104				104		95				95		94			94		84		84
U.S.S.R.-- SOUTH CENTRAL SIBERIA, SOUTHERN YENESEI RIVER																								
1922	54.03	94.03	*eniseensis*		104				104		99				99		105			105		95		95
633	54.25	91.00	*eniseensis*	107		118	99	102	106	105		91	91	95	96	119		125	105	116	92		78	85
634	54.25	93.00	*eniseensis*	98		111	130	106	111	101		99	108	95	101	110		120	100	110	96		75	86
635	53.75	92.00	*eniseensis*	98		104	99	102	101	94		102	104	101	100	114		110	105	110	94		86	90
636	53.00	90.50	*eniseensis*	103		118	114	106	110	105		105	105	102	104	114		105	100	106	98		85	86
637	52.75	90.00	*eniseensis*	98		118	107	106	107	104		111	105	102	106	114		95	105	105	118		119	118
638	52.00	93.75	*eniseensis*	103		118	99	106	106	88		102	106	93	97	100		105	105	103	86		90	88
639	51.50	93.00	*eniseensis*	107		125	91	97	105	98		102	95	97	98	114		105	111	110	92		80	86
			Average	101	104	106	102	104	103	94	101	95	96	91	94	108	101	107	100	105	90	91	74	83
U.S.S.R.-- SOUTHERN SIBERIA, ALTAI MOUNTAINS[4]																								
640	52.00	84.00	*altaica*[3]	103		111	107	106	107	118		120	115	113	116	90		95	84	90	102		85	94
641	52.00	84.00	*altaica*	89		118	137	106	112	112		109	108	118	112	100		80	84	88	108		103	106
642	52.00	84.00	*altaica*	103		118	130	106	114	114		127	122	115	120	100		95	105	100	101		85	93
643	52.00	84.00	*altaica*	107		97	122	106	108	106		124	117	115	116	86		90	100	92	102		88	95
644	52.00	84.00	*altaica*	107		83	91	102	96	116		114	115	119	116	105		100	100	102	98		98	98
[illegible]																								
U.S.S.R.-- WEST URAL MOUNTAINS																								
645	59.50	57.50	*uralensis*	98		69	91	102	90	96		96	103	91	96	100		95	100	98	94		80	87
646	58.00	45.00	*uralensis*	98		62	84	106	88	96		93	90	91	92	105		110	89	101	108		90	99
1941	55.00	57.00	*uralensis*	107		111	107	106	108	121		121	116	130	122	100		85	111	99	134		178	156
1942	58.00	57.00	*uralensis*	107		132	68	106	103	103		105	114	106	107	114		105	95	105	110		106	108
			Average	103	106	98	88	104	103	103	108	106	105	103	105	106	100	101	103	103	108	88	106	102
U.S.S.R.--CENTRAL RUSSIA																								
1935	50.00	30.00	*balcanica*[5]	103		90	84	106	96	120		129	124	139	128	100		105	100	102	130		214	172
1936	54.00	32.00	*balcanica*	94		104	107	102	102	115		125	117	125	120	100		110	95	102	144		180	162
1937	54.50	32.00	*balcanica*	107		138	114	102	115	101		101	107	102	103	100		110	111	107	104		128	116
1938	54.00	36.00	*balcanica*	103		118	137	106	116	115		124	115	122	119	86		115	105	102	130		149	140
1939	53.00	37.00	*balcanica*	103		125	114	97	110	130		130	125	133	130	90		105	111	102	130		188	159
1940	52.00	39.00	*balcanica*	107		118	107	102	108	129		125	130	136	130	90		105	111	102	126		188	157
			Average	103		116	110	102	108	118		122	120	126	122	94		108	106	103	127		174	151
U.S.S.R.--LATVIA																								
1920	57.50	25.83	*rigensis*[3]		104				104		113				113		94			94		112		112
1921	57.67	26.33	*rigensis*		104				104		109				109		100			100		117		117
			Average		104				104		111				111		97			97		114		114
NORTHERN POLAND																								
1919	53.83	20.45	*polonica*[3]		107				107		119				119		100			100		112		112
1931	53.72	20.45	*polonica*		96				96		119				119		94			94		113		113
					102				102		119				119		97			97		112		112
SOUTHERN SWEDEN																								
1933	55.87	14.08	*septentrionalis*[3]		102				102		109				109		100			100		119		119
WESTERN HUNGARY																								
1934	47.68	16.58	*pannonica*[3]		80				80		92				92		89			89		118		118
TURKEY																								
1932	40.50	32.67	*armena*[3]		93				93		64				64		94			94		140		140
				- - - - Percent - - - - -						- - - - - Meters - - - - -						- - - - - Scale[6] - - - -					- - Scale[7] - -			
Plantation mean				93	94	60	55	94	74	3.84	4.15	3.32	3.74	2.30	3.47	2.1	1.8	2.0	1.9	1.95	2.08	2.39	2.62	2.56

[1]Seed of 33 origins received in 1956, sown in 1957, field planted in 1961; 2-0 stock of 16 additional origins received in 1961, planted at Oenbigh-2 in 1963.

[2]Measurements taken at age from seed: 11 years at Horning, 12 years at Oenbigh-2, 14 years at all other sites. Horning plantation was destroyed by wildfire in April 1968.

[3]Wright et al. (1966).

[4]From different sites and age classes.

[5]Pravdin (1969).

[6]Crown density ranked on a scale of 1 = sparse, 3 = dense.

[7]Winter foliage color ranked on a scale of 1 = yellowest, 5 = darkest green.

Trees from only two seed sources suffered serious mortality (greater than 50 percent). These were trees from northern Siberia of the lapponica variety (624, 626). Survival of the 49 origins averaged over all sites was 79 percent.

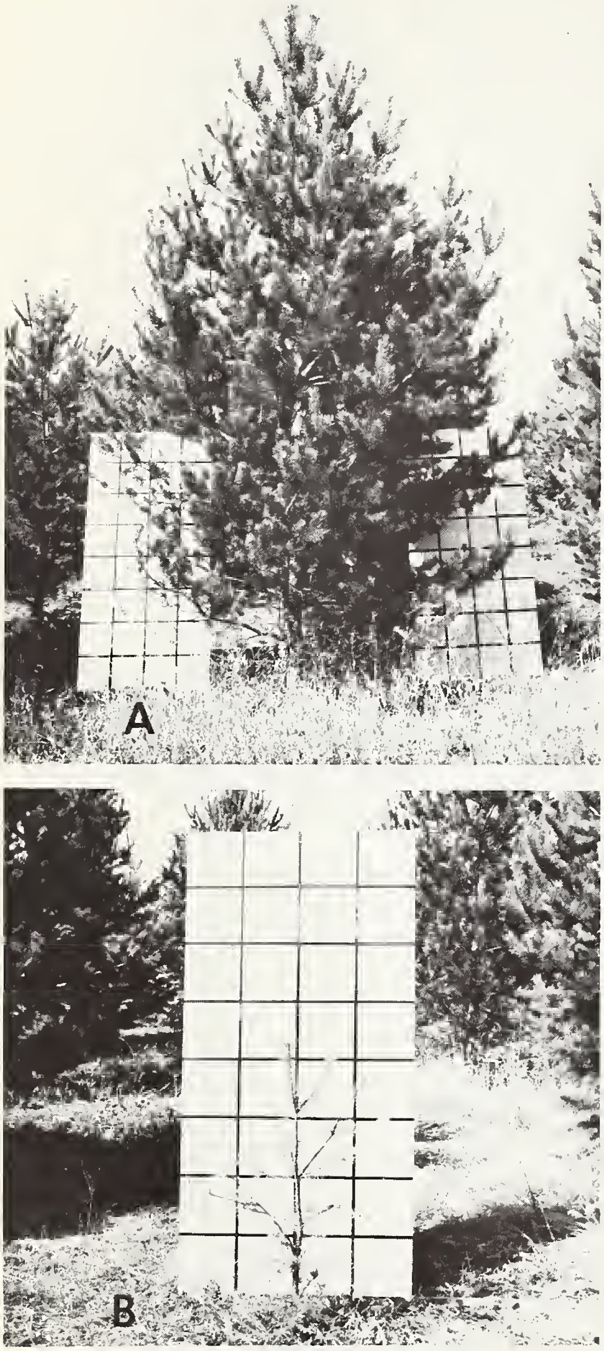


Figure 3.—Differences in height growth were striking. Origin 1936, balcanica (A), autgrew origin 624 lapponica (B), by a wide margin at all sites.

Trees of the balcanica variety from central Russia averaged the highest overall survival, followed closely by the altaica variety.

Height Growth

Generally trees from the more southwesterly origins grew tallest (fig. 3, tables 2 and 3). At Denbigh-1 and Horning, approximately 67 and 78 percent of the variation in total height could be attributed to the combined effect of latitude and longitude. At Denbigh-2 where a more restricted range of varieties were tested the combined effect of latitude and longitude accounted for 45 percent of the variation in total height.

Fastest growing varieties included polonica from eastern Europe, balcanica from central Russia, and altaica from south-central Siberia. The mongolica, and lapponica varieties from far-eastern and central Siberia grew slowest.

Significant intra-variety variation was evident in several of the geographic varieties. Origin 1941 of the uralensis variety out performed any other origin within that variety. Its more southerly location likely accounts for its superior performance.

More localized variation is expressed by the relative performances of origins 1936 and 1937. Separated by only one-half degree of latitude (about 34 miles), origin 1936 outgrew origin 1937 by a wide margin at each of the test sites.

Varietal performance at different locations was quite consistent. At least 9 of the overall top 10 origins could be predicted from individual test site performance (table 4). The maximum change in rank for any origin at any test site was four positions. This apparent lack of sizable genotype-environment interaction sug-

Table 4.--Relative ranking at each test site of the 10 provenances averaging tallest over 4 test sites

Origin number	All-site average	Ransom	Richland	Denbigh-1	Horning
1939	1	1	2	1	3
1940	2	4	1	2	2
1935	3	2	3	4	1
1941	4	8	7	3	4
1936	5	5	5	7	5
642	6	3	4	9	10
1938	7	7	10	8	6
644	8	11	8	6	7
640	9	9	9	5	11
643	10	6	6	11	9

gests that the results of this study may indicate performance of the origins over a wide range of sites in the northern and central Plains.

The accuracy with which performance after 10 years in the field could have been predicted from fifth-year data is indicated below:

Plantation	Correlation (r)	Success ratio
Denbigh-1	0.96	9/10
Denbigh-2	.98	9/10
Ransom	.96	9/10
Richland	.90	8/10

The success ratio is the number of origins correctly predicted from fifth-year data to be the best of 10 origins after 10 years. All r values are significant at the 1 percent level. These ratios show that, at 3 of the 4 locations, 9 of the top 10 origins could have been correctly predicted 5 years in advance. Early evaluation of performance should shorten the time interval between test initiation and practical application of results.

Crown Density

Considerable intra-origin variation was evident in crown density. One tree from a particular origin might exhibit a dense, compact crown while another tree from the same origin would be very open and sparsely branched (fig. 4). This intra-origin variation tended to obscure between-origin differences.

Generally the central Siberian origins from the southern Yenesei River exhibited the best crown density (tables 2 and 3). Next best were those origins of the balcanica variety. Poorest were the most northerly origins of the lapponica variety.

Crown density is a function of several variables. (Dawson and Read 1964). It appears that, in order of decreasing importance, branch angle would be the most important, followed by number of branches, live branch retention, kind and amount of foliage, and finally branch thickness. The degree to which each of these variables contributes to overall crown density requires further investigation. It should be possible, how-

Figure 4.—These trees, both from origin 1940 in central Russia, demonstrate intra-origin variation in form and crown density.

ever, to find a rapidly growing tree that exhibits good crown density, a desirable characteristic for a shelterbelt tree. Origins that combine such desirable characteristics will be discussed later.

Winter Foliage Color

Generally, the more westerly origins produced trees with the darkest green foliage (tables 2 and 3). A weaker trend was for more southerly origins to be darker green. From 75 percent to 89 percent of the variation in winter foliage color was related to the combined effect of latitude and longitude.

The six darkest green origins at each test site where color was scored were from south of 56° north latitude and west of 57° east longitude. Varieties represented by these origins were armena, septentrionalis, pannonica, regensis, polonica, and balcanica.

Conclusions and Recommendations

All of the Scotch pine varieties but two survived adequately at all test sites. Origins 624 and 626 of the lapponica variety suffered extensive mortality at all test sites. The absence of a prolonged drought during the test period precludes the identification of origins particularly susceptible to, or tolerant of, extreme drought. Scotch pine is generally considered less tolerant of drought than is ponderosa pine.

In shelterbelt plantings, adequate survival, rapid growth rate, and moderately good crown density are important traits. Foliage color, particularly winter color, is important where esthetic values should be considered, particularly in farmstead plantings.

Although crown density was not highly variable among the origins tested, the central Siberian and Russian origins were generally most dense and the northern Siberian origins the least dense.

Both growth rate and winter foliage color varied considerably (table 5). Generally, trees from the more southwesterly origins grew fastest and had the darkest green winter foliage. Read (1971) reported a similar trend with trees from origins in France, Belgium, and Germany growing faster and having greener winter foliage than trees from origins in Siberia.

For windbreaks, where foliage color is not important, the best origins for planting in the northern Great Plains are from central Russia (1939, 1940) and the Ural Mountains (1927, 1930). Nearly as good are a number of origins from central Siberia (1922, 1923, 1926, 637). For windbreak plantings in the central Great Plains, Read (1971) recommended fast-growing central European origins from Belgium, Germany, and France. The adaptability of these origins to the colder climate of the northern Great Plains has not been adequately tested.

The fastest growing origins with good color are from Poland (1919, 1931) and Latvia (1920). Other origins combining fast growth rate with good color are those from southern Sweden (1933), central Russia (1935), Hungary (1934), and Latvia (1921). Poorest were origins from northern Siberia.

For Christmas tree culture, origin 1934 from Turkey would be a good choice for the northern Great Plains. Its blue-green foliage and moderately slow growth are traits favored by Christmas tree growers. Read (1971) also recommended this variety (armena) for Christmas tree culture in Nebraska.

The incidence of insect and disease attacks has been only minor, and it is not yet possible to rank the provenances in order of susceptibility to particular insect or disease problems.

Nurserymen or tree planters should make specific inquiries to seed dealers regarding the availability of seed from desired origins or varieties. Often seed dealers can procure seed of many varieties that are not normally listed in their catalogs. At least two of the varieties recommended in this Paper are presently listed by United States seed dealers. Others may be available upon request. The extra effort invested in obtaining the best variety for a specific use is nearly always repaid many times over in the increased value of the trees produced.

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Table 5.--Groupings of Scotch pine origins by growth rate and winter foliage color

Height growth	Blue-green foliage	Green foliage	Yellow-green foliage	Yellow foliage
VERY FAST (more than 46 cm per year)		1919 Poland 1931 Poland 1920 Latvia	1927 Ural Mountains 1940 Central Russia 1939 Central Russia 1930 Ural Mountains	
FAST (38 to 45 cm per year)		1921 Latvia 1933 Sweden 1935 Central Russia 1934 Hungary	1923 Central Siberia 1929 Ural Mountains 1928 Ural Mountains 1941 Ural Mountains 1936 Central Russia 1938 Central Russia 1922 Central Siberia 1926 Central Siberia 1925 East Siberia 637 Central Siberia	642 Altai Mountains 644 Altai Mountains 640 Altai Mountains 643 Altai Mountains 641 Altai Mountains 1942 Ural Mountains
MEDIUM FAST (30 to 37 cm per year)			1937 Central Russia	1943 Ural Mountains 636 Central Siberia 634 Central Siberia 635 Central Siberia 639 Central Siberia 638 Central Siberia 632 Central Siberia 629 Central Siberia 633 Central Siberia 628 Central Siberia 630 Central Siberia 645 Ural Mountains 646 Ural Mountains 623 East Siberia
MEDIUM SLOW (22 to 29 cm per year)	1932 Turkey			627 Central Siberia 625 Central Siberia 631 Central Siberia
SLOW (less than 21 cm per year)				626 North Siberia 1924 East Siberia 624 North Siberia

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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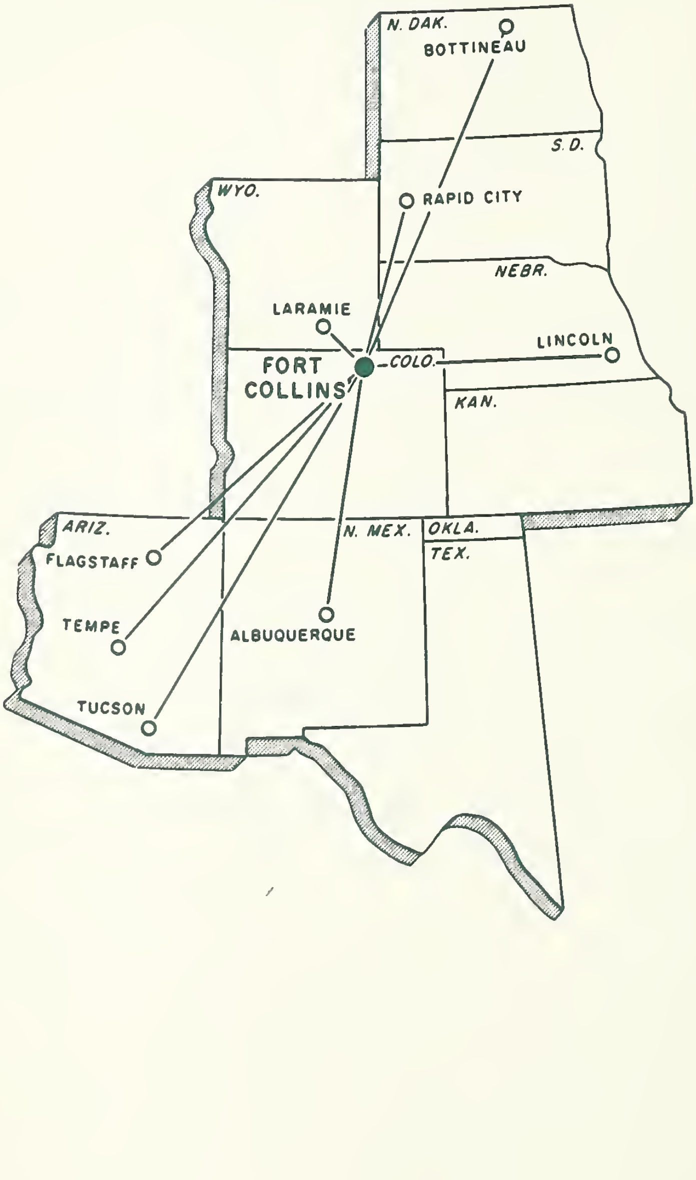
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