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STATION PAPER NO.18 JUNE 1949

WINTER INJURY AND RECOVERY OF CONIFERS IN THE UPPER MIDWEST

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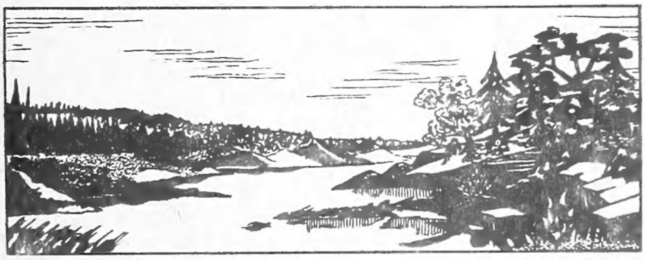

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U. S. Department of Agriculture, Forest Service
Lake States Forest Experiment Station 1/

Station Paper No. 18 July 1949

Winter Injury and Recovery of Conifers in the Upper Midwest

By

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In the northern plains and the Black Hills serious winter damage to conifers is quite common, but in the natural forest areas of the Lake States it is much less frequent. However, even in the latter region many nurseries and plantings suffered serious losses during the winter of 1947-48, and such conditions are almost sure to come again. For this reason there is considerable interest in reliable information as to species, seed sources, and practices which will help avoid or alleviate future winter damage. Such observations have been brought together for some 30 species in several localities in Wisconsin, Minnesota, North Dakota, and South Dakota.

CAUSES OF WINTER DAMAGE

Normally most conifers grown in the upper midwest are very cold resistant (2). However they may suffer freezing damage when unseasonable warm spells are followed by sudden temperature drops, or sun scald, or drought injury (3) when warm, dry days occur while the ground is very cold or frozen. Such conditions occurred over much of northern Michigan, Wisconsin, Minnesota, and North Dakota the winter of 1947-48, and in several earlier years in the Dakotas.

There was a combination of conditions which made the period from October 1947 to March 1948 unusually hard on plants in northern Wisconsin, Minnesota, and North Dakota. In much of this area, October 1947 was the warmest on record. Temperatures reached 80 degrees F. or higher. In November the weather turned cold abruptly, and subzero temperatures occurred. Up to mid-February the winter was not particularly unusual, although temperatures were below normal. But in mid-February maximum temperatures approached or exceeded 40 degrees F. In some localities, at least, this warm period was accompanied by bright sunshine and drying winds. During the first half of March, temperatures again dipped sharply and reached close to -30 degrees F. or colder.

The causes of damage to conifers may have been (1) freezing of poorly hardened tissue during the sudden cold following the unseasonably warm October, (2) excess transpiration or sun scald damage during the February warm spell,

1/ Maintained at University Farm by the United States Department of Agriculture in cooperation with the University of Minnesota.

(3) freezing damage during the March subzero period, or (4) some combination of these conditions. Observations in a northeastern Wisconsin locality did establish that the browning of hemlock foliage appeared there within 10 days after the mid-February warm period (6), during which temperatures of 44 to 46 degrees F. were accompanied by bright sunshine and strong, drying southerly winds (reaching 51 miles per hour in extreme instances).

Winter injury in previous years in the Dakotas was also accompanied by weather conditions especially conducive to freezing or drying out of plant tissues.

SPECIES INJURED AND THEIR RECOVERY

Winter injury to conifers in the upper midwest during 1947-48 varied a good deal according to species, tree size, site, exposure, and other factors. Generally, (1) introduced species were injured more than native species; (2) planted trees between 1.5 and 5 feet tall suffered more mortality than taller or shorter plantings, or natural trees; (3) some species with heavy foliage browning or even defoliation, recovered satisfactorily, but others did not; (4) ornamental and landscape specimen trees were often badly damaged, disfigured, or even killed; (5) there was little or no injury below the snow line; (6) specimen and open grown trees along the north side of roads were injured more than those protected from the south; (7) over-topped trees were damaged more than trees of good vigor; (8) from snowline to a point 2 or 3 feet above it, damage was especially severe.

Observations in Wisconsin

In the spring of 1948 a general survey was made in northern and central Wisconsin to appraise damage among forest plantations, snow trap plantings, and planted ornamentals. A follow-up was made in the fall to determine recovery (Table 1). By April many hemlocks had dropped their needles and many other species had developed brown foliage. The reaction of several species was as follows:

> Ponderosa pine, white (concolor) fir, Austrian pine, and Douglas-fir, all introduced species, suffering heavy mortality.
>
> Scotch pine suffered considerable damage and in individual plantations one and two-year-old wood and sometimes the entire tree was killed. Out of 100 trees 6 to 22 feet tall planted on the Rhinelander Golf Course, 50 percent were alive and symmetrical on August 27, 1948, 4 percent were alive and slightly mis-shapen, 28 percent were alive but badly mis-shapen (usually with dead tops), and 18 percent were dead.
>
> Red pine was damaged more in central than in northern Wisconsin. In the former locality plantations 4 to 12 feet tall suffered about 5 percent mortality and at least 25 percent of the survivors were mis-shapen because of death of tops or limbs.[2] On the other hand,, of 50 red pines 8 to 12 feet tall on the Rhinelander Golf Course survival was 100 percent, no trees were mis-shapen, and all injured foliage was replaced by new growth.

2/ Observations by Alvin Nelson, Wisconsin Conservation Department, Wisconsin Rapids.

Table 1.- Apparent winter injury and recovery of conifers in 1948 in Wisconsin.

Species or group of species	Planted or natural	Usual location or use of trees	Estimated average mortality	Mis-shapen trees among survivors	Injury as judged by browning of needles in April 1948 1/	Recovery or condition on 9/1/48 2/
			Percent	Percent		
Ponderosa pine	P	Landscape	40	80	Severe	Poor
White (concolor) fir	P	"	30	70	"	"
Austrian pine	P	"	40	20	"	"
Douglas-fir	P	"	20	80	"	"
Upright forms of non-native yew	P	"	5	50	"	"
Mugho pine	P	"	10	30	"	Fair
Pyramidal arborvitae	P	"	5	50	"	Poor
Scotch pine	P	Snow traps, forest plantations	5	10	"	"
Non-native junipers	P	Landscape	5	70	"	"
Eastern hemlock	P	"	5	5	"	Good
Eastern hemlock	N	Natural stands	1	1	"	"
Norway spruce	P	Snow traps, forest plantations	2	5	"	Fair
Blue spruce	P	Landscape	1.0	5.0	Moderate	"
Eastern white pine	P	Forest plantation, snow traps	1.0	1.0	Severe	Good
Eastern white pine	N	Natural stands	0.2	0.2	"	"
Northern white-cedar	P	Landscape	5.0	5.0	Moderate	Fair
Northern white-cedar	N	Natural stands	0.5	0.2	Light	Good
Red pine	P	Forest plantations, snow traps	0.2	0.2	Moderate	"
Red pine	N	Natural stands	0.1	0.1	Light	"
Balsam fir	P	Landscape	0.1	0.1	"	"
Balsam fir	N	Natural stands	0.0	0.1	"	"
Jack pine	P	Forest plantations	0.2	0.2	"	"
Jack pine	N	Natural stands	0.1	0.1	"	"

Table 1.- Apparent winter injury and recovery of conifers in 1948 in Minnesota (Continued)

Species or group of species	Planted or natural	Usual location or use of trees	Estimated average mortality	Mis-shapen trees among survivors	Injury as judged by browning of needles in April 1948 1/	Recovery or condition on 9/1/48 2/
			Percent	Percent		
Eastern redcedar	P	Windbreaks and landscape	0.2	1	Light	Good
Eastern redcedar	N	Natural stands	0	0	"	"
Dwarf juniper (J. communis)	P	Landscape	0	2.0	"	"
Dwarf juniper (J. communis)	N	Natural stands	0	0.2	"	"
Siberian arborvitae (globe)	P	Landscape	0	1	"	"
White spruce	P	Forest plantations	0	0	Very light	"
White spruce	N	Natural stands	0	0	"	"
Black spruce	P	Windbreaks and landscape	0	0	"	"
Black spruce	N	Natural stands	0	0	"	"
Western white (Black Hills) spruce	P	Landscape	0	0	"	"

1/ Definition of defoliation classes:
Severe - over 35 percent average defoliation. Average about 50 percent.
Moderate - 15 to 35 percent average defoliation. Average about 25 percent.
Light - 5 to 15 percent average defoliation. Average about 10 percent.
Very light - Less than 5 percent average defoliation. Average about 2 percent.

2/ Definition of recovery classes: Good - combined percentage of trees killed or seriously mis-shapen, usually less than 5 percent, with a maximum of 10 percent. Fair - combined percentage of trees killed or seriously mis-shapen, usually in the range of 10 to 20 percent. Poor - combined percentage of trees killed or seriously mis-shapen, usually in the range of 20 to 80 percent.

White pine and hemlock showed extensive needle browning even in natural trees 50 or more feet tall.

Norway spruce suffered most defoliation in the zone just above the snow line. However, one or two-year old wood was seldom injured and recovery was better than in Scotch pine. In one lot trees with 60 to 80 percent defoliation had a 50 percent reduction in height growth in 1948.

Non-native junipers fared badly.

Blue spruce suffered variable injury but its recovery was fair to good.

To supplement the generaly survey, 333 planted and natural trees near Rhinelander, Wisconsin were tagged and examined in early spring and again in late August 1948. These trees, of seven species, were 8 to 25 feet tall, 10 to 20 years old, and had somewhat better growing conditions than those over the area as a whole.

A striking feature of this study was the ability of some species to recover without deformity despite heavy defoliation (Table 2). Eastern white pine with 58 percent average defoliation and eastern hemlock with 39 to 41 percent averaged defoliation suffered no mortality. White pines with less than 60 percent defoliation showed little deformity from killing of the leader or side branches. Some individual white pines were 100 percent defoliated, but they survived, and by fall were symmetrical and of fair to good vigor. Blue spruces over 20 percent defoliated were often mis-shapen largely because of the death of limbs in the zone just above the snow line. Ponderosa pine was wiped out.

Damage in Minnesota

Winter damage to conifers was observed in three localities in Minnesota: On the Chippewa National Forest in Cass County, on the Superior National Forest in Lake and St. Louis Counties, and in the vicinity of St. Paul. According to some reports, browning of conifer needles took place in late November or December 1947, or January 1948, but the observations reported here showed the bulk of such injury after mid-February 1948.

On the Chippewa National Forest 4,800 Scotch pines from 12 to 19 years old were observed.3/ Of these, 52 percent were undamaged, 13 percent had less than 1/2 of their foliage injured, 28 percent had more than half their foliage injured; and 7 percent died. The majority of the trees which had less than half their foliage injured recovered satisfactorily, whereas the majority of those more heavily injured did not.

On the Superior National Forest experimental plantations of red pine and Scotch pine 19 years old had 11 and 44 percent of their foliage injured respectively.4/ For both species recovery appeared to be related chiefly

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3/ Field examination made by Paul J. Zehngraff, Lake States Forest Experiment Station.

4/ Field examination made by E. I. Roe, Lake States Forest Experiment Station.

Table 2.- Winter injury and recovery of tagged trees in northern Wisconsin. 1/

Species	0-20 percent defoliation			21-40 percent defoliation			41-60 percent defoliation		
	Survival	Mis-shapen	trees in class	Survival	Mis-shapen	trees in class	Survival	Mis-shapen	trees in class
	Pct.	Pct.	No.	Pct.	Pct.	No.	Pct.	Pct.	No.
Eastern white pine	100	0	7	100	6	18	100	11	46
Red pine	100	0	7	100	7	15	100	17	6
Mugho pine	100	0	3	100	0	2	100	0	1
Ponderosa pine	-	-	-	-	-	-	-	-	-
Colorado blue spruce	100	23	13	98	44	41	100	45	11
Natural hemlock	100	0	2	100	0	5	100	0	6
Planted hemlock	-	-	0	100	50	4	100	0	2
White cedar	100	0	3	100	7	14	100	14	7

1/ Tagged and observed for defoliation in late April and early May 1948. Survivals taken in late August 1948. All trees were planted except the group labeled "Natural hemlock."

61-80 percent defoliation			81-100 percent defoliation			Weighted average of all defoliation classes			
Survival	Mis-shapen	trees in class	Survival	Mis-shapen	trees in class	Surivival	Mis-shapen	Total trees all classes	Average defol-iation
Pct.	Pct.	No.	Pct.	Pct.	No.	Pct.	Pct.	No.	Pct.
100	21	53	100	22	18	100	15	142	58
100	67	3	-	-	-	100	13	31	33
100	100	2	-	-	-	100	25	8	48
-	-	-	0	-	10	0	-	10	100
100	82	11	100	100	2	99	47	78	37
100	0	1	-	-	0	100	0	14	39
100	0	1	-	--	0	100	29	7	41
100	0	4	-	-	0	100	7	28	39

to severity of injury (Table 3). Considering new growth on at least half of the crown of injured trees as satisfactory recovery, 98 percent of the red pine, and 23 percent of the Scotch pine fall into this class. If trees with good and excellent recovery are combined with those not injured, the percentages become 99 for red pine and 56 for Scotch pine (Table 3).

Trees which did not have more than 1/4 their foliage injured recovered satisfactorily (good or excellent) in either species. Poor recovery was confined to those trees which had more than 3/4 of their foliage injured. There was satisfactory recovery by about 25 percent of the red pines, but by only about 3 percent of the Scotch pines which had more than 3/4 of their foliage injured (Table 3).

Less detailed observations in this general locality indicated extensive winter injury on ponderosa pine and Norway spruce and little or no injury on balsam fir, jack pine, white spruce, black spruce, and northern white-cedar. White pine suffered severe foliage injury chiefly in the south side of the crown, but recovery was good. On the Aurora District of the Superior National Forest, white pines suffered most damage in a zone about 4 to 6 feet above ground; the tips of the trees and the parts below snow line were unaffected. There was sun scald on the southwest side of the trunks, and one-year needles were injured much more than older needles.

Some observations were also made in a commercial nursery near St. Paul.5/ There was no injury to conifers below the snow line. Spruces, red pine, and white pine recovered well from the winter injury, but Austrian pine and ponderosa pine were so badly damaged that they were grubbed out. Arborvitaes made partial recovery but none were saleable in 1948. Recovery was about 50 or 60 percent in the larger Savin and Pfitzer junipers. Four juniper clones (Burk, Canaert, Schott, and Silver) were a total loss. Two conifers which escaped injury were western white (Black Hills) spruce and the Hill Dundee juniper. Damage apparently occurred after December 25, 1947, since uninjured cuttings of pyramidal arborvitae were taken at that time.

Observations in North Dakota

Considerable browning of needles occurred among conifers in north-central North Dakota in late March 1946, during or following some abnormally warm winds. Among experimental plantations in McHenry County the injury was especially prevalent on ponderosa, Austrian, and Chinese pines, and was also quite general on Chinese juniper, Rocky Mountain juniper, red pine, and limber pine. Uninjured species were western white (Black Hills) spruce, white spruce, blue spruce, and certain hardy lots of Rocky Mountain juniper (from western North Dakota), Scotch pine (of Finnish origin), eastern red cedar, and dwarf juniper (from La Crosse, Wisconsin).

More detailed observations on ponderosa pine (6-10 years old) in the same area disclosed these facts: (1) about 2 percent of the trees were killed and 6 to 7 percent had tops killed back, (2) only 1 percent of bud-pruned trees had tops killed back, (3) the season following injury annual height growth was reduced about 10 percent for each 10 percent of defoliation (Table 4), (4) growth the second season after winter injury was better, but that of injured trees was still about 30 percent below that of uninjured trees, (5) injury varied according to soil -- trees on dune sand had no

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5/ Observations made by Gordon Bailey of the J. V. Bailey Nurseries.

Table 3.- Degree of recovery according to severity of foliage injury during 1947-48 winter - pine plantations on Superior National Forest

RED PINE

Amount of foliage injured	Degree of recovery 1/					No injury	Total	Basis trees	Proportion of total
	None	Poor	Fair	Good	Excellent				
Pct.	Pct.	Pct.	Pct.	Pct.	Pct.			No.	Pct.
0	....	....	....	....	....	100.0	100.0	485	27.9
1-10	....	....	....	0.1	99.9	.....	100.0	745	42.9
11-25	....	....	....	2.1	97.9	.....	100.0	333	19.2
26-50	....	....	2.7	18.0	79.3	.....	100.0	111	6.4
51-75	....	....	9.3	46.5	44.2	.....	100.0	43	2.5
76-90	....	13.3	53.4	20.0	13.3	.....	100.0	15	.9
91-100	....	25.0	75.0	....	....	.....	100.0	4	.2
Total	....	.2	1.1	2.9	67.9	27.9	100.0	1,736	100.0

SCOTCH PINE

Amount of foliage injured	None	Poor	Fair	Good	Excellent	No injury	Total	Basis trees	Proportion of total
0	....	....	....	....	....	100.0	100.0	477	42.3
1-10	....	....	....	....	100.0	.....	100.0	21	1.9
11-25	....	....	....	20.0	80.0	.....	100.0	25	2.2
26-50	....	....	16.0	40.0	44.0	.....	100.0	50	4.4
51-75	....	3.6	39.8	42.1	14.5	.....	100.0	83	7.3
76-90	.4	74.1	19.7	5.4	.4	.....	100.0	259	22.9
91-100	.9	87.6	10.6	.9	....	.....	100.0	214	19.0
Total	.3	33.8	10.2	6.7	6.7	42.3	100.0	1,129	100.0

1/ Based on proportion of crown with new growth, as follows: None, 0; poor, less than 1/4; fair 1/4 - 1/2; good, 1/2 - 3/4; and excellent, more than 3/4.

Table 4.- Growth of 6-year-old Ponderosa Pine as affected by defoliation caused by winter injury in March 1946. Denbigh, N. D.

Defoliation	Annual growth	
	First season after winter injury	Second season after winter injury
Percent	Feet	Feet
0	1.02	1.36
10	0.94	1.18
20	0.87	1.08
30	0.78	1.04
40	0.68	1.01
50	0.57	0.99
60	0.45	0.97
70	0.32	0.95

injury, those on Valentine sand (upland) had 22 to 35 percent defoliation, and those on Gannett fine sandy loam (swales) had 55 to 73 percent defoliation.

An examination of the same ponderosa pine plantations in September 1948[6/] showed rather similar results from the 1947-48 winter. In general, the larger trees showed the least injury. Trees with less than 50 percent foliage injury showed good recovery; those with 50 to 80 percent injury recovered fairly well, and those with 90 percent or more injury recovered poorly. Of the trees on Valentine sand (upland) 21 percent were uninjured, 68 percent had light injury, 6 percent had moderate injury, 3 percent had heavy injury, and 2 percent were dead. On the Gannett fine sandy loams (swales) the corresponding percentages were 0 (none), 13 (light), 14 (moderate), 41 (heavy), and 32 (dead).

Some more general observations[7/] indicated that browning of eastern red cedar and Rocky Mountain juniper foliage has been prevalent, especially during the 3 or 4 winters just preceding 1947-48. It was generally confined to the north and west sides of trees exposed to northwest winds, and in some cases one-and two-year-old wood was killed.

During 1947-48, however, the trees "burned" on all sides regardless of exposure. Injury was most severe in eastern North Dakota, but occurred throughout the State. There was no injury below the snow line. Worst hit in 1947-48 was ponderosa pine, followed in decreasing order by redcedar, Scotch pine, western white (Black Hills) spruce, and blue spruce.

Damage in the Black Hills

In the Black Hills of South Dakota severe winter damage to the native ponderosa pine has been observed at intervals. It has usually been associated with Chinook winds which sometimes cause changes of temperatures of as much as 40 to 60 degrees F. from subzero levels to points above freezing within a period of several minutes to a few hours (1).

Severe foliage injury and some winter kill were noted in various localities about 1911,[8/] 1936,[9/][10/] and 1943[8/][10/] on ponderosa pine. In 1943 damage was also noted on native pin cherry, aspen, oak, and service berry. Both freezing of tissue and excess transpiration appear to have played parts in causing damage in this area.

6/ Examination made by F. H. Eyre, Lake States Forest Experiment Station.

7/ Made by E. J. George, Northern Great Plains Field Station, Mandan, North Dakota.

8/ By C. G. Bates, Lake States Forest Experiment Station.

9/ By Jacob Roeser, U. S. Forest Service.

10/ By Lee Luckinbill, U. S. Forest Service.

It is foolish to persist in planting species which suffer heavy winter damage. Yet, the fact often overlooked is that many tree species include several races which may vary in resistance to winter damage as they do in other characteristics. Evidence of such racial variation has been assembled for red pine, Scotch pine, ponderosa pine, white spruce, Norway spruce, and other species planted in the upper midwest. It indicates that trees of native sources or those from similar or slightly colder climates suffer less winter damage than those from milder climates.

Red Pine

On the Superior National Forest in northeastern Minnesota, a 19-year old (from seed) plantation containing 37 sources of red pine, representing 35 localities in the Lake States and two in New England (4), was examined late in the summer of 1948. One growing season had elapsed after the 1947-48 winter.

Among the various red pine sources from 2 to 55 percent of the foliage had been injured. On the average, the local northeastern Minnesota sources had suffered least (4 percent). There was a trend toward increasingly greater injury with distance of origin from the planting site, as follows: Northwestern Wisconsin (5 percent), north-central Minnesota (6 percent), northeastern Wisconsin (7 percent), upper Michigan (12 percent), central Wisconsin (13 percent), lower Michigan (31 percent), and New England (39 percent). If the poorest northeastern Minnesota source (6.2 percent foliage injury) be taken as a base, significantly more injury was suffered by trees of the following sources: One from north-central Minnesota, 2 from upper Michigan, 2 from central Wisconsin, and all those from lower Michigan and New England (Table 5). Viewed from another aspect, the best 25 percent of the lots (those with least injury) included 4 from northeastern Minnesota, 3 from northwestern Wisconsin, and 2 from north-central Minnesota. The poorest 25 percent, on the other hand, included 5 from lower Michigan, 2 from New England, and one from upper Michigan.

Recovery was satisfactory (new growth on more than half of the injured crown) among all trees of the sources from northern Minnesota, Wisconsin, and Michigan. There were small but increasing percentages of trees with unsatisfactory recovery among the sources from central Wisconsin, lower Michigan, and New England. However, some individual lots even from these latter localities showed satisfactory recovery for all trees.

Scotch Pine

On the Chippewa National Forest there are experimental plantations of Scotch pine of 40 seed sources representing 15 European countries. Three plantations with ages of 12, 17, and 19 years from seed were studied. Because of similarities of response the results were grouped together.

The percentage of trees with browned foliage ranged from 0 to 98 for the different sources. Generally those from the more northerly sources showed less damage than those from farther south. But, latitude alone did not explain the differences. However, when those sources from a climate similar to that of the Chippewa National Forest (according to Köppen's classification) were compared with those from milder localities, the differences were striking.

Table 5.- Winter injury and recovery among planted pines of different seed origins in northeastern Minnesota

RED PINE

Region of seed origin	Sources	Amount of foliage injured		Trees with unsatisfactory recovery	
		Average	Range	Average	Range
	Number	Percent	Percent	Percent	Percent
Northeastern Minnesota	7	4.0	2.2 - 6.2	0	-
Northwestern Wisconsin	5	4.6	3.0 - 6.1	0	-
North-central Minnesota	3	6.5	3.3 - 12.3	0	-
Northeastern Wisconsin	7	7.1	5.2 - 8.0	0	-
Upper Peninsula, Michigan	4	11.7	6.1 - 20.4	0	-
Central Wisconsin	4	12.9	10.6 - 15.4	0.6	0 - 1.6
Lower Michigan	5	31.4	18.9 - 44.3	6.4	0 - 19.0
New England	2	38.8	22.1 - 55.3	9.6	0 - 30.8
All sources	37	10.7	2.2 - 55.3	1.2	0 - 30.8

SCOTCH PINE

Region of seed origin	Sources	Average	Range	Average	Range
Manchuria	1	0.0	-	0	-
Northern Europe	7	2.4	0.0 - 21.9	1.2	0 - 17.1
Central Europe	19	78.8	58.6 - 92.0	79.2	50.0 -100.0
All sources	27	44.4	0.0 - 92.0	44.3	0 -100.0

In the former group (sources from Romania, Finland, Poland, Sweden, Norway, Latvia, East Prussia, and Russia) from 0 to 27 percent of the trees had injured foliage, and no source had over 3 percent of the trees with heavy injury. In the latter group (sources from Romania, Poland, Hungary, France, central Germany, Denmark, Holland, Scotland, and Austria) from 61 to 98 percent of the trees had injured foliage and from 10 to 72 percent of the trees were heavily injured (5).

On the Superior National Forest observations were made in a plantation containing 20 sources of Scotch pine 19 years old from seed and an additional 7 sources of Scotch pine two years younger. They were obtained partly from foreign sources and partly from local plantations, and included one lot from Manchuria, 7 of known or supposed northern European origin, and 19 of known or supposed central European origin.

The trees of Manchurian origin were uninjured during the winter of 1947-48. Those of known or supposed northern European origin were much less injured than trees of central European origin (Table 5). The best of the latter (59 percent) had more than double the amount of foliage injury sustained by the poorest of the former (22 percent).

Scotch pines of Manchurian and northern European origin actually averaged less foliage injury than local northeastern Minnesota red pine sources. On the other hand, Scotch pines of central European origin were damaged much more than the poorest red pine lots. On the basis of the number of trees with less than 10 percent of their foliage injured, there were included 94 percent of the northern European Scotch pine (including one Asiatic source), 71 percent of the red pine, and only 4 percent of the central European Scotch pines.

Pondorosa Pine

Ponderosa pine of four seed sources planted in McHenry County, North Dakota, differed in the amount of foliage injured during March 1946. Among these 6-year-old trees those of nearest native origins (western North Dakota, and eastern Montana) suffered the least damage (Table 6). Trees of the western Nebraska and Black Hills sources suffered more foliage injury. By the end of the second growing season, however, recovery was quite complete for trees of all sources, and there was no mortality among trees of any source.

Following the winter of 1947-48, trees of the near-local sources again showed less foliage injury than those of the two more distant sources.

Spruces

An experimental plantation of several species and sources of spruce, 17 years old from seed, was examined[11] on the Nicolet National Forest in northeastern Wisconsin in the summer of 1948. Needle damage varied a great deal within species as well as between species (Table 7). Undamaged were western white spruce and white spruces of three northern sources. White spruce of two

11/ By C. F. Arbogast, Lake States Forest Experiment Station.

Table 6.- Effect of seed source of ponderosa pine on Resistance to winter injury in March 1946 at Denbigh, N. D.

Seed source	Total trees	Trees in various percentage classes of needle browning						Average defoliation
		0	1-20	21-40	41-60	61-80	81-100	
	No.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Glendive, Montana	90	73	23	2	2	0	0	4.1
Medora, North Dakota	82	65	34	1	0	0	0	4.8
Western Nebraska	97	61	28	8	2	1	0	7.0
Black Hills, South Dakota	99	10	62	22	7	0	0	16.3

Table 7.- Damage to spruces during winter of 1947-48 - northern Wisconsin

Species	Seed source	Trees damaged	Needles killed on damaged trees	Basis plots 2/
		Pct.	Pct.	No.
Western white spruce 1/	Custer, S. D.	0	0	2
White spruce	Superior N. F., Minn.	0	0	2
White spruce	Chippewa N.F., Minn.	0	0	2
White spruce	Port Arthur, Canada	0	0	3
White spruce	Douglas, Ontario	16	9	5
White spruce	Wisconsin	20	5	1
Siberian spruce	Unknown	40	17	2
Norway spruce var. borealis	Unknown	29	15	2
Norway spruce	Bryansk, USSR	39	13	7
Norway spruce	Gomel, USSR	65	35	3
Norway spruce	Mosirs, USSR	74	55	5
Norway spruce	Belgrade, Yugoslavia	97	50	6
Oriental spruce	Caucasus, USSR	100	45	2
Serbian spruce	Belgrade, Yugoslavia	100	50	1
Red spruce	Pennsylvania	100	51	1
Red spruce	North Carolina	100	65	2

1/ Sometimes known as Black Hills spruce.
2/ Plots usually originally contained 100 trees, and have present survivals of about 50 to 80 percent.

sources suffered light injury. All Norway spruces suffered more winter injury than any of the white spruces, but trees of two northern sources suffered notably less damage than those from milder climates. Heavy damage was sustained by Norway spruce from Yugoslavia, oriental spruce, Serbian spruce, and two sources of red spruce. In spite of severe defoliation there was little or no mortality in any lots.

LESSONS FOR FUTURE PLANTING

Losses from winter injury sustained by conifers in the upper midwest can be turned to advantage by heeding the lessons which are evident. Through proper selection of species and seed sources, and the use of certain cultural practices, future losses from severe winter conditions can be minimized.

Species Selection

Among the points that stood out in the studies reported, were (1) the superiority of the native pines and spruces over introduced species in the northern Lake States; (2) the uniformly good showing of western white (Black Hills) spruce; (3) the remarkable recuperative power of white pine and some of the spruces after severe foliage injury; and (4) the general superiority of white spruce over Norway spruce in the Northern Lake States.

Seed Source

The superior hardiness of trees grown from seed originating locally or from areas of similar climate was clearly demonstrated for red pine, Scotch pine, ponderosa pine, white spruce, and Norway spruce. Other species which grow over an extensive natural range can be expected to show similar racial differences. In many cases damage of minor consequence for forest production may be of serious nature for landscape or ornamental purposes. Growers should, therefore, choose seed sources with care.

Cultural Practices

Maintenance of vigorous growth of trees in plantations by proper selection of site, adequate ground preparation, and preventing excessive suppression and shading by overstory trees may reduce winter injury. Adequate care of planted trees, especially by cultivation of windbreaks and ornamentals is helpful. Landscape stock may in some instances benefit by watering just before the plants go into the winter.

Spring planting has a distinct advantage over fall planting in that heavy first year losses such as those caused by unusual weather conditions during winter may sometimes be avoided.

In windbreaks and shelterbelts in the Great Plains area, winter injury of conifers caused by dessiccating winds may be reduced by planting them where they receive some protection from deciduous species.

Cutting and pruning of defoliated limbs shortly after winter injury seems inadvisable until the growing season is well along. Many such limbs produce another crop of needles and recover completely if left undisturbed for one or two years.

General

Whether for forest production, windbreaks, shelterbelts, snowtraps, landscape purposes, or other ornamental use, the planting of well adapted seed sources of the proper species on the right sites and the use of good cultural practice before and after planting are the surest means to success.

REFERENCES CITED

1. Cameron, D. C. Midwinter Temperature Antics in the Black Hills. Weatherwise. 1(6): 126-127, 138, illus. Dec. 1948.

2. Maximov, N. A. A Text Book of Plant Physiology. P. 126-129. McGraw Hill Book Co., Inc., New York. 381 pages. 1930.

3. Miller, E. C. Plant Physiology. P. 502. McGraw Hill Book Co., Inc., New York. 1,201 pages. 1938.

4. Rudolf, P. O. Importance of Red Pine Seed Source. Proc. Soc. Am. For. Meeting 1947. 384-398, illus. 1948.

5. Rudolf, P. O. Winter Damage to Scotch Pine in Northern Minnesota. Lake States Forest Exp. Sta. Tech. Note No. 305. 1 p. (proc.). October 1948.

6. Stoeckeler, J. H. Recovery of Winter Injured Conifers. Amer. Nurseryman. 88(9): 9, 54. November 1, 1948.

List of Common and Scientific Names of Species Referred to in Text

COMMON NAME	SCIENTIFIC NAME
Aspen, quaking	Populus tremuloides
Arborvitae, pyramidal	Thuja orientalis, clone stricta
Arborvitae, Siberian	T. occidentalis, clone Globe
Cherry, pin	Prunus pensylvanica
Douglas-fir	Pseudotsuga taxifolia
Fir, balsam	Abies balsamea
Fir, white (concolor)	A. concolor
Hemlock, eastern	Tsuga canadensis
Juniper, Burk	Juniperus virginiana clone burki
Juniper, Canaert	J. virginiana clone canaerti
Juniper, Chinese	J. chinensis
Juniper, dwarf	J. communis clone nana
Juniper, Hill Dundee	J. virginiana clone hilli
Juniper, Pfitzer	J. chinensis clone pfitzeriana
Juniper, Schott	J. virginiana clone schotti
Juniper, Savin	J. sabina
Juniper, silver	J. virginiana clone glauca
Juniper, Rocky Mountain	J. scopulorum
Oak, bur	Quercus macrocarpa
Pine, Austrian	Pinus nigra
Pine, Chinese	P. tabulaeformis
Pine, eastern white	P. strobus

COMMON NAME	SCIENTIFIC NAME
Pine, jack	*P. banksiana*
Pine, limber	*P. flexilis*
Pine, mugho (Swiss mountain)	*P. mugo*
Pine, ponderosa	*P. ponderosa*
Pine, red	*P. resinosa*
Pine, Scotch	*P. sylvestris*
Redcedar, eastern	*Juniperus virginiana*
Serviceberry	*Amelanchier* sp.
Spruce, black	*Picea mariana*
Spruce, blue	*P. pungens*
Spruce, Norway	*P. abies*
Spruce, oriental	*P. orientalis*
Spruce, red	*P. rubens*
Spruce, Serbian	*P. omorika*
Spruce, Siberian	*P. obovata*
Spruce, western white (Black Hills)	*P. glauca* var. *albertiana*
Spruce, white	*P. glauca*
White-cedar, northern	*Thuja occidentalis*