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# SILVICAL *Characteristics* OF... WHITE SPRUCE

(*Picea glauca*)

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## THE SILVICAL REPORTS

During 1907 and the following several years the U. S. Forest Service issued a series of silvical leaflets which covered the broad characteristics of a considerable number of major timber species. Since then much new knowledge has accumulated--some of it published in a variety of sources. There is also a considerable store of unpublished silvical information in the files of the forest experiment stations, the forest schools, and some other agencies. To compile this information systematically and make it available to foresters generally, the Lake States Forest Experiment Station is preparing reports on 15 individual species. Similar reports are being prepared by the other Federal forest experiment stations. When completed, these individual species reports will provide the basis for a comprehensive manual of silvics for the important trees of the United States, to be published by the U. S. Forest Service.

This report is one of the series being prepared by the Lake States Station. A preliminary draft was reviewed by several members of our own Station staff and by a number of well qualified staff members of other forest experiment stations, colleges, and universities; Federal, State, and Provincial forestry organizations; and forest industry. Their comments helped the author to make this report more complete, more accurate, and more up to date. Especially helpful reviews were submitted by Prof. I. C. M. Place, formerly with the Department of Forestry and Wildlife Management, University of Wisconsin, now with the Petawawa Forest Experiment Station, Ontario; Prof. Earl E. Stone, Jr., Department of Agronomy, Cornell University; and Carl Arbogast, Lake States Forest Experiment Station.

Every effort has been made to ensure the accuracy and completeness of the information concerning the silvical characteristics of each species consistent with a brief treatment of the subject. We shall appreciate it, however, if any errors or omissions of important information are brought to our attention.

M. B. Dickerman

M. B. Dickerman, Director

Cover: Mature white spruce of good form and quality, Superior National Forest, Minnesota. Drawing represents needles and cones.

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# SILVICAL CHARACTERISTICS OF WHITE SPRUCE

(*Picea glauca* (Moench) Voss)

By

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White spruce is a medium-sized tree and one of the three North American conifers with a transcontinental distribution. It attains greater size than either of the two other transcontinental species: tamarack and black spruce. Its needles and twigs have a rank or "catty" odor when crushed and it has, therefore, sometimes been called cat spruce and skunk spruce. Other common names which have been used are Canadian spruce, eastern spruce, Black Hills spruce, single spruce, and spruce pine (20, 38).[2]

## DISTRIBUTION

White spruce grows naturally from Newfoundland and Labrador west across Canada along the northern limit of trees to Hudson Bay, Northwest Territories, Yukon, and northwestern Alaska, south to southern, but not southeastern, Alaska, south in British Columbia east of the main range of the mountains, east in Alberta and Manitoba at a latitude of approximately 52° N., and southeast through the northern parts of Minnesota and Wisconsin to central Michigan, northeastern New York, northwestern Massachusetts, and Maine (38). Outlying populations occur in the Black Hills of South Dakota and in Montana and Wyoming (fig. 1).

In the North white spruce is one of the most important members of the boreal forest and reaches the tundra in the forest-tundra zone in some portions of its distribution. The portion of range south of the boreal forest in Canada and the United States is all part of the commercial range of the species.[3] Only the most southern zone--the close-

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1/ Maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minnesota, in cooperation with the University of Minnesota.

2/ Underlined numbers in parentheses refer to literature cited on page 20.

3/ Commercial range is defined as that portion of the botanical range in which the species grows to commercial size and is a major or important component of the type.

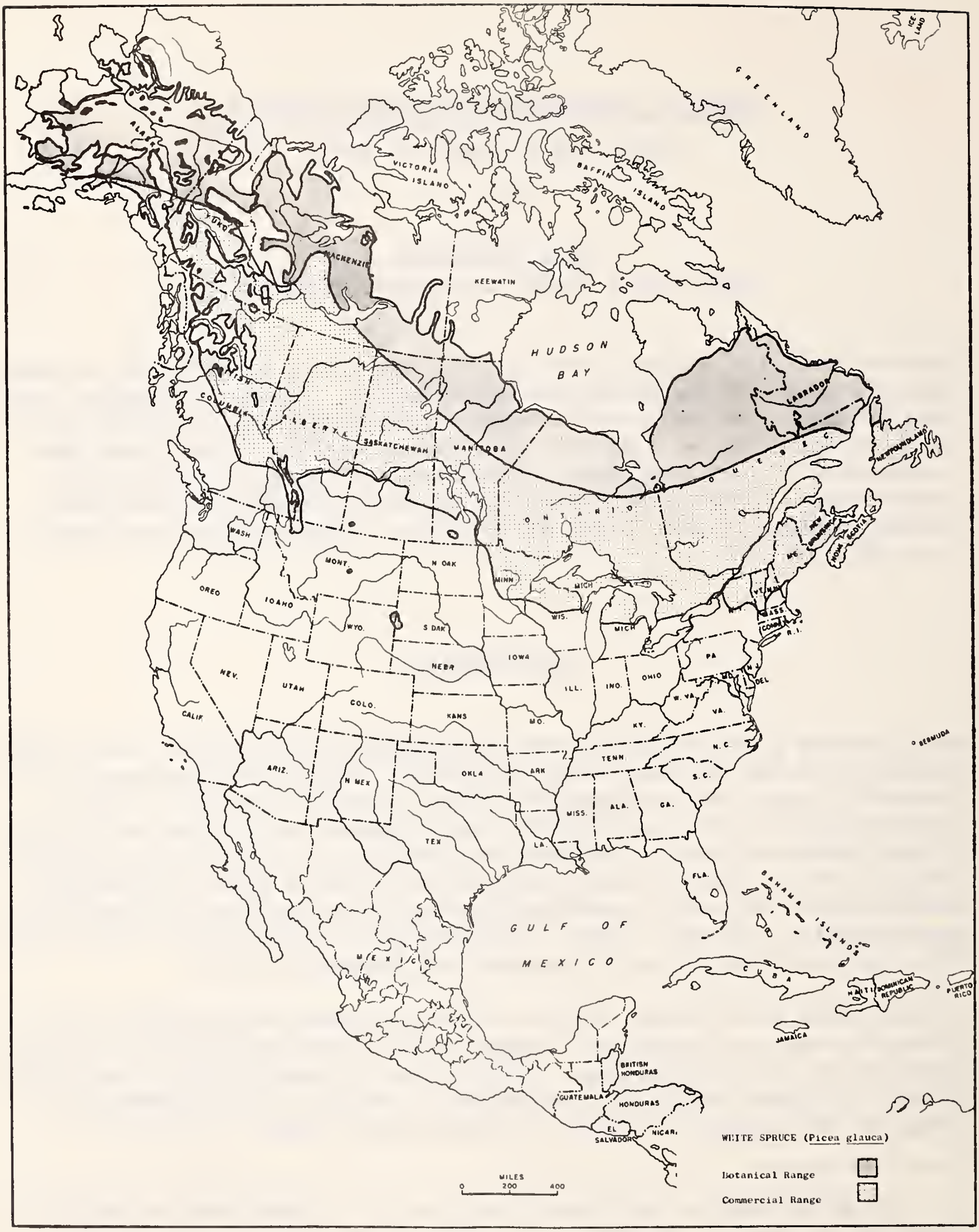


Figure 1.--Botanical and commercial range of white spruce.

forest[4/]--of the boreal forest is of potential commercial importance, largely as a source of pulpwood. The northern limit of this zone is imperfectly mapped except in Labrador (fig. 1).

## HABITAT CONDITIONS

White spruce grows under a variety of climatic conditions from the wet insular Nova Scotia to the semiarid continental Spruce Woods Forest Reserve in southwestern Manitoba. It occurs on many soils ranging from the heavy clays in the Upper Peninsula of Michigan, to the alluvial plains along the Peace River in Wood Buffalo National Park in Alberta, where it reaches its best development.[5/]

### Climatic Factors

White spruce is one of the hardiest conifers. Thus in Alaska and parts of Canada it grows in a climate with a mean daily January temperature of -20° F. In the extreme southeastern portion of the range the comparable January temperature is +20°. Temperatures below -70° have been reported over a large part of the range in Alaska, Yukon, and Northwest Territories, and temperatures as low as -60° have been recorded over almost all the range except the most southern and southeastern parts. The mean daily July temperature varies from about 70° in the extreme southeastern area of distribution to 55° throughout large parts of Canada and Alaska. Maximum temperatures as high as 110° have been recorded within the range in southwestern Manitoba and highs of 90° have been recorded over practically the entire range of the species. Mean annual precipitations vary from highs of 50 inches in Nova Scotia and Newfoundland to extreme lows of 10 inches through the Northwest Territories, Yukon, and parts of Alaska. Conditions are most severe, however, along the southern edge of distribution through Alberta, Saskatchewan, and Manitoba where a mean annual precipitation of from 15 to 20 inches coincides with mean July daily temperature maxima of 75° or more.

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4/ Hare (30) recognizes the following subzones in the boreal forest: (1) Forest-tundra, (2) woodland, and (3) close-forest, the latter consisting of fully stocked stands of spruce and fir (and other species).

5/ H. E. Seely, Canada Dept. of Northern Affairs and National Resources. Personal correspondence on file at Lake States Forest Experiment Station, 1956.

The growing season[6/] varies from about 160 days in parts of Maine to as little as 20 to 25 days within certain portions of the Canadian distribution. Generally speaking, however, white spruce grows south of a line indicating a growing season of 60 days (10, 11, 12, 83).

A considerable portion of the range of the species falls within the permafrost zone in northern Canada.

## Edaphic Factors

White spruce grows on a variety of soils of glacial, lacustrine, marine, or alluvial origin. Similarly it grows on soils overlying greatly differing substrata: limestones, pre-Cambrian and Devonian granite, gneisses, Silurian sedimentaries, schists, slates, conglomerates, etc. (29). The species grows best on loamy soils, but will also grow well on sands and clays providing the water relationship is not a limiting factor.

Gray wooded soils, brown forest soils, and podzolized soils prevail throughout the range of the species. White spruce is an important species on the gray wooded soils and on the brown forest soils (54). Wilde, Wilson, and White (93) list it as occurring on 7 of the 18 soil-forest types they recognize in the podzol region of Wisconsin: sandy poszols, loam podzols, podzolized gley loams, strongly podzolized clays, gley-podzol clays, stream-bottom soils, and wood peat. On sandy podzols the species is only of minor importance; it reaches its best development on the podzolized gamma gley loams and strongly podzolized clays. In the Algoma District of Ontario the species is a major component of the stands on the calcareous podzol loams and clays. In this area exceptionally good development on melanized loams and clays has been described (92).

White spruce will tolerate a wide range of moisture conditions, but the growth will be stunted and scrubby on both wet and too dry soils. For maximum development it requires a supply of well aerated water (14).[7/] It grows poorly on alpha-gley soils, but its productivity increases with increasing depth to the gley horizon (91).

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6/ Growing season is the number of days between the occurrence of a temperature of 32° F. in the spring and autumn.

7/ I. C. M. Place, University of Wisconsin. Personal correspondence on file at Lake States Forest Experiment Station, March 14, 1956.

Apparently white spruce is more exacting in its nutrient requirements than either red or black spruce.[8/] Heiberg and White (31) studied the symptoms of potassium deficiency in spruce and pine plantations on sandy wornout agricultural soils in the Adirondacks. Of all the species observed including *Picea abies*, *Pinus strobus*, *P. resinosa*, and several others, white spruce showed the most pronounced effects. Typical symptoms include stunting of the growth and yellowing and early dropping of the needles.

The species will tolerate a considerable range in pH. Spurway (72) records its optimum range as 5.0 to 6.0 with a maximum upper limit of 7.0. Stone[8/] reports it growing in the Adirondacks on sandy loams and loam derived from rocks rich in ferromagnesian minerals and with a pH of 4.5 to 5.0. In the same area it also occurs on acid to slightly acid sandy loams and loam influenced by small amounts of limestone in the substrate. Stoeckeler (73) has described two soil profiles in Manitoba supporting white spruce one of which showed a pH of 7.6 4 to 17 inches below the surface and as high as 8.4 below that, and the other had a pH of 6.4 to 6.6 to a depth of 24 inches and 8.0 at greater depths. Stone[8/] has observed the species on soils with a pH as high as 7.5 in the surface layers. He warns, however, that the "lime tolerance" of the species should not be unqualified; symptoms of chlorosis have occurred on heavily limed nursery soils with a pH of about 8.3.

## Physiographic Factors

White spruce occurs from a north latitude of about 42° 30' in northwestern Massachusetts to 69° at the Alaska-Yukon territory boundary. This corresponds to a difference in daylength of approximately 8 hours and 40 minutes (effective photoperiodic daylength is longer as it includes part of the morning and evening twilight) (53). Altitudinally it reaches from sea level to about 5,000 feet (75). Sargent (68) mentions it growing near 2,000 feet on the central tableland of Labrador north of 52° northern latitude, and along streams and lakes at 5,000 feet in the Rocky Mountains of Alberta, British Columbia, and northern Montana.

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8/ Earl L. Stone, Jr., Cornell University. Personal correspondence on file at Lake States Forest Experiment Station, May 9, 1956.

## Biotic Factors

White spruce is a component of 15 of the 106 eastern forest types listed by the Society of American Foresters (71), and of 4 of the 50 western types. In the New England States it is a pioneer species in abandoned fields, where it will form pure stands; in western North America it occurs in pure stands in the white spruce type. In mixed stands it reaches its greatest abundance in the black spruce (*Picea mariana*)-white spruce, the white spruce-balsam fir (*Abies balsamea*), and the white spruce-balsam fir-aspen (*Populus tremuloides*) types of the boreal forest, and in the white spruce-balsam fir-paper birch (*Betula papyrifera*) type in the northern forest of eastern North America. It is an integral member of the white spruce-birch type in the northern interior region (comprising essentially the entire range of the species from Manitoba to Alaska with the exception of one middle elevation type mentioned below). In addition the species is a minor associate in the following types in the boreal forest in the eastern part of the continent: jack pine (*Pinus banksiana*), jack pine-paper birch, balsam fir, black spruce, black spruce-balsam fir, jack pine-aspen, and black spruce-aspen. In the northern forest it is found in these types: paper birch, sugar maple (*Acer saccharum*)-beech (*Fagus grandifolia*)-yellow birch (*Betula alleghaniensis*), red spruce (*Picea rubens*)-yellow birch, and red spruce-balsam fir. In the West it is a minor component of the poplar-birch and the middle elevation aspen type.

Raup (61) has described two additional types in northern British Columbia. One is the white spruce-lodgepole pine (*Pinus contorta*)-aspen type; this forms the transition between the lodgepole pine and aspen, which come in after fire, and the ultimate stands of pure white spruce. The type is best developed on the better drained soils below 2,800 feet. The second type, which also covers extensive areas but is not of high quality, is an association of black spruce, white spruce, and lodgepole pine.

The types listed above give some indication of the more important tree species with which white spruce is associated. In the North, the stand composition is simple; black spruce and white spruce predominate, with tamarack and balsam fir as associate species. The forest floor is dominated by lichens of the genus *Cladonia* and by shrubs of the genera *Betula*, *Vaccinium*, *Kalmia*, and others (30). In the close-forest zone[9] the conifers, particularly black spruce and fir, form a dense overstory with a ground cover rich in mosses, especially feather mosses (*Hylocomium*, *Hypnum*, *Dicranum*, and related genera) and characteristic herbs such as bunchberry dogwood (*Cornus canadensis*) and American wood-sorrel (*Oxalis montana*).

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9/ Hare: See footnote 4 on page 3.

In the East the boreal forest changes rapidly from the typical spruce-balsam fir forest into associations of great complexity. Thus white spruce (here only of minor importance) is found with the following species in the sugar maple-beech-yellow birch type: sugar maple, American beech, yellow birch, American basswood (Tilia americana), red maple (Acer rubrum), eastern hemlock (Tsuga canadensis), northern red oak (Quercus rubra), white ash (Fraxinus americana), balsam fir, black cherry (Prunus serotina), paper birch, sweet birch (Betula lenta), American elm (Ulmus americana), rock elm (U. thomasii), eastern hop-hornbeam (Ostrya virginiana), and red spruce.

Similarly the lesser vegetation associated with the species varies with geographical location and soil type. In the East, white spruce may grow with dense understories of mountain and striped maples (Acer spicatum and A. pensylvanicum) (86, 89) and in Ontario with a heavy growth of American cranberrybush viburnum (Viburnum trilobum), alder buckthorn (Rhamnus alnifolia), mountain maple, beaked hazel (Corylus cornuta), and American fly honeysuckle (Lonicera canadensis) (92). The literature contains numerous descriptions of the herbaceous vegetation associated with the different forest types of which white spruce is a component. Discussion of the vegetation in terms of indicator plants as such, however, is very limited. Examples of these vegetation types are included in the following references: 32, 35, 46, 52, 59, 60, 62, 63, 67, 70, 93.

White spruce is of limited value as a game food, although one of the principal foods of the spruce grouse (Canachites canadensis) is spruce buds. Other birds and mammals which influence the regeneration and growth of the species will be discussed in the following sections.

# LIFE HISTORY

## Seeding Habits

### Flowering and Fruiting

The dates for the developmental steps in flower formation are not known, but would undoubtedly vary considerably at different latitudes within the range of the species (13). Male strobili pass the winter in the pollen mother-cell stage. No information is available regarding the first appearance of the female strobili primordia, but they do apparently overwinter in the mega-spore mother-cell stage.[10/]

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10/ Unpublished data, Lake States Forest Experiment Station.

Flowering is in May (84). Over a 4-year period it occurred between May 25 and May 30 near Ely, Minn.[10/] Other observations from the same area list initial pollen shedding as varying between May 12 and June 1 over a 5-year period.[11/] At Dukes in Marquette Co., Mich., the average date of flowering ("start of cone formation") over a 5-year period was May 25.[10/] On the coast of James Bay north of 53° N. latitude, pollination was as late as July 11 to 12 (34). The cones ripen in August or September. Ahlgren[11/] observed the first opened cones between September 5 and September 17 in northeastern Minnesota and the average date in Marquette Co., Mich., was September 17.[10/] The seed is disseminated very rapidly after the cones open (19). Roe (64) found that about 80 percent of the seed had been shed approximately 5 weeks after cone opening; after 9 weeks 93.5 percent had been shed.

## Seed Production and Dissemination

Commercial seed production starts at approximately 30 years of age, and optimum production occurs when the trees are 60 years or older (84). Cook[12/] has mentioned excellent seed crops on 20-year-old plantation-grown white spruce. In the mixed spruce and aspen stands of Saskatchewan and Manitoba production begins when the trees are 45 to 60 years old (67). At more northern latitudes seed production apparently is much delayed and infrequent.

White spruce is a fairly prolific seed producer with good crops every 2 to 6 years and light crops in the intervening years (84). Roe (65) estimated that an open-grown 75-year-old tree in northern Minnesota produced 11,900 cones with a total of 271,000 viable seed in a heavy crop year. This value agrees fairly well with the more intensive study by Tripp and Hedlin (82). Twenty-five trees had an average of 8,000 cones per tree. They estimate that in a good seed year, 25 percent of the potential seed production, or 23 seeds per cone, will be filled and uninjured; thus a tree would yield approximately 184,000 good seed.

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10/ Unpublished data, Lake States Forest Experiment Station.

11/ Clifford Ahlgren, Quetico-Superior Wilderness Research Center. Personal correspondence on file at Lake States Forest Experiment Station, 1956.

12/ David B. Cook, New York Conservation Department. Personal correspondence on file at Lake States Forest Experiment Station, 1956.

Seed dissemination is by wind. The greatest distance of seed dispersal which has been accurately determined in the field is 330 feet. However, with sufficient wind, dispersal in excess of 1,000 feet can be expected from mature trees; turbulence and convection currents might increase this distance (67).

## Factors Limiting Seed Production

A number of insects may reduce white spruce seed crops (81, 82). The two most serious pests are the spruce seedworm (*Laspeyresia youngana*) and the spruce cone maggot (*Pegohylemyia anthracina*). Other insects attacking the cones and seed are several Cecidomyids and Chalcids (51, 82). A white spruce cone has an average of 140 seeds of which 92 are in the productive center portion of the cone. Some 44 to 53 percent of these are hollow leaving a possible 40 to 50 filled seed per cone. An additional 28 to 53 percent of the potentially sound seed may be destroyed by insects--especially the seedworm and the maggot--depending on the size of the cone crop. In a light seed year, therefore, little or no seed is produced; in heavy cone years about 25 percent of the potential may be produced. In some areas only one of the major pests is present and greater yields may be expected (82).

One cone rust, *Chrysomyxa pyrolae*, is reported on white spruce; the extent of its damage is not known.

The seed is sought by several birds, among them the chickadee (*Parus* spp.), pine grosbeak (*Pinicola enucleator*), rose-breasted grosbeak (*Pheucticus ludovicianus*), red crossbill (*Loxia curvirosta*), and white-winged crossbill (*L. leucoptera*). Red and gray squirrels (*Tamiasciurus hudsonicus* and *Sciurus carolinensis*), chipmunks (*Tamias* spp. and *Eutamias* spp.), voles and mice (*Clethrionomys* spp., *Microtus* spp., and probably *Peromyscus* spp.) also feed on the seed (48, 66).

## Vegetative Reproduction

Vegetative reproduction through layering has not been recorded. In the greenhouse with the right environmental conditions seedling material can be rooted with good results, although cuttings from older trees are very difficult to root. Such material can be grafted readily, using the side-graft method on potted 2-1 or 2-2 rootstocks.

## Seedling Development

### Establishment and Early Growth

The germinative capacity under controlled indoor conditions varies from 7 to 91 percent, the average being 49 percent (84). Under field conditions, Place (58) obtained germination percentages varying from 0 to 89 percent depending on seedbed and weather conditions. Stoeckeler and Jones (74) give the approximate ratio of 1-0 nursery stand to laboratory germination as 0.35--lower than most other commercial nursery stock.

Germination in the field takes place primarily in June and July as soon as seedbed temperatures become favorable (60° to 90° F.); seedlings developing after the middle of July in the shade have little chance of survival (58). Crossley (18) found that the majority of seed had germinated by June 19 on a mountain podzol in Alberta; in Manitoba and Saskatchewan, on the other hand, Rowe (67) found no appreciable germination until the warm weather of early July. Sometimes the seed holds over to the second summer; Moore (50) obtained poor germination the first season but good germination the second.

The moisture condition is the single most important factor determining germination and early survival of spruce seedlings; an adequate but not excessive supply of moisture is required. White spruce has small seed (240,000 per pound average) and the first-year seedling is therefore small, with the root only rarely penetrating more than 3 inches (42, 57, 58). Any seedbed which easily dries out to a depth of 2 to 3 inches or more will, therefore, be detrimental to spruce during the first season; hence, generally speaking, humus, litter, and beds of moss are poor seedbeds and mineral soils are good. However, where modifying conditions insure a continued supply of moisture, humus and beds of moss may support good spruce reproduction (43, 50, 58). Heavy mineral soils, on the other hand, often are too wet and cold, at least under cover, and frost heaving may be a serious problem, especially in the open. Coarse soils may dry out before the germinating seedling becomes established (58). Germination and survival on mineral soils can be improved by a light covering of needles (50) or sawdust (47).

In the undisturbed forest the majority of seedlings are found on decayed wood. It has several advantages over most other natural seedbeds; usually better moisture, less chance of smothering from fallen leaves, better temperature and light conditions, freedom from damping-off, and perhaps better mycorrhizal development (6, 56, 67, 89). Survival and growth, however, are better on the mineral soil; thus Rowe (67) found that spruce on mineral soil reached breast height in 10 to

15 years, as compared to 20 to 30 years on decayed wood. In coarse mineral soils, however, especially in high rainfall areas, the $A_2$ horizon may be leached to the point where good growth of spruce cannot be obtained (58).

Although tolerant, white spruce--in part because of its small size the first year--is not able to compete with dense growth of perennials, bracken fern (Pteridium latiusculum), shrubs, and understory trees (6, 58, 67, 86, 89). White spruce is, therefore, particularly difficult to maintain where it is growing in mixture with hardwoods. Hardwood litter is an unfavorable seedbed (58), and the competition from the herbaceous vegetation is particularly severe (43).

It appears that attempts to improve white spruce reproduction by silvicultural means should concentrate on two problems: (1) Improve seedbed conditions, and (2) eliminate competition of the lesser vegetation. Where the mineral soil is not too heavy or light (coarse) any practices which would expose it should be beneficial (6, 56, 67). Rowe (67), however, does not consider logging disturbance sufficient to insure adequate reproduction. Scarification usually makes a natural seedbed more favorable for germination; furrows, however, tend to act as traps for leaf litter which is apt to smother the seedlings (58). The use of fire has been suggested (58, 67). It must be severe enough to allow most of the humus to burn, thus exposing mineral soil. However, during dry years the charred surfaces tend to be too hot to allow much germination. Much additional experimentation is needed before fire can be used as a silvicultural tool in white spruce management.

Various cutting practices to insure white spruce reproduction have been recommended. Day (23) and Westveld (89) have suggested using shelterwood cutting with a light initial cut in the white spruce-balsam fir-paper birch type in the Lake States. It is questionable to what extent this method can be used; in the majority of cases it would probably result in an undergrowth too heavy for white spruce seedlings. Long (43), based on observations on spruce regeneration in New Brunswick and Quebec, states that mature spruce forests reproduce much more easily than immature stands and that regeneration may be obtained under almost any type of silviculture. Immature softwood stands, however, present a much more difficult problem; here Long suggests using the selection system. Considerably more research will be required on this highly complex problem, which may be basically different in different parts of the range of the species. The limiting factors, i.e., (1) moisture, (2) light intensities below 20 percent of full sunlight (58), and (3) competing vegetation, undoubtedly are present throughout the range.

Phenological data for the species are limited. Near Albany, N. Y., Cook (15, 16) found the period of height growth of an individual tree varying from 46 to 76 days over a 5-year period. The date of beginning of height growth varied from May 4 to May 19, and the date of cessation from July 2 to July 24. Rowe (67) mentions the time of flushing in Manitoba and Saskatchewan to be about June 1, with frequent frost injury; regrowth of the damaged plants the same year is rare. In 3 years of observation in Maine, time of flushing varied between May 17 and June 3. Growth in that area extends over a period of 12 weeks (4). From 8 years of observation in the Upper Peninsula of Michigan, the average date of flushing was May 25; elongation started May 23 and terminated July 28. Thus the period of height growth was a little over 9 weeks.[13/]

### Factors Limiting Seedling Development

Snow blight, *Phacidium infestans*, causes some damage on nursery stock in northeastern United States and eastern Canada and has been found under field conditions.

Mammals and birds are important factors in white spruce management. Damage from the snowshoe hare (*Lepus americanus*) becomes a very serious problem when populations reach their peaks. Where brush cover and small plantings give the hare protection, practically all trees may be damaged (1). Rowe (67) has mentioned cases in which repeated browsing by the hare has caused the death of trees up to 3 feet tall. The most effective method for protecting young seedlings is planting on open sites several acres in size. Small brushy sites should only be planted during periods with low populations.

Deer (*Odocoileus virginianus*) and moose (*Alces alces*) rarely feed on white spruce. Swift (77) lists white spruce as a starvation diet for deer, but does not exclude possible heavy browsing in areas with high deer concentrations and absence of more favorable browse (78).

## Sapling Stage to Maturity

### Growth Rate and Sizes Attained

White spruce trees (see cover picture) 110 feet in height and over 21 inches in diameter are not uncommon (9). Peattie (55) mentions trees 150 feet tall and 3 to 4 feet in d.b.h. (diameter at breast height),

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13/ Unpublished data, Lake States Forest Experiment Station.

and Seely[14/] reports trees of a measured height of 184 feet on the alluvial plains along the Peace River at 58° to 59° north latitude. Under more severe conditions and farther north the sizes attained are smaller. Hustich (35) reports trees 60 feet tall and 30 inches in diameter in interior Labrador at about 54° north latitude and 2,000 feet in elevation. Lutz (46) found that the maximum heights seldom exceeded 85 to 100 feet and maximum diameters 20 to 24 inches in interior Alaska. The average values were considerably less.

The most complete yield data for white spruce refer to old-field stands in New England (49). They are summarized in table 1.

Table 1.--Stand data for pure white spruce in New England at 90 years of age[1/]

| Item | Site Class | |
|---|---|---|
| | Good (70) | Poor (40) |
| Diameter (breast high)--inches | 11.4 | 6.7 |
| Average height dominants and codominants--feet | 80 | 45 |
| Total number of trees per acre 0.6 inch and over | 345 | 785 |
| Basal area per acre of trees 0.6 inch and over--square feet | 243 | 191 |
| Cubic-foot volume per acre, all trees 0.6 inch and over | 8,700 | 4,450 |
| Board-foot volume per acre, International rule, 1/8" saw kerf, all trees 7 inches d.b.h. and over | 60,700 | 6,650 |

1/ With regard to this table the author (49) notes: "....there is a chance that these tables do not represent the best conditions for growth, but rather an overstocked condition, resulting in poor individual tree development."

14/ Seeley: See footnote 5 on page 3.

Yields similar to those listed in table 1 have been recorded by Place.[15/] One 54-year-old stand in New Brunswick produced 6,300 cubic feet per acre; a 60-year-old stand in Nova Scotia had an average diameter of 9 inches, a height of 60 feet, and a volume of 55 cords or 22 M bd. ft. per acre. On strongly podzolized clays, yields of from 15 to 25 M bd. ft. at 100 years (all species included) may be attained. Uneven-aged mixed stands 90 to 150 years old on good sites in the Algoma District in Ontario showed an average diameter in excess of 20 inches, an average height of the dominant trees close to 110 feet and an estimated standing volume of 30 to 40 M bd. ft. per acre (92). In the mixedwood cover type in Saskatchewan the average stand at maturity contains 632 trees per acre of which 365 are white spruce, the total cubic-foot volume is 3,946 of which 2,176 or 55 percent is white spruce (69). The large forest areas in the interior of Alaska north of the Alaska Range contain an estimated 25 million acres of fairly dense white spruce and mixed stands. Here volumes may reach 4,400 cubic feet per acre in stands with an average age of 200 years (79).

White spruce grows rapidly in early years under good conditions and full sunlight. In a 13-year-old plantation on a sandy clay loam in northern Wisconsin, dominants ranged in height from 18.2 to 21.4 feet and in d.b.h. from 2.8 to 4.2 inches. The average height on the sample plot was 12.2 feet, the d.b.h. 1.94 inches. Height growth for the last 3-year period averaged 5 feet with a range from 3 to 6 feet.[16/] Natural seedlings, however, may grow very slowly if they are under shade.

White spruce reaches considerable age. Sudworth (75) mentions full-grown trees 250 to 350 years old, but trees as much as 500 years old have been recorded in the Mackenzie River Delta (26).

## Reaction to Competition

White spruce is comparable in tolerance to black spruce, both species being classed as "tolerant" by Baker (3) in his five groups of tolerance. He puts red spruce in the same class but points out that many consider red spruce "very tolerant". Balsam fir--another important associated species--is classed "very tolerant" by Baker. On a scale from 0 to 10 (hemlock being very tolerant with a score of 10), Graham (27) gives white spruce a score of 6.8 compared to 6.4 for black spruce and 9.8 for balsam fir. Place (58), considering tolerance as the ability of seedlings to survive in deep shade and heavy root competition and retain the capacity to respond to release, considers red

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15/ Place: See footnote 7, page 4.

16/ Unpublished data supplied by L. Burkett, Nicolet National Forest, Rhinelander, Wis. 1956.

spruce more tolerant than either white spruce, black spruce, or balsam fir. There is little difference between the latter three species in this respect in New Brunswick. In the Lake States, where balsam fir is a shorter lived, poorer tree, white spruce surpasses it in the response to release (7). White spruce will survive 40 to 50 years of suppression and still respond to release.

Where it grows with hardwoods established at the same time, white spruce falls behind and will remain an understory tree unless it is released. In coniferous mixtures, however, it will reach dominance with balsam fir and black spruce and will eventually outgrow them. In spite of this, balsam fir tends to replace white spruce in the spruce-fir type. This is probably a result of some combination of balsam fir's larger seed, less exacting seedbed requirements, and greater chance of initial survival; its more frequent seed years; and perhaps its resistance to damage from the snowshoe hare.

White spruce is usually considered a climax species and--in the northwestern portion of its distribution--forms large areas of pure stands (fig. 2). In New England it is an associate of the climax sugar maple-beech-yellow birch type. Most of the other types in which the species occurs are also climaxes or subclimaxes. In New England and the Maritime Provinces of Canada, white spruce sometimes is a pioneer in old fields.

Figure 2.--A mature stand of white spruce near Kapuskasing, Ontario. The variation in crown type within a stand is typical of the species (Photo courtesy of Mark Holst, Canada Department of Northern Affairs and National Resources).

## Limiting Factors

The factors determining the southern limit of the range of the species are not known. In the North where it follows the tree line the limit is probably thermal in nature. The value of 12 to 13 inches annual potential evapotranspiration in the Thornthwaite scale of thermal efficiency fits the tree line very well (30).

A number of insects attack white spruce. The three most important are the spruce budworm (*Choristoneura fumiferana*), the European spruce sawfly (*Diprion hercyniae*), and the eastern spruce beetle (*Dendroctonus piceaperda*).

The budworm may cause extensive mortality in heavy outbreak areas, particularly where white spruce is associated with balsam fir. White spruce, however, is much better able to withstand attack than balsam fir (80). The sawfly also may cause considerable mortality. This insect is limited to New York, New England, New Brunswick, and parts of Quebec and Ontario. Damage has been especially serious on the Gaspe Peninsula, but has been overcome by the introduction of a virus disease.

The eastern spruce beetle may cause very serious losses in mature and overmature timber. In Alaska and northwestern Canada the Alaska spruce beetle (*Dendroctonus borealis*) has caused extensive mortality in mature timber and is considered potentially the most destructive forest insect in Alaska. In the Yukon River drainage *Ips interpunctus* is capable of extensive destruction (76).[17] A number of borers attack white spruce but are of little or no economic importance.

The following leaf-feeders are of minor importance: the yellow-headed spruce sawfly (*Pikonema alaskensis*), *Epinotia nanana*, and *Recurvaria piceaella*.

The eastern spruce gall aphid (*Chermes abietis*) may kill up to 85 percent of the crown of heavily infested trees; individual trees, however, vary greatly in their susceptibility to attack (17).

White spruce is highly resistant to the white pine weevil (*Pissodes strobi*). The spruce root-collar weevil (*Hypomolyx piceus*) may girdle the roots on larger trees. Roots less than 1 inch in diameter and the distal parts of the roots less than 2 inches in diameter on larger trees are seldom damaged (87). Although the damage causes mortality only occasionally, the wounds do form the entry for root rots (90). The damage is more common on wet sites than on dry ones.

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17/ R. F. Taylor, Alaska Forest Research Center. Personal correspondence on file at Lake States Forest Experiment Station, 1956.

White spruce is susceptible to windthrow, especially on shallow soils. Bowman (7) considers it more windfirm on upland soils than either black spruce or balsam fir, but still believes windthrow an important factor in white spruce management. Kelly and Place (36), however, found considerably less loss in the spruce-fir type after a heavy cut than expected. After 3 years only 5 percent of the residual stand was windthrown and the majority of these trees were windbroken because of butt rot.

White spruce flushes somewhat earlier than black spruce, and the new growth is, therefore, much more frequently nipped by frost in late spring. In other respects the species is very hardy as is seen from its distribution into the far north. It is very resistant to salt water damage and will grow on shores and headlands exposed to salt-laden winds.[18/]

White spruce is surprisingly devoid of serious fungus diseases. It is, however, attacked by a number of needle rusts including *Chrysomyxa ledicola*, *C. chiogenis*, *C. empetri*, and *Pucciniastrum americanum*; only rarely, however, do infestations reach serious proportions. Yellow witches'-broom caused by *Peridermium coloradense* is occasionally observed on white spruce but is unimportant. Neither does the damage from eastern dwarf mistletoe (*Arceuthobium pusillum*) nor from lodgepole pine dwarf mistletoe (*A. americanum*) reach any importance.

Of the heart-rotting fungi, *Fomes pini*, the red ring rot is undoubtedly the most important. *F. officinalis*, *F. pinicola*, and *F. sub-roseus* are of less importance. *Fomes annosus* is not important within the native range of the species, but has been reported on plantation trees in Denmark (25). Plantations on this continent bear watching for outbreaks of this organism. Of the polypores, the red brown rot (*Polyporus schweinitzii*) and a brown cubical rot (*P. sulphureus*) cause some damage on the species, and *P. abietinus* and *P. guttulatus* have been observed (8, 88). In the Maritimes, *Corticium galactinum* and *Polyporus circinatus* were the most commonly isolated butt rot fungi (22). In the Central Provinces, *Polyporus circinatus* and *Flammula connissans* were important butt rots, and *Stereum sanguinolentum* was an important top rot although not as important as *Fomes pini* (24).

An interesting type of injury in living wood of white spruce has been reported by Lutz (45) in Alaska. Small clefts in the wood result from collapse caused by imbalance between loss and replenishment of water.

Red squirrels sometimes cut the leaders and ends of the upper branches. Rowe (66) found that the damage was particularly severe during years of cone failure. The leader is usually replaced by an internodal bud, and the damage is only serious where forks develop.

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18/ Place: See footnote 7 on page 4.

Porcupine (Erethizon dorsatum) damage has been reported on white spruce, and black bears (Euarctos americanus) cause serious damage in some parts of Alaska by stripping the bark from the lower part of the trunk. How extensive this latter type of damage is, is not known, although it has been reported in a few other areas (44).

Field mice (Microtus pennsylvanicus) do not gnaw the bark of white spruce as they do of several other tree species (41).

## SPECIAL FEATURES

Commerce makes little distinction between white, black, and red spruces as the mechanical properties of the woods are similar. White spruce is somewhat lighter than the two other species, however (28). The wood dries easily and has moderate shrinkage, strength, stiffness, toughness, and hardness. The largest uses are for pulpwood and lumber. A considerable volume of pulpwood is imported annually by the United States from Canada. Spruce lumber goes into framing material and general millwork. Spruce wood also is used for boxes, crates, ladder rails, and piano sounding boards (85).

White spruce is commonly planted as an ornamental and has some use as Christmas trees.

Chemical weed killers such as 2,4-D and 2,4,5-T esters may damage new tender foliage. However, the new foliage apparently hardens off earlier than on other conifers and shows no apparent effect from treatments after July 15 in Lower Michigan (2).

On alluvial soils along the Peace River in northwestern Canada, where frequent floods deposit deep layers of silt over the original root system, white spruce may develop two or more layers of roots, one above the other. Such trees undoubtedly are particularly windfirm.[19/]

## RACES, HYBRIDS, AND OTHER GENETIC FEATURES

In addition to a number of horticultural varieties, three botanical varieties have been listed: (1) *Picea glauca* var. *densata* Bailey, Black Hills spruce typified by dense bright to bluish-green foliage and a somewhat compact growth form; (2) *P. glauca* var. *porsildii* Raup,

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19/ Seeley: See footnote 5 on page 3.

occurring throughout Alaska and Yukon Territories, distinguished chiefly by smooth bark with resin blisters and a relatively broad crown; and (3) P. glauca var. albertiana (S. Brown) Sarg., a large tree of narrow pyramidal habit. This latter variety, however, is in all likelihood a product of introgression with P. engelmannii (94).

A natural hybrid between P. glauca and P. sitchensis is called Picea x lutzii Little (39). This hybrid is being tested on a large scale in Iceland (5). More recently a hybrid between P. glauca and P. mariana has been described (40).

The racial variation of white spruce is not well known. The species may fall into two thermoclines[20/] of opposite orientation, one pointing east, the other west. Similarly western proveniences show a clinal variation correlated to daylength, while proveniences from eastern Quebec and New Brunswick behave quite differently (33).

The vegetative cells of white spruce trees contain 12 pairs (24) of chromosomes (21).

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20/ A cline is a geographical gradient in phenotypic characters. A general term covering populations within a species which show geographical or ecological variation (37).

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# SPECIES COVERED IN SILVICAL REPORTS

This is the eighth silvical report published by the Lake States Forest Experiment Station. Reports that have already appeared are:

| | |
|---|---|
| Station Paper 44 | Red pine |
| Station Paper 45 | Black spruce |
| Station Paper 47 | Rock elm |
| Station Paper 49 | Quaking aspen |
| Station Paper 50 | Sugar maple |
| Station Paper 52 | Tamarack |
| Station Paper 54 | American elm |

Ensuing reports will cover the following species:

| | |
|---|---|
| Bigtooth aspen | Jack pine |
| Basswood | Balsam poplar |
| Slippery elm | Northern white-cedar |
| Black maple | |

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Publications of the Lake States Forest Experiment Station.
L. P. Olsen and H. A. Woodworth.
Station Paper 39, 130 pp. 1956.

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Paul O. Rudolf.
Station Paper 40, 32 pp., illus. 1956.

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Station Paper 41, 58 pp., illus. 1956.

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