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SILVICAL *Characteristics* OF... BLACK SPRUCE

(*Picea mariana*)

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THE SILVICAL REPORT SERIES

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 There is also a considerable store of unpublished silvical information in the files of the forest experiment stations, the forest schools, and some other agencies.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 C. E. Ahlgren, Quetico-Superior Wilderness Research Center; J. W. C. Arlidge, British Columbia Forest Service; E. R. Bonner, Spruce Falls Power and Paper Co.; Maurice Day, Dunbar Forest Experiment Station; Professor J. R. Farrar, Faculty of Forestry, University of Toronto; R. L. Knox, Minnesota Conservation Department; D. W. MacLean and Dr. Andre Linteau, Canada Department of Northern Affairs and National Resources; John Macon and Stanley Hurd, Consolidated Water Power and Paper Co.; J. B. Millar, Kimberly-Clark Corp.; Dr. I. C. M. Place, Department of Forestry and Wildlife Management, University of Wisconsin; and staff members of the Lake States and California Forest Experiment Stations.

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 design: A typical mature swamp-grown black spruce. Height 65 feet, diameter at breast height 10 inches, age about 120 years. Drawing represents needles and cones.

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SILVICAL CHARACTERISTICS OF BLACK SPRUCE

(*Picea mariana* (Mill.) B.S.P.)

by

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DISTRIBUTION

Black spruce is one of the most abundant conifers of northern North America. It spans the continent from Labrador and the northeastern United States west and northward to the Bering Strait (fig. 1). The botanical range includes the Boreal Forest Region of Halliday (27),[2] an extension of this region in Alaska, and the Acadian and Great Lakes-St. Lawrence Regions of the same author, as well as the north half of the Northern Forest Region as defined by the Society of American Foresters (59). There are outliers in Halliday's Sub-Alpine Region in Alberta and British Columbia.

The bulk of both the botanical and commercial ranges is in Canada, but there are important stands of this spruce in the Lake States, notably in Minnesota and Upper Michigan. The "commercial range" in figure 1 is the approximate limit of trees of pulpwood size (4 inches or more in diameter at breast height). Much of this area in Canada is still remote from markets but potentially exploitable. Along the northern perimeter of the commercial range a high percentage of the black spruce apparently is growing on sites that will not produce merchantable timber, but scattered stands are located in habitats that are favorable enough to grow trees to good sizes.

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, page 28.

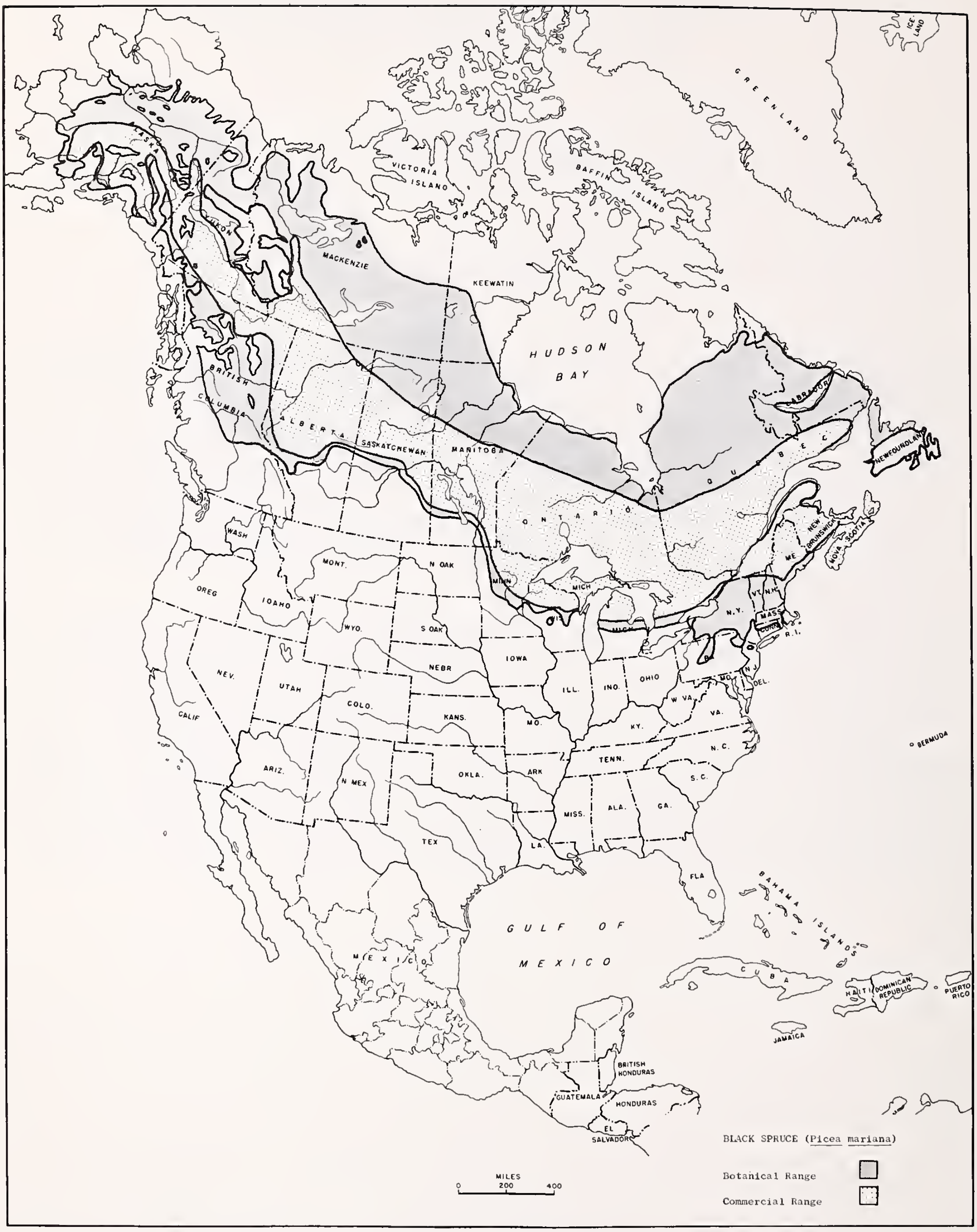

Figure 1.--Botanical and commercial range of black spruce.

HABITAT CONDITIONS

Climatic Factors[3/]

As a generalization the climate over the botanical range might be characterized as cold-subhumid, but the amplitude of climatic factors is large because the species occurs from 41° to 68° of latitude and in the interior as well as near the coasts. In the far north, the last outliers are seldom far from the mean July isotherm of 51° F. The southern limit corresponds roughly to the 70° July isotherm in the eastern United States. The average daily maximum temperature in July is about 70° to 76° F. over the main commercial range, but it falls to 60° at some far northern points and reaches 80° in the southeast. Annual maxima vary from 94° along the southeastern limit of spruce bogs to about 80° at the tundra margin. Highest temperatures on record exceed these values by about 10°.

Mean January temperatures range from 20° below zero in the far northwest to 20° above at the southeastern limits of the species. Average winter minima fall to -50° in the north, but only to about -20° in the southeast. Lowest temperatures ever recorded run from -75° in the Yukon to about -30° at the southeastern limit.

The frost-free season varies from 130 to 140 days in the southeast to less than 60 days at many far northern stations. The microclimates associated with organic soils and local air drainage influence the frequency of frost in spruce bogs. For this reason it is probable that frost-free seasons are shorter in many bogs than the records of adjacent upland weather stations indicate.

Annual precipitation varies from a high of 45 to 55 inches in Quebec and the Maritimes to less than 10 inches at the tundra in northwest Canada. Over most of the commercial range it averages 15 to 35 inches. Half or more of this total occurs as rain during the growing season. Winter is a season of lighter precipitation, but snow accumulations are substantial because of sustained cold. Mean snow depths on the last of February run about 20 to 30 inches over much of the commercial range, but exceed 40 inches in parts of Quebec and Labrador (62). Some areas near the southern and western limits, and in Northwest Territories have late February snow accumulations of only 5 to 15 inches. Average annual snowfall ranges from a high of about 200 inches in parts of eastern Quebec and Labrador to only 40 inches in much of the western portion of the range.

3/ Climatic data for the Canadian range are largely from Thomas (61); those for the United States are from U. S. Department of Agriculture (63).

Permanently frozen soil (permafrost) is common north of latitude 62°, from Great Slave Lake northwestward into Alaska (61). Southward the occurrence of permafrost becomes sporadic, but it probably exists in scattered spruce bogs to about latitude 52° 15' in Saskatchewan,[4/] to central Lake Winnipeg in Manitoba, and to at least latitude 50° in Eastern Canada (12). In the northern Lake States there are scattered reports of frozen bog soils in midsummer, but the condition is rare and true permafrost layers probably do not occur. Summer thawing of soil ice creates a steady moisture supply in some areas where it might otherwise be deficient (41).

The combination of low temperatures, reduced evapotranspiration, the spring snowmelt, and a summer rainfall pattern makes possible fairly productive black spruce forests in regions where total annual precipitation is only 15 to 25 inches.

Edaphic Factors

Black spruce occurs on both organic and mineral soils. In the south it is confined largely to peat bogs and muck-filled seepages and stream courses where it often forms a pure type. Farther north, the type is abundant on clayey glacial tills and glacio-lacustrine clay plains (27). It also occurs on loams and sandy loams and even on sands and gravelly or rocky soils in the north, but here it is more often mixed with other species.

In the Lake States and adjacent Ontario and Manitoba good pulpwood stands often are found on organic soils (see cover picture) but there are many poor-quality bog areas of black spruce (fig. 2) as well. Northwestward through the northern Prairie Provinces into Alaska, and throughout the northern half of the boreal forest in eastern Canada, black spruce is nearly always stunted and unmerchantable on bog sites (31, 41, 51). Extensive stands occur on organic soils in the bed of glacial Lake Agassiz in northern Minnesota, western Ontario, Manitoba, and eastern Saskatchewan, and in former Lake Ojibway in the Clay Belt of Ontario and Quebec (43).

As a rule the best swamp stands are near the edges of the bogs, although there are frequent exceptions (37). This relationship may be a function of successional development or, in some cases, the result of less well known factors. Peat profiles in Minnesota spruce swamps

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4/ Correspondence with A. Kabzems, Saskatchewan Department of Natural Resources, December 3, 1956, on file at Lake States Forest Experiment Station.

Figure 2.--An all-aged stand of black spruce on a very poor muskeg site with a peat depth of 4.9 feet in northern Minnesota. The main stand ranges from 80 to 180 years in age and averages 20 to 30 feet tall. The only merchantable product is Christmas trees.

vary considerably. In the Lake Agassiz basin, peats run from 1 to 8 feet in depth and are underlain mostly by lacustrine clays and silts, but occasionally by sands.

Many of the poorest stands are growing on poorly decomposed yellowish-brown sphagnum peats containing inclusions of wood and ericaceous shrubs. At a depth of 1 to 3 or more feet this layer may be underlain by brown fibrous sedge peat. Better stands often are found on dark brown to blackish well disintegrated peat or "muck" which frequently contains much partially decomposed wood. A layer of sedge peat sometimes underlies these surface peats also. Both good and poor sites may have a basal organic layer of greenish or blackish aquatic ooze, but this horizon is frequently thin or entirely lacking. The reaction of surface peats is often strongly acid on both good and poor sites, especially if sphagnum mosses predominate in the ground cover. Surface peats usually range from pH 3.5 to 4.5, but the pH increases with depth, frequently reaching 6.0 to 7.0 near a calcareous mineral soil substratum. Poor sites are said to be more acid than good sites, but this does not appear to be a good distinguishing criterion. The organic soils of spruce swamps have received little detailed study, and in the Lake States most of the forested swampland has either been mapped merely as "peat", or soil surveys have not yet been made. Wilde et al (67) report peats in the Algoma District of Ontario similar to those in Minnesota.

In smaller bogs on the Laurentian Shield and on pitted outwash plains and morainic areas, peat depths and profiles are still more varied. Spruce sometimes occurs on 60 feet of peat, and frequently on depths of 10 feet. Stands of excellent quality have been found on 12 feet of peat in Minnesota, but the best stands are usually on shallower areas (37).

In the Lake States black spruce is common on mineral soil sites only on the Laurentian Shield in northeastern Minnesota and in a few isolated areas of Upper Michigan. On the Shield in Minnesota and adjacent Ontario this tree occurs on gravelly and bouldery loams and shallow soils over bedrock, where it usually is mixed with other species, but occasionally forms a pure type (37). Growth is best where slopes are gentle and moisture is plentiful, either from shallow water tables or seepages. South of the Shield black spruce occasionally is found on mineral soils along swamp margins and in areas with high water tables in Minnesota, Wisconsin, and Michigan.

In the main commercial range in Canada the better stands of black spruce type tend to occur on moist to somewhat wet clay loams and clays on long gentle slopes and lowlands (43). The species occupies extensive areas of this character in the Clay Belt of Ontario and Quebec. There soils have developed on clayey glacial till derived from the lacustrine deposits of former Lake Ojibway or from the unmodified lake clays themselves. Podsolization and glei formation are typical. Most of the parent materials are moderately calcareous, but some low-lime acidic clays are present. Maximum growth rates are attained on loams and clay loams with somewhat better drainage, but here black spruce is more often a minor component of other types (the Canadian Mixedwood type) (43).

Much of the till soil occupied by black spruce in the Prairie Provinces is in the Grey Wooded Soil group. These soils are characterized by calcareous parent materials, an A_2 horizon less leached and somewhat thinner than the typical podsol, and a neutral to slightly alkaline reaction in the B or C horizon (31, 33, 55).

In New Brunswick, Nova Scotia,[5/] and parts of Quebec the species often occurs on sandy and gravelly outwash plains, river terraces, eskers, and related landforms. Here soils are more acidic and strongly podsolized than the heavier soils typical of the western range (39). There is some evidence that black spruce stands induce rapid hardpan formation on these sandy sites (48).[5/]

In Alaska and the Far North clayey soils are common sites, but growth is poor because lateral groundwater movement is slow and permafrost is usually near the surface (41).

Physiographic Factors

Black spruce is characteristically a tree of the northern interior lowlands, and the great majority of the range falls between elevations of 500 and 2,500 feet. There are also substantial areas of the type below 500 feet in eastern Canada and in the Hudson Bay region (27). In the Adirondacks and the mountains of New England the species attains elevations of at least 2,000 feet but is not abundant. Maximum elevations are reached on the slopes of the Canadian Rockies in northern Alberta where scattered stands occur up to 5,000 feet or more. Farther northwest between Fort St. John and Fort Nelson, B. C., Raup (50) reports extensive forests containing much black spruce up to 4,000 feet. In the Alaskan interior, the timberline is at about 2,500 feet in many areas (41). Over most of the range local relief, because of its decisive effect on drainage conditions and bog formation, is more important than the absolute elevation in determining the abundance of this species.

Biotic Factors

Over its wide range black spruce is represented in 20 of the cover types defined by the Society of American Foresters (59). By regions these types are:

5/ Correspondence with I. C. M. Place, University of Wisconsin, November 15, 1956, on file at Lake States Forest Experiment Station.

Moisture regime	Type number	S.A.F. cover type
Boreal Forest Region:6/		
Dry to fresh	1	Jack pine
Fresh	2	Black spruce-white spruce
Dry	3	Jack pine-paper birch
Fresh to moist	4	White spruce-balsam fir
Fresh to moist	5	Balsam fir
Dry to moist	6	Jack pine-black spruce
Fresh to moist	7	Black spruce-balsam fir
Fresh to moist	8	Jack pine-aspen
Fresh to moist	9	White spruce-balsam fir-aspen
Fresh to moist	10	Black spruce-aspen
Fresh to moist	11	Aspen-paper birch
Dry to wet	12	Black spruce
Wet	13	Black spruce-tamarack
Northern Forest Region:		
Dry	1	Jack pine
Fresh to moist	36	White spruce-balsam fir-paper birch
Wet	12	Black spruce
Wet	37	Northern white-cedar
Wet	38	Tamarack
Wet	39	Black ash-American elm-red maple
Western types-Northern Interior Region:		
Wet	204	Black spruce

Black spruce is the major component of those types that begin with the species name, and a principal associate in the one type where the species name is secondary. It is generally only a minor element in the balance of the types. In addition this species may occur in various

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6/ Moisture regimes for the Boreal Region for types 1, 2, 6, and 12 are modified slightly to correspond with ratings recently developed in Canada, at the suggestion of Mr. D. W. MacLean, Canada Department of Northern Affairs and National Resources. The four-step scale adopted by the S.A.F. is retained, however. Correspondence with Mr. MacLean, November 2, 1956, is on file at the Lake States Forest Experiment Station.

mixtures with lodgepole pine (Pinus contorta), white spruce (Picea glauca), and subalpine fir (Abies lasiocarpa) in Alberta, British Columbia, and Yukon territory (51).

Bog and muskeg types are often pure black spruce, especially in Minnesota and northwestward through Canada. In Wisconsin and Michigan and in southeastern Canada this tree is a frequent element in the mixed coniferous swamp type group. Mixed swamps include varying percentages of spruce together with northern white-cedar (Thuja occidentalis), tamarack (Larix laricina), balsam fir (Abies balsamea), and sometimes black ash (Fraxinus nigra), paper birch (Betula papyrifera), American elm (Ulmus americana), red maple (Acer rubrum), and balsam poplar (Populus balsamifera). Northern white-cedar does not occur in swamps west of Manitoba. Throughout the range tamarack is an important species on wet sites, and although it often occurs as a pure type, intergrades with black spruce are common.

On moist loamy or clayey uplands in the boreal region the common associates are white spruce, quaking aspen (Populus tremuloides), balsam fir, paper birch, and tamarack. Jack pine (Pinus banksiana) is the usual associate on the somewhat drier sandy and rocky sites, but in parts of Alberta and in British Columbia its place is taken by lodgepole pine (27).

In southeastern Canada and in the United States, black spruce is occasionally found as an understory element, usually minor, in stands of red pine (Pinus resinosa) and eastern white pine (Pinus strobus). Mixtures with red spruce (Picea rubens) also occur.

On the Laurentian Shield in Minnesota and adjacent Ontario the jack pine-black spruce cover type occurs on gravelly loams and rocky soils. It often contains minor components of quaking aspen, paper birch, white spruce, balsam fir, and red or white pine. Here, the older stands of relatively pure jack pine are frequently invaded by a black spruce understory (37).

Perhaps the most conspicuous element of the ground cover in black spruce forests is the profusion of mosses and lichens. The "feather mosses" that predominate on somewhat drier sites and under heavy stands include Calliergonella schreberi, Hylocomium splendens, and Hypnum Crista-castrensis in the Hypnaceae, and species of Dicranum and Polytrichum and other less common species (18, 41, 47, 49, 51). On the wetter bogs and seepages many species of Sphagnum are found, often forming a mosaic with the "feather mosses". Common Sphagna include S. magellanicum, S. papillosum, S. recurvum, S. capillaceum, S. subsecundum, S. squarrosum, and S. fuscum (18, 41, 47, 49, 67). Many species of lichen, including the common reindeer lichen (Cladonia rangiferina), are frequent but usually do not cover much area.

The most characteristic bog shrubs are the heaths, Labradortea (Ledum spp.), leatherleaf (Chamaedaphne calyculata), kalmia (Kalmia spp.), downy andromeda (Andromeda glaucophylla), many blueberries and cranberries (Vaccinium spp.), creeping snowberry (Gaultheria hispidula), and the dwarf birches (Betula pumila and B. glandulosa). In some swamps, however, speckled alder (Alnus rugosa) and redosier dogwood (Cornus stolonifera) are the principal shrubs (18, 22, 41). Upland shrubs frequently associated with black spruce include American green alder (Alnus crispa) and beaked hazelnut (Corylus cornuta).

Herbs include common goldthread (Coptis groenlandica), yellow beadlily (Clintonia borealis), Canada beadruby (Maianthemum canadense), cloudberry (Rubus chamaemorus); species of Petasites, Pyrola, Equisetum, Lycopodium; Calamagrostis canadensis, many sedges (Carex), and the cottonsedges (Eriophorum) (18, 22, 39, 41). Across the continent species in the groundcover vary somewhat, but the same genera, with ecologically equivalent species, appear with surprising unformity in each habitat.

Insects, mammals, and disease organisms that are known to affect black spruce communities are discussed in the following sections.

LIFE HISTORY

Seeding Habits

Flowering and Fruiting

The staminate flowers of black spruce are borne on branchlets of the previous year, and are distributed over much of the upper crown. They are red, ovate, and 1/4 to 3/8 inch long. Pistillate flowers also develop on the previous year's branchlets, but they occur only in a narrow zone at the crown. The fertile flowers are slightly larger than the male flowers and are erect and oblong-cylindric, with purple scales (54).[7/]

7/ Data from J. B. Millar, The Silvicultural Characteristics of Black Spruce in the Clay Belt of Northern Ontario, unpublished thesis, University of Toronto, 1936. Some of the material in this thesis has since been published in literature citations 45 and 46.

Initial flowering occurs about the middle of May in the Lake States,[8/] and about the first of June in northern Ontario.[9/] Flowers are fully developed and pollen is shed about the first week in June in the southern portion of the range and 1 to 2 weeks later over much of Canada. Flowering dates vary as much as 2 or 3 weeks between seasons.

The ovoid cones are only 1/2 to 1-1/2 inches long. They are single or paired, and concentrated in such a small area of the upper crown that they appear clustered when abundant. Cones mature in early September of the first season. Unlike other members of the genus, black spruce cones turn purple when first ripe, but they later become brown and finally gray. The seeds are exceedingly tiny, averaging 404,000 to the pound when dewinged and cleaned (64).

Seed Production

Cones first appear at between 10 and 20 years, and most stands over 25 years of age bear regularly. The optimum age for seed production is said to be 50 to 150 years (64), but good crops are often observed on stands 200 years old or more. Observations near Ely, Minn. (37), indicate that total seed crop failures are infrequent, and failures for as many as 2 or 3 successive seasons are rare. Heavy crops occur about 1 in 4 years (64).[9/]

Black spruce is unique in the genus in having persistent, semiserotinous cones. This characteristic, plus the frequent medium-to-good seed years, means that a supply of seed is almost constantly present in stands over 40 years of age (37, 41).[9/] Although some seed is shed during the first winter and only about 2 percent of the good seed remains after 4 years,[9/] nevertheless cones may remain on the trees as long as 19 years, and some viable seed has been found in 15-year-old cones on standing trees (17).

In Minnesota the average annual number of viable seeds per acre in new and 1-year-old cones in a swamp stand was found to vary from 140,000 to over 500,000 in a 4-year period (37), with new cones averaging 180,000 seeds per acre compared to 137,000 for year-old cones.

The red squirrel (*Tamiasciurus hudsonicus*) is perhaps the chief biotic agent that reduces the abundant seed production of this spruce. So many cones and branchlets are removed over a period of years that

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8/ Flowering dates for the Lake States are based on unpublished data of the Lake States Station, and on correspondence with C. E. Ahlgren, Quetico-Superior Wilderness Research Center, Ely, Minn., April 9, 1956, on file at the Lake States Forest Experiment Station.

9/ Millar: See footnote 7, page 10.

segments of the leader are often bare for 2 feet or more. This cone clipping by red squirrels is responsible for the characteristic "bunchy" appearance of black spruce crowns (37, 41).[10/] Cone insects also consume a substantial amount of seed (37).

Seed Dissemination

Cone opening is a gradual and irregular process which permits some seed dispersal in every month. Studies in northeastern Minnesota show less fluctuation in seed fall than in annual seed crops. A swamp stand yielded 188,000 seeds per acre annually over a period of several years. On the average 9 percent fell in August, 19 percent in September, 38 percent from October to April (winter season), 13 percent in May, 14 percent in June, and 7 percent in July (37). Germination tests gave 31 percent viability for these seeds. Traps in upland spruce yielded an annual average of 313,000 seeds per acre, with a monthly distribution almost identical to that for swamp stands.

Seed dispersal is accomplished largely by wind. In spite of their small size and light weight, the seeds of black spruce usually are not carried great distances although under special circumstances, as on crusted snow in northern Canada, they may be carried a mile or more.[11/] In Minnesota the seed fall in a clear-cut area adjacent to standing timber was found to decline from a maximum of 300,000 per acre within the stand to only 19,000 at 100 feet from the edge, and virtually none beyond 300 feet (34). Similarly, in a clear-cut strip the catch of seed ranged from 240,000 per acre in the stand to a low of about 80,000 per acre in the center of the 100-foot strip (37). These records suggest that effective seed dispersal can be expected only to about two or three tree heights.

When fires kill black spruce stands, much of the seed in the isolated cone clusters is uninjured (fig. 3). Heat from the fire probably promotes further cone opening, and a heavy seed fall generally follows. This adaptation is undoubtedly responsible for many of the pure even-aged black spruce forests so sommon throughout the range (34, 41, 45, 46).[10/]

10/ Millar: See footnote 7, page 10.

11/ Unpublished information from R. N. Johnston, Ontario Department of Lands and Forests, with letter of 2/25/57, on file at Lake States Forest Experiment Station.

Figure 3.--Close-up view of clustered cones in a black spruce crown, blackened by a forest fire but still sound and seed-filled.

Vegetative Reproduction

Vegetative reproduction by "layering" has been known in black spruce for many years (19, 24). When pendant lower branches become overgrown by mosses or buried in the duff, adventitious roots develop along the buried stems. These rooted branchlets frequently become independent trees. Layering is common in swamps and bogs and on some upland situations. It is a major source of reproduction in open *Sphagnum-Chamaedaphne* muskegs (25).

The importance of layers as a source of regeneration on some commercial sites is still uncertain. Kenety (32) maintained that most black spruce was of layer origin. However, LeBarron (37) points out that this could hardly be the case with stands of fire origin. Bowman (13) observed layering along bog edges in Michigan, but considered it of little practical consequence.

In New Brunswick, Place (49) found that seedlings exceeded layers in the advance reproduction of a small swamp if 1-year seedlings are counted, but layers outnumbered seedlings 2 to 1 in the shade and 3 to 2 in the open if 1-year seedlings were dropped.

In Minnesota, Schoenike and Schneider (58) reported that 53 percent of the "best specimens" of reproduction in uncut swamp stands were layers. Where seedlings occured, however, they usually were more vigorous than layers. Buckman and Schneider (15) found that on swamp cutovers layering was greatest on good sites of true peat, next on medium sites, and least on good site swamp margins.

Reproduction counts for all cutting methods on a large-scale swamp cutting study in Minnesota, indicate that 24 percent of all quadrats were stocked with layers as opposed to 29 percent with seedlings.[12/] On the poorest sites reproduction was largely of layer origin, while on some heavily cut medium and good sites it was mostly seedlings.

As yet no quantitative studies are known that indicate what proportion of layers make acceptable trees. Because of their tie to the parent tree they are inclined to occur in poorly distributed clumps.

A recently described form of vegetative reproduction called "rooting" (38) may be more common than previously realized. The "rootlings" are said to originate from near-surface roots that produce vegetative buds. In form and general appearance of above-ground portions, the "rootlings" are quite similar to layers, with which they have evidently been confused in the past. This phenomenon has as yet been described only in Quebec, and its significance in the spruce regeneration picture is still uncertain.

Seedling Development

Establishment

Despite the very small size of black spruce seed, germination and establishment are good on many sites. In Minnesota, germination in upland plots averaged 46 percent on mineral soil, 29 percent on burned duff, and 7 percent on undisturbed duff (35). Germinative capacity under laboratory conditions averages 61 percent (64). Stratification in moist soil improves laboratory results, but is not considered essential for field seeding. Some delayed germination may occur, however.

In New Brunswick, Place (49) reported 66 percent germination on mineral soil in a clear-cut area, 72 percent on burned duff, 47 percent on scarified duff, 53 percent for weeded plots, and 49 percent for controls. Germination averaged 33 percent under a conifer overstory, and

12/ Unpublished data, Lake States Forest Experiment Station.

49 percent under hardwoods. The data were for a wet summer and indicate that good germination can be expected on most upland seedbeds under these conditions.

The forest floor in bogs and swamps presents a complex mosaic of seedbeds of living *Sphagnum*, "feather mosses" (mostly *Calliergonella* and *Hylocomium*), *Dicranum* and *Polytrichum* mosses, grasses and sedges, lichens, bare peat, and rotten wood. Some of the same seedbeds occur on uplands, especially in the north.

Sphagnum has been observed to be a good germination medium in Minnesota, apparently because it is almost constantly moist. However, some of the *Sphagna* grow faster than the tiny spruce seedlings and engulf and kill most of them (37, 53). Controlled germination studies on natural seedbeds (49) gave 30 percent for *Sphagnum*, 25 percent on *Polytrichum commune*, 15 percent on *Dicranum*, 7 percent on *Calliergonella*, and 6 percent on litter. Grass, lichen, *Vaccinium*, and *Polytrichum* were poor seedbeds in the open. Place (49) notes that *Sphagnum* may be too wet in rainy years, and thin mats of *Polytrichum*, *Dicranum*, and *Calliergonella* may be favorable in spite of the definitely poor conditions created by thick layers of these mosses.

Once germination has occurred, establishment is possible on many seedbeds providing certain requirements are met. Rainfall in early summer of the first year is probably the most critical factor. In wet years Place (49) found many upland seedbeds satisfactory, but in dry seasons access to mineral soil or other seedbeds with a dependable moisture supply seems essential, especially in the open. However, early mortality is high on some classes of mineral seedbeds, despite good germination.[13/] Exposed clays seem to be difficult sites in Ontario, while sands with a high water table are more favorable.[14/]

Though establishment may be more successful under some cover, subsequent growth and survival are generally better in the open (35). On some very open sites late spring and summer frosts have damaged planted black spruce. Here a light overstory of aspen or other species may be beneficial.

13/ Correspondence with D. W. MacLean, Canada Department of Northern Affairs and National Resources, November 2, 1956, on file at Lake States Forest Experiment Station.

14/ Correspondence with E. R. Bonner, Spruce Falls Power and Paper Company, Kapuskasing, Ontario, December 20, 1956, on file at Lake States Forest Experiment Station.

15/ Correspondence with E. R. Sexsmith, Long Lac Pulp and Paper Co., Long Lac, Ontario, January 7, 1957, on file at Lake States Forest Experiment Station.

In bogs microrelief plays an important role. Observations in Minnesota indicate that most established seedlings are neither on the highest hummocks nor in the deepest depressions, but rather on microsites of average level. Depressions are too wet and the hummocks too drouthy, especially if the seedbed is a "feathermoss" carpet.

The compaction and disturbance of peat that occur on swamp strip roads and haul roads appear to create ideal conditions for black spruce establishment in Minnesota.

Light slash has little effect, but the heavy slash "windrows" left after clear cutting dense spruce are an effective barrier to establishment of seedlings until partial decay takes place. This requires 6 to 10 years in Minnesota swamps. There are many instances of successful regeneration on large clear cuts in swamp spruce types, but much of the reproduction is advance growth that escaped burial by slash and much of the balance probably originated from seed in the slash or on the ground at the time of cutting (11, 15, 57). Establishment in large openings is apparently dependent on the fortuitous combination of advance growth, slash distribution, and moisture conditions in the first few seasons following cutting. Where the stand is reasonably windfirm, a more reliable silvicultural practice for swamp spruce may be clear cutting in patches or strips laid out so that none of the open area is more than 150 feet from a seed source.[16/] Shelterwood cuts are also effective, but probably too risky on many sites.

Burning, if severe, often improves seedbeds and reduces competition, but in dry years the blackened surfaces may be too hot (35, 49). In nature, vast areas of black spruce have successfully reseeded following fires.

In addition to heat, drouth, flooding, and moss encroachment, some seedling losses in the establishment period are due to insects, damping-off fungi, and frost-heave (35, 49). In Minnesota, insects were responsible for 41 percent of seedling mortality in the first two seasons on upland plots. Some of these losses were due to feeding on the cotyledons and leaves by a grasshopper (*Camnula pellucida*), caterpillars (*Halisidota* spp.), sawfly larva (*Empria* spp.), and the spruce budworm (*Choristoneura fumiferana*), and to root damage by June beetle larvae (*Phyllophaga* spp.) (35). Frost-heaving is most serious on heavy mineral soils. Seed that germinates in June is most apt to result in tree establishment. Seedlings that appear after about the first week in July are often eliminated by summer drouth or over-winter losses. The natural regeneration of upland black spruce stands through cutting is more difficult than in swamp types, especially where it grows in mixture with other species. Clear cutting of large areas results in

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16/ Unpublished studies, Lake States Forest Experiment Station.

partial or total failure of black spruce on many sites (37, 46). A satisfactory alternative has not yet been found, however, and planting is being resorted to in some instances.

Early Growth

In its first year black spruce grows to only about 1 inch in height on open sites and even less under stands (35). Early height growth is often slower on mineral soil than on duff or burned duff. At 3 years wild seedlings attain maximum heights of 12 to 18 inches, but under average conditions they are much shorter, perhaps 3 to 5 inches. From this early start growth begins to show extreme variations with habitat. On the poorest muskegs height growth may be as little as 1 inch per year, even during youth. But on productive uplands, or in the better swamps of the Lake States seedlings free to grow in the open may average 6 to 10 inches a year in the juvenile stage after the first 3 or 4 seasons. Millar[17/] found height at 10 years averaged about 30 inches on good sites in the Ontario Clay Belt.

Height growth in nurseries and plantations often exceeds that of wild seedlings, at least for a time. Good 2-2 transplants average about 9 or 10 inches tall.[18/] After 10 years in the field, planted stock in Wisconsin has averaged 4 to 6 feet tall on upland sites (60).[19/] The stronger dominants in such plantations may be 10 feet tall and making a foot or more of height growth per year by this age.

The most common competitors, tamarack, quaking aspen, and jack pine, usually outstrip black spruce in height growth within a few years, unless site conditions are very unfavorable for them. But the juvenile height growth of black spruce is often more rapid than that of white spruce where both occur together.

The primary rootlets penetrate to a depth of about a half inch within a week of germination, but subsequent growth is slow. Average penetrations at the end of the first season were reported to be about 2 inches on an upland site in Minnesota (35).

In New Brunswick, penetrations after 2 years were only 1.4 inches in *Sphagnum* and 1.3 inches in *Calliergonella*. Mycorrhizae were scarce on roots in *Sphagnum*, but abundant in other seedbeds (49).

17/ Millar: See footnote 7, page 10.

18/ Bonner: See footnote 14, page 15.

19/ Correspondence with J. B. Millar, Kimberly-Clark Corp., Neenah, Wis., November 30, 1956, on file at the Lake States Forest Experiment Station.

As the seedling develops, black spruce early acquires its characteristic plate-like shallow root system. There is normally no taproot, but on some older trees there may be "sinker" roots that penetrate 1 or 2 feet. The shall w rooting habit is most often associated with bogs but apparently is also the rule on uplands. Bannan (8) found that 15-year-old trees growing on coarse podsolized sands had average root penetrations of only 3.5 inches. The roots of many good swamp stands are entirely within the peat layer and do not even approach mineral soil.

In some *Sphagnum* bogs rapidly growing moss buries the roots so deeply that adventitious roots develop nearer the surface, possibly in response to rising groundwater. LeBarron (36) reports an old tree that had 4 or 5 strata of roots formed in this manner, with a total depth of 20 inches. The lower roots had been dead many years. Capps (16) described a similar situation on a permafrost site in Alaska, but there the phenomenon was attributed to a rise in the level of frozen peat as moss accumulated. It is a common observation that young seedlings put out adventitious roots if they become partially engulfed by fast-growing *Sphagnum*.

Over the range of black spruce there is a considerable spread in phenological dates. In the Lake States buds first swell noticeably between mid-April and mid-May, but height growth does not begin until June 1 to June 15. It is generally complete by late August. In Maine, Baldwin (7) found height growth to begin on May 17 and on June 7 for the 2 years observed, and it ceased on August 16 and August 30, respectively. For the Ontario Clay Belt Millar states that leaf buds are open about the middle of June.[20] In Upper Michigan leaf bud opening has averaged about June 6.[21] Late spring frosts do not often injure black spruce in the Lake States, probably because bud opening occurs so late that the danger of severe frosts has passed. In the Ontario Clay Belt very late frosts occasionally cause damage on open sites in spite of late vegetative development.[22]

Radial growth begins about the middle of May in the northern Lake States and ceases in August. At Cedar Lake, Ontario (Lat. 50°, 15' N., Long. 93°, 15' W.), Belyea et al (9) report radial growth began June 1, reached the 50-percent point by July 10, and ceased about September 3.

20/ Millar: See footnote 7, page 10.

21/ Phenological data for the Lake States based on unpublished records in files of the Lake States Forest Experiment Station, and on correspondence with C. E. Ahlgren, Quetico-Superior Wilderness Research Center, Ely, Minn., April 9, 1956, on file at the Station.

22/ Sexsmith: See footnote 15, page 15.

Sapling Stage to Maturity

Growth and Yield

The great diversity of growth rates over the botanical range of black spruce and between habitats even in local areas makes categorical statements about growth hazardous. Near the tundra margin in the Far North, and everywhere in the poorest muskegs this tree is little more than a large shrub. It may be only an inch or two in diameter and 10 to 20 feet tall in 100 to 200 years. On some sites in the North it is even prostrate (41). In contrast, the Ontario Clay Belt produces occasional specimens with a breast-high diameter of 18 inches and heights of 90 feet.[23/] The optimum range seems to lie in a broad belt stretching from southern Quebec to Saskatchewan. In Minnesota trees up to 14 inches d.b.h. and 80 feet tall are sometimes found on the best swamps. Over much of the commercial range average pulpwood stands run 5 to 9 inches d.b.h. and 50 to 65 feet tall (30, 37, 43).

Black spruce is moderately long lived--individuals attain ages up to at least 250 years. Trees as large as the maximums given above are nearly always over 140 years of age. Upland stands often develop butt rot at 70 to 100 years and become subject to wind breakage thereafter. In swamps, deterioration from butt rots and other causes occurs later--usually between 130 and 180 years. The poorer site swamp stands seem to outlast the better stands.

The laymen's impression that black spruce seldom attains commercial size probably arises from the abundance of poor muskeg spruce, and from pioneer stands along the sedge mats of bog lakes. Actually, dense even-aged stands produce surprisingly large volumes (fig. 4 on next page). Volumes of 30 cords or 2,700 cubic feet per acre to a 3-inch top at 80 to 100 years are common. At that age there often are 500 to 900 stems per acre over 4 inches in d.b.h. giving a basal area of 120 to 140 square feet. Volumes as high as 60 cords per acre have been measured on small plots in Minnesota swamp spruce. The effect of site quality on heights and yields can be seen in the Minnesota data in table 1. Poor muskeg stands are considered "off-site" and do not appear in this table. Similar heights or volumes have been reported for Saskatchewan by Kabzems (31), for Ontario by Millar[23/] and MacLean and Bedell (43), and for Quebec by Linteau (39).

The best swamps in the Lake States and southern Canada are comparable in productivity to good upland sites, but farther north there is little or no merchantable spruce in the bogs. Studies of the effect of swamp drainage on yields in Minnesota indicate that growth rates are definitely increased near the ditches, especially immediately adjacent to them (5). The effect does not usually extend more than about 330 feet

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23/ Millar: See footnote 7, page 10.

Figure 4.--Good quality swamp stand of black spruce, growing on 3.2 feet of peat, Koochiching County, Minn. Volume 38 cords per acre, age about 110 years.

feet from the ditch. Groundwater records reported by Manson and Miller (44) show large fluctuations in levels through the growing season and particularly between wet and dry years in both undrained and ditched Minnesota swamps. The beneficial effects of drainage may be due as much to increased groundwater movement as to lowered water tables.

Reaction to Competition and Place in Succession

Black spruce is capable of existing under the environmental conditions associated with fairly dense forest canopies or brush cover. Most of the foresters canvassed by Baker (6) rate black spruce as "tolerant". But many workers do not consider it as tolerant as two of its most common competitors, balsam fir and northern white-cedar. Place (49) found that light intensity of about 10 percent of that in the open was sufficient for seedling establishment. Although seedlings have somewhat better opportunities for establishment beneath an overwood, vigor and height growth are definitely superior in the open.

Table 1.--Yields per acre of well-stocked stands of black spruce in northeastern Minnesota[1/]

Age of stand (years)	Height of average dominant			Merchantable volume in trees over 3.5 inches d.b.h. to 3-inch top		
	Good site	Medium site	Poor site	Good site	Medium site	Poor site
	Feet	Feet	Feet	Cords	Cords	Cords
40	33	28	22	17	6	--
60	44	37	29	32	22	6
80	52	44	34	41	31	16
100	58	48	38	47	36	24
120	62	52	41	52	40	27
140	65	54	43	54	43	30
160	67	56	44	56	45	31

1/ From Fox and Kruse (23).

Some advance reproduction is usually present even in dense stands, but many seedlings evidently fail to survive more than a few seasons under heavy shade. For this reason, the better stocked even-aged stands commonly lack an understory of saplings until they begin to open up at advanced ages. In heavily stocked stands black spruce prunes itself quite well, but open-grown trees retain their branches nearly to the ground.

Upland black spruce in Minnesota and in at least portions of the Canadian range is believed to be mainly a fire type that is succeeded by balsam fir, white spruce, and paper birch in the absence of further disturbance (34, 46). Certainly these species often invade upland spruce stands of fire origin when they reach maturity.

Ecologists consider black spruce to be one of the first pioneer trees to invade the advancing sedge mat in filled-lake bogs. It is usually preceded only by tamarack (18, 22, 47). In some swamps black spruce is ultimately replaced by northern white-cedar and balsam fir, but on many bogs this is an extremely slow process and over much of the northwestern range these species are lacking from the flora. Swamps that contain a strong northern white-cedar element are usually circumneutral in acidity (18) and often have better decomposed peats and more active groundwater movement than the pure spruce areas. In the mixed swamp types of Upper Michigan where balsam, cedar, and sometimes black ash, American elm, red maple, and balsam poplar are the competitors, black spruce usually does not hold its position well after either partial cutting or clear cutting (69). In Minnesota, spruce-tamarack swamps with a heavy understory of speckled alder are difficult to maintain. Cutting of these types often leads to dominance of a lowland brush cover type, at least for a time.

All-aged stands are common in the poor-site bogs and muskegs and on many sites in the Far North (34, 41). Even on the better swamps all-aged or group-wise stands frequently occur. These many-aged stands appear to have succeeded previous forests of the same species. Thick layers of woody peat containing cones and needles of black spruce often attest to a long history of spruce in such areas. For practical purposes black spruce may be considered a physiographic or edaphic climax on many bogs (37, 47) and on cold poorly drained soils in the Alaskan Interior (41).

However, some of the best swamp forests of this species are even-aged and of fire origin. In the Clay Belt of Ontario and in northeastern Minnesota there is much evidence that both swamp and upland stands are largely fire types (37, 46). Frequently only the wettest muskegs seem to have escaped burning.

Black spruce is fairly common as an understory in jack pine, lodgepole pine, and white spruce-balsam types in western Canada (30, 51). In these situations it will evidently be a component of the future stand unless eliminated by some disturbance. On the Laurentian Shield in Minnesota and western Canada understories of black spruce often are present in the older jack pine stands. Here black spruce, together with balsam fir and white spruce, will succeed the jack pine if fire or cutting do not intervene (37).

Limiting Factors in Older Stands

In the northern portions of its range the growth of black spruce is no doubt limited mainly by low soil and air temperatures and an extremely short period free of severe frosts. Little is known about climatic limitations in the main commercial range or near the southern extremities of its botanical range. In the southern fringe area this tree is confined almost exclusively to *Sphagnum* bogs, apparently because it cannot compete with most of the upland species found there. It seems to be the only tree other than tamarack that can survive in the cold microclimates, unfavorable soils, and high water tables of the bogs.

Limited planting trials on uplands in the Lake States and Ontario indicate, however, that black spruce may grow well on sites that it seldom is able to occupy in nature (60).[24/]

Even in the better swamps of the northern Lake States there are extreme variations in productivity over very short distances. In some situations studied in the Minnesota portion of Glacial Lake Agassiz the differences in site quality may not be a simple function of successional development, because the poorest stands sometimes are growing on peats that contain spruce wood to depths of several feet. The open water stage, if present at all, was evidently passed thousands of years ago.

In general, the good quality swamp stands are found on shallower peat than poor stands, and, as noted under edaphic factors, the better sites are characteristically near the swamp margin. These facts have led many to conclude that peat depth is a limiting factor. However, the existence of occasional good stands on deep peat is proof that a thick peat layer is not necessarily limiting. Other factors that are usually associated with deeper peat may be the cause of the poor growth. The factors most often reported to be limiting in bogs are: Low soil and air temperatures, the strongly acid reaction of many peats, lack of nutrients in peat soils, high water tables causing poor aeration of the soil, and lack of groundwater movement.

Bog spruce is notably vulnerable to flooding and disruption of normal groundwater movement. These are often caused by highway fills and have resulted in many instances of damage to bog spruce. In some cases many acres of swamp spruce have been killed out with the damage extending back as much as a quarter-mile from the road. In Minnesota a good deal of volume has been lost through the damming of man-made drainage ditches by beaver (Castor canadensis) (66). Blocking of natural stream courses by these animals also kills some spruce throughout the range. Beaver do not prefer the bark of black spruce, but quaking aspen is a favorite food species that often grows along ditch banks and streams adjacent to spruce swamps.

Both crown fires and surface fires kill black spruce readily. During drouth years fires sometimes burn into the peat in swamps and may consume so much peat that the "burn outs" revert to grass and sedge meadow or even to aquatic vegetation in normal and wet years. Fires that do not burn much peat often result in a new spruce stand originating from seed in the semiserotinous cones high in the crowns where the heat was insufficient to kill it. However, because spruce does not bear cones until 10 to 20 years of age, repeated fires at intervals shorter than this will completely eliminate the type (41).

24/ Johnston: See footnote 11, page 12.

Windstorms cause frequent blowdowns in both upland and swamp stands. The shallow root system of black spruce makes it notably susceptible to uprooting by wind (37).[25/] Observations in Minnesota indicate that windbreakage of stems with butt rot and uprooting are the most common causes of mortality in mature and overmature stands. Thrifty swamp stands are able to withstand normal storms in the 40 to 50 mile-per-hour range quite well, even when their stocking is reduced moderately by partial cuts; so too can trees along the edges of small stand openings such as clearcut patches or strips. But stands exposed for many chains in the direction of storm winds are definite blowdown hazards, especially if they are over-mature or growing on shallow peat overlying bedrock and boulder or on some classes of mineral soils.

A good deal of the windfall in older stands is due to windbreakage of stems infected by wood-rotting fungi. Black spruce is relatively free of serious defect other than butt rots, but these are common in upland stands at about 70 to 100 years and in swamp stands after perhaps 100 to 130 years. The most common causal organisms are *Polyporus schweinitzii*, *Stereum sanguinolentum*, *Armillaria mellea*, *Fomes pini*, and *F. pinicola* (40).

The black spruce dwarf mistletoe (*Arceuthobium pusillum*) causes the most serious disease of this tree. It is a frequent source of mortality in the Lake States and eastern Canada (4, 37) but is virtually absent west of Manitoba (52). It causes the "witches'-brooms" so common on this species, and results in stunting of growth and eventual death of the host. Infection centers start in small groups and gradually spread outward. Old centers show up as definite holes in the stand, identifiable on aerial photos. Control appears possible only by the eradication of all infected trees and reproduction in the mistletoe pocket, including an isolation strip in apparently uninfected timber (4). New stands originating from seed in fire-killed stands may be comparatively free of mistletoe for many years. LeBarron (37) believes the disease could prove more serious in managed forests where this "rejuvenating" effect of fires is absent.

Several needle rusts infect black spruce. While they are not known to injure the tree seriously, they may cause enough defoliation to interfere with its use for Christmas trees. These rusts have various species of the *Ericaceae* as their alternate hosts. The four species that are known on black spruce, together with their alternate hosts, are (14):

25/ Millar: See footnote 7, page 10.

Rust	Alternate host
Chrysomyxa cassandrae	Chamaedaphne calyculata
Chrysomyxa ledi	Ledum spp.
Chrysomyxa ledicola	Ledum spp.
Chrysomyxa chiogenis	Gaultheria hispidula

The spruce budworm (Choristoneura fumiferana) occasionally defoliates black spruce, but this spruce is not a preferred food. Only trees associated with much balsam fir and white spruce are attacked to any extent (26). In mixed stands where most of the balsam fir has been killed, secondary losses of black spruce through windfall are common. There is some evidence that the budworm can maintain itself on black spruce over a period of years and that such a population may serve as a reservoir for the much more serious attacks on balsam fir and white spruce.

The eastern spruce beetle (Dendroctonus piceaperda) occasionally attacks and kills black spruce (20). Heavy defoliation of this tree by the European spruce sawfly (Diprion hercyniae) has been reported in eastern Canada (42). The yellow-headed spruce sawfly (Pikonema alaskensis) also is an occasional defoliator (20). One of the Neodiprion sawflies feeds on black spruce and may cause damage (20).

In the Lake States black spruce is the alternate host for the pine leaf aphid (Pineus pinifoliae) (20), which has caused heavy damage to young white pine in northern Minnesota. And lastly, the white-pine weevil (Pissodes strobi) occasionally attacks black spruce (10). While the above list of insect enemies may sound imposing, fortunately serious damage to black spruce stands is uncommon, and the tree has a reputation for relative freedom from insect losses.

Snowshoe hares (Lepus americanus) sometimes debark black spruce seedlings and saplings and nip off leaders and branches, although this spruce is not a preferred food. In dense reproduction some natural thinning is accomplished in this manner. When hares are abundant in lowland brush types they may be a factor in retarding natural spruce regeneration and a problem in plantations (1, 65). This spruce is rarely eaten by the white-tailed deer (Odocoileus virginianus), but under starvation conditions the needles are sometimes taken in small quantities (3, 21). Moose (Alces alces americana) occasionally browse the leaders,[25/] but again black spruce is not a preferred species (2).

25/ Millar: See footnote 7, page 10.

USES AND SPECIAL FEATURES

The wood of black spruce is used chiefly for groundwood and sulphite pulp in the manufacture of newsprint and high-grade papers. In the decade 1945 to 1955 the Lake States production of spruce pulpwood averaged 386,000 cords annually, of which about 85 percent of 328,000 cords were black spruce (28). In addition to the domestic production, large quantities were imported from Canada. Some mills in the Eastern States and New England also use substantial quantities of black spruce. Across a broad belt of Canada's boreal forest, from Quebec to Saskatchewan, black spruce is the most valued and one of the most abundant pulpwood species. Pulpwood markets are just beginning to reach the black spruce areas in the Prairie Provinces. Black spruce also is used to make dissolving pulps in Canada.[26/]

A sizable Christmas tree industry relies on this species for its trees. Much of the cut goes into "processed trees" of table size that are spray painted and supplied with stands. Several million trees of this type are sold each year in addition to a large volume of taller household trees that are marketed fresh. A high percentage of the Christmas tree harvest comes from "stagnant" and "semi-stagnant" muskeg stands that would produce little or no pulpwood. Cutting operations in the Christmas tree bogs can be conducted year-round except for the peak of the growing season, if the processor paints his trees and has cold storage facilities. Special tractors and semiamphibious vehicles are often used for hauling when the bogs are not frozen. Small quantities of black spruce are used for lumber, mine lagging, poles, and posts, especially in northern Canada where other species may be in short supply.[26/]

RACES AND HYBRIDS

The existence of races in black spruce is considered likely by forest geneticists. The relative ecological isolation of many stands in bogs should provide opportunities for variation to develop. There has been some speculation about possible bog and upland ecotypes, but no published studies are known to have demonstrated this. Wright (68) lists natural hybrids between the female of red spruce and the male black spruce. The abundance of such natural hybrids with red spruce in the area of range overlap is an unknown quantity at present. Some workers believe that hybridization is extensive, with black spruce characters becoming more prominent to the northwest, and red spruce to the south

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26/ Johnston: See footnote 11, page 12.

and east.[27/] Separation of these species by field characters is difficult in much of the overlap area.

A natural hybrid with white spruce has recently been reported from Minnesota by Pauley.[28/] Wright (68) lists a possible cross between the male black spruce and the female white spruce. A reciprocal artificial cross with *Picea jezoensis* is listed by Johnson (29), and crosses of the male black spruce with *P. abies* and *P. omorika* are also reported by Wright (68).

Normal vegetative cells of black spruces have 12 pairs (24) of chromosomes (56).

27/ Place: See footnote 5, page 7.
28/ Information obtained verbally from Dr. Scott Pauley of the University of Minnesota School of Forestry.

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SILVICAL REPORTS BY THE LAKE STATES STATION

This is the second of the 15 silvical reports being prepared by the Lake States Forest Experiment Station. A report on red pine has already been published. Ensuing reports will cover:

- Bigtooth aspen
- Quaking aspen
- Basswood
- American elm
- Rock elm
- Slippery elm
- Black maple
- Sugar maple
- Jack pine
- Balsam poplar
- White spruce
- Tamarack
- Northern white-cedar

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