

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

Black Spruce

Pinaceae Pine family

Leslie A. Viereck and William F. Johnston

Black spruce (*Picea mariana*), also called bog spruce, swamp spruce, and shortleaf black spruce, is a wide-ranging, abundant conifer of the northern parts of North America. Its wood is yellow-white in color, relatively light in weight, and strong. Black spruce is the most important pulpwood species of Canada and is also commercially important in the Lake States, especially Minnesota.

Habitat

Native Range

Black spruce (fig. 1) ranges in a broad band from northern Massachusetts to northern Labrador on the Atlantic coast, west across Canada to the west coast of Alaska. Its southern limits consist of isolated patches in northern New Jersey, western Connecticut, Pennsylvania, southern Michigan, southern Wisconsin, southern Minnesota, and southern Manitoba; west across south-central Saskatchewan, Alberta, and central British Columbia. Its northern limit across Canada and Alaska is about that of the northern tree line, although it alternates with white spruce (*Picea glauca*), tamarack (*Larix laricina*), and balsam poplar (*Populus balsamifera*) as the tree line species at different points.

The commercial range of black spruce is considerably less than its geographic range.

Climate

The climate for black spruce can be characterized as cold with a moisture regime varying from humid to dry subhumid. Mean annual temperatures range from 7° C (45° F) in the southern areas to -11° C (13° F) near tree line in central and western Canada. Average January temperatures range from -30° C (-22° F) in northwestern Canada and Alaska to -6° C (21° F) at the southeastern edge of its range. Average July temperatures range from 16° to 24° C (60° to 76° F) in the main part of the range of black spruce and from 10° to 27° C (50° to 80° F) in extreme locations. The extreme low temperatures

range from -62° to -34° C (-79° to -30° F), the highs from 27° to 41° C (80° to 105° F).

Annual precipitation decreases from east to west. In the maritime provinces, it may be as high as 1520 mm (60 in) and in western Alaska as low as 150 mm (6 in), but annual precipitation ranges from 380 to 760 mm (15 to 30 in) in most of the black spruce range. Much of the precipitation is snowfall—from 500 cm (200 in) in eastern Canada to 100 cm (40 in) in western Canada and central Alaska. Mean snow depths are 50 to 75 cm (20 to 30 in) over most of the range but may be more than 100 cm (40 in) in parts of Quebec and Labrador, where snow may persist into late May or early June.

Maximum length of days during the growing season varies from continuous north of the Arctic Circle to about 16 hours near the southern limits of the range. The frost-free period varies from 140 days in the southeastern portions of the range to 60 days or less near tree line.

Soils and Topography

Black spruce (fig. 2) usually grows on wet organic soils, but productive stands are found on a variety of soil types from deep humus through clays, loams, sands, coarse till, boulder pavements, and shallow soil mantles over bedrock. In the Lake States and adjacent Canadian provinces, it grows on soils of the order Histosols: peat bogs and swamps that have formed on old glacial lakebeds and in muck-filled seepages on peat deposits that range in thickness from 0.5 to 6 m (20 in to 20 ft). The most productive black spruce stands are on dark brown to blackish peats, which usually have a considerable amount of decayed woody material. Stands of low productivity are usually found on thick deposits of partially decomposed sphagnum peat.

In central Canada, upland stands tend to be of higher quality than the lowland peat stands. Here, podzolic soils of the order Spodosols and gley soils of the order Inceptisols are common on gentle slopes underlain by clay-loam or clays that have been derived from glacial tills. Many of these clay soils are derived from calcareous materials and are neutral to slightly alkaline in the B or C horizons. The most productive black spruce stands are found on the better drained sites such as sandy glacial deposits, river terraces, and outwash plains of the order Entisols, usually in association with hardwood species.

The authors are Principal Plant Ecologist, Pacific Northwest Research Station, Portland, OR, and Principal Silviculturist (retired), North Central Forest Experiment Station, St. Paul, MN.

Picea mariana

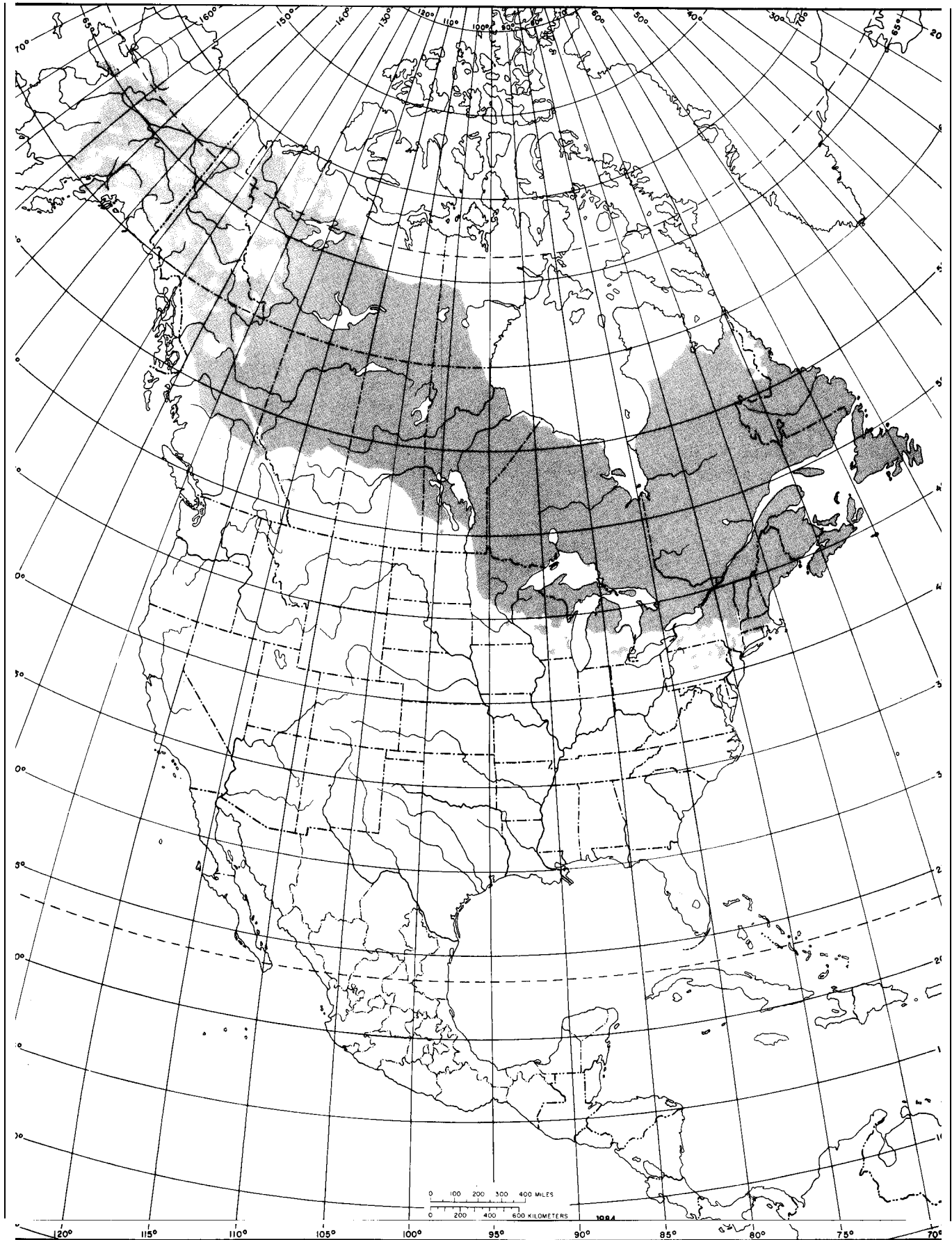




Figure 2—Black spruce stand in a swamp in Minnesota.

In the north, black spruce sites are commonly underlain by permafrost (perennially frozen soils). Black spruce seems to be the tree species best adapted to growing on permafrost soils because of its shallow rooting habit. Often the annual thaw depth (active zone) may be as little as 40 cm (16 in). In northwestern Canada, black spruce often grows in alternating organic and mineral soil layers, on hummocklike mounds that overlie the permafrost (57). In central Alaska, black spruce is found on permafrost sites of shallow wind-deposited loess and on old river terraces. At tree line, it is often found on shallow, poorly developed mineral soils. On most black spruce sites on permafrost, wildfire results in a temporary increase in the thaw depth.

Black spruce is found from sea level in eastern and northern Canada and western Alaska to 1830 m (6,000 ft) in northern Alberta. It is considered to be a tree of interior lowlands, however, and usually grows at between 150 and 760 m (500 and 2,500 ft). In the mountains of Alaska, Yukon Territory, and Northwest Territories, it is often the tree line species at elevations of 300 to 1220 m (1,000 to 4,000 ft). Local topography and drainage seem to be more important than elevation in determining the range of black spruce.

Associated Forest Cover

Black spruce most commonly grows as pure stands on organic soils and as mixed stands on mineral soil

sites. It is a major component of forest types with white spruce, balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), and tamarack and also grows in association with paper birch (*Betula papyrifera*), lodgepole pine (*P. contorta*), quaking aspen (*Populus tremuloides*), balsam poplar, northern white-cedar (*Thuja occidentalis*), black ash (*Fraxinus nigra*), American elm (*Ulmus americana*), and red maple (*Acer rubrum*). In the southern parts of its range, black spruce is commonly found in mixed stands with several species, especially northern white-cedar, white spruce, balsam fir, and tamarack. In the main part of its range, it is commonly associated with white spruce, quaking aspen, balsam fir, paper birch, and tamarack. Jack pine is a common associate on dry sites. At the northern and northwestern limits of the range, pure stands are common, but black spruce is also found associated with paper birch, quaking aspen, white spruce, and tamarack.

Because of its broad distribution and varying ecological site characteristics, the Black Spruce forest cover type (Society of American Foresters Type 12, eastern, and 204, western) (11) has been divided into six subtypes: (a) black spruce-feather-moss, most common in the southern and central boreal forest; (b) black spruce-lichen, most abundant near the northern limit of the boreal forest; (c) black spruce-dwarf shrub, in the southern and central portions of the boreal forest; (d) black spruce-sphagnum, on wet soils; (e) black spruce-speckled alder (*Alnus rugosa*), on waterlogged soils with standing or slowly flowing water; and (f) black spruce-sedge, on peatlands with minerally enriched moving water. Black spruce is also a major component of cover types Black Spruce-Tamarack (Type 13); Black Spruce-White Spruce (Type 253); and Black Spruce-Paper Birch (Type 254).

One of the most conspicuous aspects of many black spruce stands is a nearly continuous ground cover of feathermosses (*Hylocomium splendens*, *Pleurozium schreberi*, and *Ptilium crista-castrensis*) and sphagnum mosses (*Sphagnum* spp.). On some sites, the moss layer is replaced by nearly continuous mats of lichens, primarily species of *Cladonia*; this is especially typical of open stands in northern areas where the open lichen woodland is a common vegetation type.

The shrubs associated with black spruce change gradually from east to west. Dominant shrubs in the eastern range include mountain maple (*Acer spicatum*), beaked hazel (*Corylus cornuta*), speckled alder, red-osier dogwood (*Cornus stolonifera*), and red raspberry (*Rubus idaeus*) on better sites; and low birch (*Betula pumila*), bog birch (*B. glandulosa*), bog-rosemary (*Andromeda glaucophylla*), lambkill (*Kal-*

mia angustifolia), Labrador-tea (*Ledum groenlandicum*), leatherleaf (*Chamaedaphne calyculata*), and bog-laurel (*Kalmia polifolia*) on the less productive peatlands. In the western part of the range, littletree willow (*Salix arbusculoides*), grayleaf willow (*S. glauca*), Bebb willow (*S. bebbiana*), prickly rose (*Rosa acicularis*), American green alder (*Alnus crispa*), Labrador-tea, bog blueberry (*Vaccinium uliginosum*), and mountain cranberry (*Vaccinium vitis-idaea*) are the most important shrubs. The most important herbs, found over most of the range, are panicle bluebells (*Mertensia paniculata*), fireweed (*Epilobium angustifolium*), one-sided pyrola (*Pyrola secunda*), twinflower (*Linnaea borealis*), bunchberry (*Cornus canadensis*), wild sarsaparilla (*Aralia nudicaulis*), false lily-of-the-valley (*Maianthemum canadense*), star-flower (*Trientalis borealis*), bluejoint reedgrass (*Calamagrostis canadensis*), and sheathed cottonsedge (*Eriophorum vaginatum*).

Life History

Reproduction and Early Growth

Flowering and Fruiting-Black spruce is monoecious. Female flowers (ovulate strobili), produced in the upper meter of the crown, are usually erect, cylindrical, and green or purplish. At the time of fertilization, the female conelet is about 15 to 25 mm (0.6 to 1.0 in) in length. The male flowers (staminate strobili), produced on the outer branches of the crown below the zone of female flowers, are ovate, 12 to 20 mm (0.5 to 0.8 in) long and dark red to purplish during expansion. The pollen sacs are yellow, and after pollen dispersal the staminate flowers appear yellowish brown. A few cones may be produced after 10 years (2), but the main cone-bearing age of black spruce is from 30 to 250, with maximum production between 100 and 200 years (6).

The flower buds formed by early August develop rapidly the following spring. Female flowers are receptive and pollen is shed in late May or early June in southern areas of the range and 1 to 2 weeks later in the north. The female conelets then develop rapidly, and at maturity the cones are 1 to 4 cm (0.4 to 1.6 in) long.

Seed Production and Dissemination-Black spruce seeds mature 3 months after pollination, in late August or early September. Some are produced almost every year, but heavy seed years occur at intervals of 2 to 6 years and peak crops every 4 years over most of the range. Good seed years may be less frequent in the north; vegetative reproduction of

clonal populations occurs at the northern limit of black spruce in Canada (36).

The cones of black spruce remain partially closed and disperse seed for several years, providing an adequate supply of seeds to reproduce the stand whenever fire occurs. Both the number and viability of the seeds decline rapidly, but some viable seeds may remain in the cones for as long as 25 years (15). In Minnesota, 1-year-old cones contained an average of 50 seeds; 7-year-old cones, 10 seeds; and 19-year-old cones, only 1 or 2 seeds (50). In Newfoundland, the number of seeds per cone was greatly reduced in 4 years (3.7 seeds per cone), but seed germination remained high (above 90 percent) for 12 years and then declined rapidly in older seeds (44).

Black spruce seeds are dispersed throughout the year, but dispersal is highest in the spring and lowest in the fall (16). Fires open the cones and accelerate seed fall for periods of 60 days (55) to 2 to 3 years; the effect apparently varies with fire intensity.

The average annual seedfall is about 490,000/ha (200,000/acre) for Minnesota (26) and substantially higher for Ontario—2,450,000 to 4,180,000/ha (990,000 to 1,692,000/acre) (15). A maximum of 12,720,000 seeds per hectare (5,148,000/acre) has been reported from Ontario (29). In northern areas, even near tree line, amounts of seed are within the range of those from southern areas, with annual amounts from 590,000 to 1,300,000/ha (240,000 to 528,000/acre) reported from Inuvik in Northwest Territories (6) and 850,000/ha (344,000/acre) from central Alaska (49).

Black spruce has the smallest seed produced by any spruce in North America, averaging 890,000/kg (404,000/lb). Despite their light weight and relatively large wings, the seeds are not commonly dispersed over long distances. Seed dispersal, primarily by wind, is effective up to 79 m (260 ft) from the windward edge of a mature stand (27).

Seedling Development-Sphagnum mosses provide a continuously moist seedbed in many areas, but growth of black spruce seedlings may be slow in sphagnum moss because of a poor supply of nutrients (23,241, and they may not be able to keep ahead of some fast-growing sphagnum species that eventually overtop them. Feathermosses may provide a suitable seedbed during wet years, but they are unreliable and usually dry out before penetration by the seedling root occurs. Moist mineral soils usually provide good seedbeds for black spruce, but exposed mineral soil may be too waterlogged or subject to frost heaving in some low-lying areas (23).

Fires that completely remove the surface organic layer usually provide good seedbeds for black spruce. Slash removal by broadcast burning or full-tree skidding is also beneficial (8,26). Seedling mortality seems to be highest on burned duff and lowest on some moss and mineral soil surfaces with an adequate moisture regime.

Seedbed scarification increases stocking. Under optimal climatic conditions, direct seeding on these scarified surfaces results in seedlings representing 10 to 30 percent of the sown seed (25,56). A sowing of 79,000 seeds per hectare (32,000/acre) should result in at least 60 percent milacre (4.05 m² or 43.56 ft²) stocking of seedlings, which is considered satisfactory (26). Spring sowing results in the best germination and survival, and viability is drastically lowered if germination does not occur during the same year (13,56). Germination is epigeal (42).

Nursery-grown transplants (2-2) survive better, grow faster, and are more economical than seedlings (3-0) when black spruce plantations are established (34,35). Average initial height growth of black spruce seedlings varies from 2.5 cm (1 in) per year on moss



Figure 3—Vegetatively reproduced layering of black spruce; the “mother” trees were damaged by logging 6 years earlier.

to 15 cm (6 in) per year on some mineral soil substrates, but annual growth may be as low as 5 mm (0.2 in).

Vegetative Reproduction-Layering (fig. 3) is an important means of reproduction in black spruce on some sites, especially where rapidly growing mosses cover the lower branches of the slow-growing seedlings and saplings (45). Layerings from the lower branches develop most abundantly in the more open-grown, poorer stands and less frequently in dense, productive stands. Layering is common in black spruce growing at tree line, probably as a result of depression of the lower branches by snow, and accounts for the presence of “candelabrum” spruce, a circular clump originating from one individual with the tallest tree in the center. Layering is also common in black spruce/speckled alder communities on organic soils but is rare in well-stocked black spruce/Labrador-tea stands (45). The trees established from layerings constitute advance growth on some sites and are particularly important where logging disturbance is light.

Black spruce may reproduce from shoots originating from roots (12), but this is uncommon. Cuttings from black spruce seedlings can be rooted successfully with periodic misting but without application of auxins (3).

Sapling and Pole Stages to Maturity

Growth and Yield—Under normal unmanaged conditions, black spruce (fig. 4) at maturity averages 12 to 20 m (40 to 65 ft) tall and about 23 cm (9 in) in d.b.h. on good sites; 8 to 12 m (25 to 40 ft) and about 13 cm (5 in) in d.b.h. on poor sites. Extreme sizes vary from semiprostrate shrubs or trees to 3 to 6 m (10 to 20 ft) tall and 3 to 5 cm (1 to 2 in) in d.b.h. in the far north to occasional individuals that are about 27 m (90 ft) tall and 46 cm (18 in) in d.b.h. in the Ontario Clay Belt (12,50). Average maximum age is about 200 years, but ages up to 280 years have been reported.

Volumes of 196 m³/ha (2,800 ft³/acre) are common in 80- to 100-year-old stands on the best peatlands and good upland sites in southern Canada and the Lake States (12). One unmanaged stand had a total volume of 492 m³/ha (7,024 ft³/acre) and a basal area of 53.5 m²/ha (233 ft²/acre) when it was slightly more than 100 years old.

Regional differences in the site index of black spruce are apparently related to climatic factors, whereas differences within regions are associated with soil moisture and nutrients. The moisture-aeration regime influences growth more than the

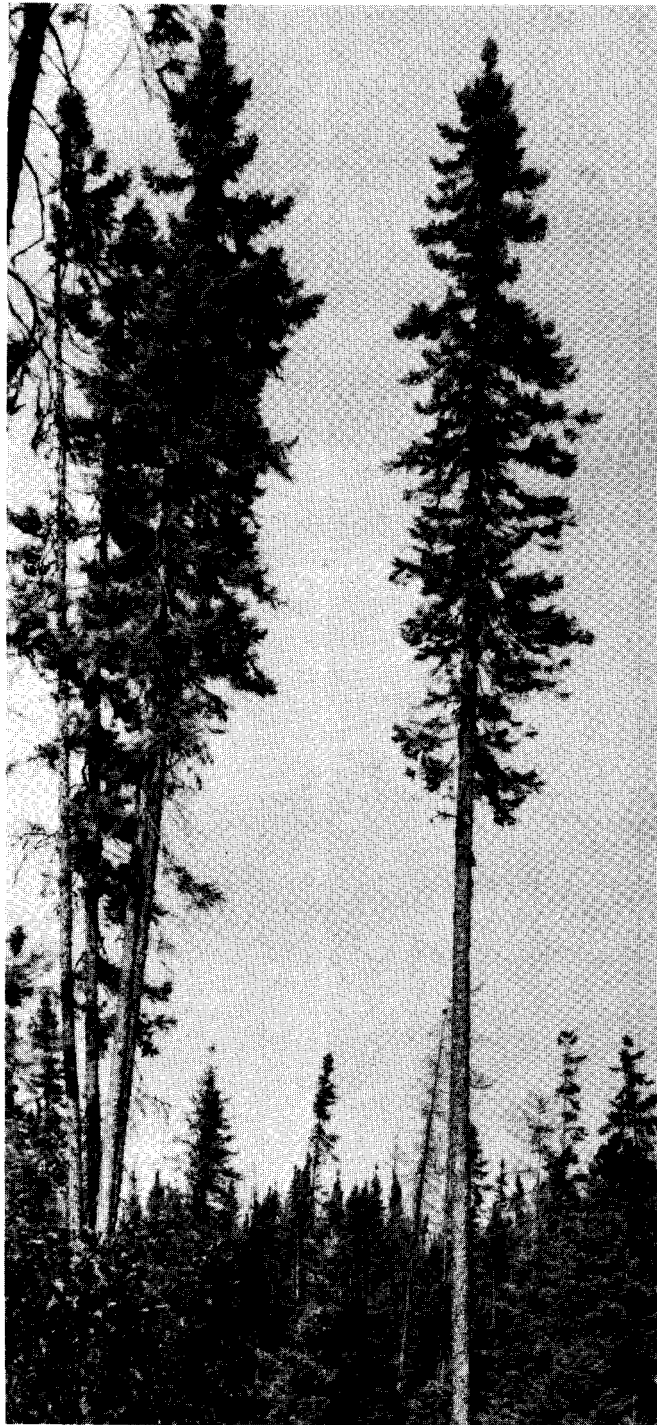


Figure AA 120-year-old black spruce (center). It is 25 cm (10 in) in d. b. h. and 20 m (65 ft) tall.

nutrient regime (22). Within peatlands, water chemistry-as determined by water sources and

Table 1-Merchantable yields of 120-year-old black spruce stands in Ontario for trees 10 cm (4 in) d.b.h. and larger (adapted from 10).

Characteristic	Stocking ¹ at age 30	Site index at base age 50 years		
		12.5 m or 41 ft	10.7 m or 35 ft	8.2 m or 27 ft
Average height, m	Full	17	14	11
Average d.b.h., cm	Half	17	14	11
Trees per hectare	Full	1,520	2,480	1,490
Basal area, m ² /ha	Half	1,110	1,880	1,780
Volume, m ³ /ha	Full	4.2	3.5	1.5
	Half	3.6	3.3	1.9
Average height, ft	Full	29.8	21.2	7.4
Average d.b.h., in	Half	2.60	2.02	9.4
Trees per acre	Full	5.7	4.7	3.7
Basal area ft ² /acre	Half	5.7	4.7	3.7
Volume, ft ³ /acre	Full	7.4	5.3	4.4
	Half	8.0	5.9	4.6
Trees per acre	Full	615	1,005	605
Basal area ft ² /acre	Half	450	760	720
Volume, ft ³ /acre	Full	181	152	65
	Half	158	145	83
Trees per acre	Full	4,260	3,030	1,050
Basal area ft ² /acre	Half	3,710	2,880	1,350

¹"Full" refers to a basal area-for trees 2.5 cm (1 in) in d.b.h. and larger-of 16.4 m²/ha (60 ft²/acre) on site index 12.5 m (41 ft) good site/medium site; 13.8 m²/ha (60 ft²/acre) on site index 10.7 m (35 ft); and 4.6 m²/ha (20 ft²/acre) on site index 6.2 m (27 ft) poor site. "Half" refers to one-half of the respective basal areas used for full stocking.

movement-seems to be the principal factor influencing site quality (19).

Black spruce site index curves differ among regions and substrates. For example, the curves are lower at older ages in Newfoundland than in continental Ontario and Quebec. In Ontario, the height-growth patterns of black spruce are different for peatland and upland stands, particularly for site indexes less than 8 m (26 ft) at 50 years and stands older than 80 years (38).

Variable-density yield tables-for stands of various stocking levels-provide better estimates of black spruce growth than normal and empirical yield tables in Ontario (10). They show that both site and stocking influence tree size and volume production. Good sites can grow larger trees than poor sites, whereas stocking has an adverse effect on average d.b.h. and no effect on average height. Merchantable volume, however, increases with stocking except on poor sites (table 1). Variable-density yield tables are also available for black spruce stands in Minnesota (39).

Normal yield tables show that rotation age increases as site quality decreases. They also show that

the corresponding merchantable volume and mean annual increment decrease greatly from good to poor sites. Averages for black spruce stands of three site classes in the boreal forest of Canada (5, p. 50,91,155,186) are as follows:

	Good	Medium	Poor
Rotation age, yr	95	113	132
Merchantable volume, m ³ /ha	218	160	101
Mean annual increment, m ³ /ha	2.3	1.4	0.8
Merchantable volume, ft ³ /acre	3,110	2,285	1,440
Mean annual increment, ft ³ /acre	33	20	11

Rotation age is the age at which the mean annual increment of merchantable volume culminates and hence yields the most material per unit area per annum.

Little is known about the growth and yield of uneven-aged stands, but they apparently grow more slowly and have lower volumes than even-aged stands (17).

Black spruce plantations reach heights of 1.5 to 4.0 m (5 to 13 ft) 10 years after planting (2,34). A 40-year-old plantation in Minnesota, planted at a 1.2- by 1.2-m (4- by 4-ft) spacing, was 13.3 m (43.6 ft) tall and had a basal area of 32.8 m²/ha (143 ft²/acre) (43). On rich sites in New Brunswick, extensive fast-growing plantations of black spruce have been established for 45-year rotations because the species has good potential height growth and is resistant to spruce budworm.

In experimental studies, fertilization with nitrogen and phosphorus generally results in increased growth in 60- to 90-year-old stands on upland boreal sites (48). The best response to fertilization apparently occurs in stands of low vigor (33,53). For example, fertilization (with nitrogen and phosphorus combined) may convert some marginally nonproductive muskeg stands of black spruce into commercial forest stands (1). Benefits from fertilization will probably be greatest in thinned stands (51).

Drainage may increase the growth and yield of black spruce, but maximum response on peatlands and other wet sites will probably also require fertilization and (in dense stands) thinning. Full-tree harvesting will probably not reduce future productivity, except on sites of marginal fertility (52).

Rooting Habit-Although some black spruce roots may penetrate to 60 cm (24 in), most spread laterally at the moss-humus interface. The bulk of the root biomass is in the upper 20 cm (8 in) of the organic horizons. In areas with rapidly accumulating organic layers, several sets of progressively younger roots may develop adventitiously. These new roots

may grow as fast as 1 m (3 ft) per year and as much as 4.6 m (15 ft) in 8 to 9 years (2).

Reaction to Competition-Black spruce is classed as tolerant of shade but is less tolerant than balsam fir and northern white-cedar, two common competitors in the eastern part of its range. Seedlings (and apparently layerings) develop in as little as 10 percent of full light intensity, but survival and growth are much better in the open (12). The maximum overstory basal area that can be tolerated without serious loss of seedling vigor is probably 9 to 11 m²/ha (40 to 50 ft²/acre).

Aerial spraying of selective herbicides such as 2, 4-D usually results in effective release of black spruce in brushy stands (26,50). Released trees, however, apparently do not increase growth for about 2 years, and complete release can result in winter drying. Applying pellets of the nonselective herbicide picloram to speckled alder clumps seems to control regrowth longer than 2,4-D but can damage associated black spruce even on well-drained soils (40). Although quite expensive, recently introduced selective herbicides such as glyphosate and hexazinone are also registered for release of spruce. Directions on all herbicide labels should be followed carefully and pertinent precautions heeded.

In spruce-fir stands, mature black spruce apparently responds better to release than white spruce and subalpine fir (*Abies lasiocarpa*); its diameter increment increases by several times (9). Many intermediate and suppressed black spruce in swamp stands, however, die after heavy cutting (21).

Black spruce has less ability than white spruce to overcome stagnation in even-aged stands because it develops a smaller range of crown classes. Heavy thinning in dense, middle-aged stands increases diameter increment but often decreases volume increment, probably because the site is not fully utilized (47).

Black spruce is often a postfire pioneer on both uplands and peatlands, and fire usually results in the immediate reestablishment of black spruce as long as a seed source is available. Black spruce often dominates fire-prone areas, such as upland ridges, because it produces seed at an early age (20). It also becomes dominant on poor peatland (bog) sites where it has little competition. Tamarack and black spruce are the first trees to invade the sedge mat in filled-lake bogs.

Postfire stands of black spruce are generally even aged. Uneven- to all-aged stands are almost absent in virgin forests because wildfires have been frequent and extensive enough to prevent their development on most sites. Such stands are common on bogs and

muskegs, however, where the average interval between fires is probably longer than on uplands. Closed stands that escape fire for more than 100 years usually become uneven aged when black spruce layerings fill the gaps created by deterioration of the overstory (17).

Black spruce grows more slowly than many of the trees and shrubs with which it is associated. Thus, it encounters substantial competition where these species are abundant, particularly when they reproduce from sprouts or suckers rather than from seed. Black spruce is fairly common as an understory tree in jack pine and lodgepole pine stands on dry sites, and succeeds the pines in the absence of fire or harvesting (12). Various mixtures of black spruce, white spruce, and balsam fir-plus northern white-cedar south of the boreal forest-eventually form the main stand on most well-drained sites supporting quaking aspen, paper birch, or balsam poplar. On the better peatland sites, black spruce is often overtopped by quaking aspen, paper birch, tamarack, black ash, or red maple for many years before it becomes dominant. Over much of its range, it is eventually succeeded by balsam fir and, to a lesser extent, northern white-cedar if undisturbed by fire (17).

Black spruce does not compete successfully with balsam fir, northern white-cedar, red maple, balsam poplar, and black ash after cutting in mixed stands on good peatland sites (12). Similarly, harvesting or other disturbances on well-drained sites often lead to high proportions of balsam fir, paper birch, quaking aspen, and balsam poplar, or shrubs (50). Speckled alder is a strong competitor following harvesting on good peatland sites. The spruce, however, is generally able to grow through the alder canopy after several years (50). In Newfoundland and parts of Quebec, there has been extensive conversion of black spruce stands to heathland, dominated by lambkill and Labrador-tea, following repeated fires.

Clearcutting in strips or patches is generally considered to be the best silvicultural system for managing black spruce (21,26,50). Satisfactory reestablishment of black spruce after clearcutting, however, requires an adequate source of reproduction and often some kind of site preparation, such as slash disposal. Uneven- or all-aged management is best applied on poor sites where stands are windfirm and have abundant layering (27).

Damaging Agents-Eastern dwarfmistletoe (*Arceuthobium pusillum*) is a destructive disease of black spruce in the Lake States and eastern Canada, but it appears less often in the West and is completely absent in northwestern Canada and Alaska (18).

In most areas, infection by mistletoe results in reduced vigor, clumped branches (witches' brooms), and deformed trees; but in some stands it may kill many trees. Successful control is possible by incorporating control methods in the silvicultural management (37).

Several rusts of the genus *Chrysomyxa* infect both the buds and needles of black spruce. The infection usually remains at low levels but occasionally becomes epidemic and causes defoliation, reduced vigor, and even death of seedlings, saplings, and trees. The cone rust (*Chrysomyxa pirolata*) often results in greatly reduced seed production but does not kill the tree.

Other diseases of black spruce include a needle cast fungus (*Lophodermium* spp.), which may cause defoliation and death in local areas; a yellow rust witches' broom (*Chrysomyxa arctostaphyli*); and a snow blight (*Lophophacidium hyperboreum*), which may cause extensive damage to black spruce growing in nurseries or young regeneration in the field.

White pocket rots of roots and stems, most commonly *Inonotus tomentosus*, occur in black spruce and may cause significant damage in some upland stands (4,54).

The spruce budworm (*Choristoneura fumiferana*) is one of the insects most damaging to black spruce, even though black spruce is less susceptible than red spruce (*Picea rubens*), white spruce, and balsam fir. Budworm defoliation for several years in succession may result in moderate to severe mortality. The budworm and several other insects often cause serious damage to the flowers or cones, resulting in reduced seed crops (50).

The European spruce sawfly (*Diprion hercyniae*) is an important pest in eastern Canada but has not invaded western portions of the range. The yellowheaded spruce sawfly (*Pikonema alaskensis*) and greenheaded spruce sawfly (*P. dimmockii*) occasionally defoliate black spruce but seldom cause serious damage over large areas. Occasionally, a buildup in populations of the spruce beetle (*Dendroctonus rufipennis*) in white spruce leads to invasion and death of black spruce, usually where the two species are growing together. The spruce bud midge (*Rhabdophaga swainei*) may affect height growth in black spruce under some conditions (7). *Monochamus* wood borers have been known to kill considerable numbers of trees in areas adjacent to strip cuts as a result of initial buildup of populations in logging slash (50).

Snowshoe hare may cause extensive damage to seedlings and saplings when populations of hare are high. Red squirrels gather cones in large quantities and give a peculiar clumped appearance to the top of the tree. Squirrels and microtines may consume a

large percentage of the seed supply in some areas during poor seed years.

Black spruce tops are often broken at a height of 3 to 6 m (10 to 20 ft) by snow and ice. In Alaska, one storm in 1967-68 broke 28 percent of the stems in a 160-year-old black spruce stand (46). Windthrow and breakage are two of the principal causes of mortality in black spruce stands in the Lake States; they must be considered when planning for harvesting black spruce stands.

Black spruce is easily killed by both ground and crown fires. It generally rates high in fire hazard, although many peatland stands have a low risk except during very dry periods (26).

Black spruce growing in peatlands is especially susceptible to changes in the water table, which sometimes occur naturally as the result of damming of small streams by beavers, but also result from increased or impeded drainage caused by road construction.

Special Uses

The principal commercial use of black spruce both in Canada and the United States is for making high quality pulp with balanced strength properties. It is also used for lumber, Christmas trees, and other products. Black spruce Christmas trees were harvested in considerable numbers from natural stands until fairly recently, especially on poor sites in Minnesota (26). Historically, black spruce has provided some highly specialized products, a few of which are still used occasionally: healing salves from spruce gum (exuded resin); beverages from twigs and needles; aromatic distillations from needles (42); and binding material ("wattape")-from long, split roots-for birchbark canoes.

The spruce grouse depends mainly on black spruce stands for food and cover (26). Birds with relatively high densities in black spruce stands during the summer include the ruby-crowned kinglet, magnolia warbler, Cape May warbler, and ovenbird. Birds such as the pine grosbeak, pine siskin, and crossbills commonly feed on black spruce seed.

Genetics

Genetic variation in black spruce is clinal, primarily along a north-south geographical gradient. Differences in photoperiod response, productivity, and survival rate have been shown to be related to the geographical area of seed origin. Although black spruce ecotypes related to upland and peatland sites have been reported from some areas, they have not

been recognized in several studies of black spruce variation. Seed zones should be recognized, but separation of seed by peatland and upland location is probably not necessary (30,31).

Hybrids between black spruce and red spruce are common, and introgressive hybridization between the two species has been reported in Nova Scotia, New Brunswick, and Quebec (14,32).

A natural hybrid between black spruce and white spruce found in northern Minnesota has been called the Rosendahl spruce (28). Intermediate forms between black and white spruce have been reported occasionally from other areas (41), but the genetic isolation of these two species must be nearly complete.

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