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Silvicultural Management of Black Spruce in Minnesota

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Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE

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Silvicultural Management of Black Spruce in Minnesota[1]

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[3] Maintained by the United States Department of Agriculture at University Farm, St. Paul, Minn., in cooperation with the University of Minnesota.

INTRODUCTION

Black spruce (*Picea mariana*) wood, like that of other spruces, has several inherent characteristics, especially its long fibers, light color, and relative freedom from resins, that make it unusually well suited to the manufacture of paper and other wood pulp products. The pulp and paper industry of Minnesota was, in fact, at first almost wholly dependent upon black spruce and the less abundant white spruce (*Picea glauca*) for basic raw material. New and improved methods now make it possible to use a great variety of other woods in the manufacture of wood pulp products, so that in recent years spruce made up only slightly over half of the pulpwood used by Minnesota mills. However, it is still the premium wood and standard of excellence (fig. 1). For this reason ways have been sought of managing and harvesting black spruce that will assure continuous future supplies.

F-380670

Figure 1.—Spruce pulpwood stacked in the storage grounds of a pulp and paper mill in Minnesota.

Perhaps the best evidence of the high esteem in which spruce is held by the wood-pulp industry is the price paid for it in comparison with other kinds of pulpwood. The Office of Price Administration in November 1942 established the following maximum prices [4] per cord [5] for peeled pulpwood in Minnesota, Wisconsin, and Michigan: Spruce $17, balsam fir (*Abies balsamea*) $14, jack pine (*Pinus banksiana*) $12, and poplar (chiefly quaking aspen *Populus tremuloides*) $9. Somewhat lower prices, but in the same general relationship, were set for "rough" or unpeeled wood. Subsequent upward revisions of the

[4] Price at rail shipping point or at mill if delivered by truck for 128 to 133 cubic feet of stacked 100-inch bolts.

[5] A standard cord is 128 cubic feet of properly stacked bolts. Throughout this report the term "cord" applies to that quantity of unpeeled wood, except that (1) mill consumption data for roughly the past 15 to 20 years includes partly 100-inch or 50-inch bolts scaled in cords of 133 cubic feet, and (2) approximately half of the mill consumption data are for peeled pulpwood which contains about 10 to 15 percent more solid wood than unpeeled pulpwood. Hence, an allowance of about 8 percent should be made in comparing consumption data with timber volume and growth figures.

maximum prices have preserved the same pattern with spruce commanding the top price.

Despite the substantially higher prices paid for spruce, the woodpulp industry was unable to procure adequate supplies of spruce during 1943 and 1944. At the same time production of aspen and jack pine pulpwood remained in reasonably good balance with the requirements.

The first pulp mill in Minnesota was established in 1889, but there are no records of the quantities of pulpwood used prior to 1909 when consumption of spruce was reported to be 47,000 cords (fig. 2). By 1923 it had risen to 271,000 cords after which it fell to 124,000 cords in 1930, and rose to 254,000 cords in 1942. Thus the use of spruce pulpwood in Minnesota has been strongly correlated with general business conditions. It should be noted that, in 1936 and later years, part of the pulpwood was imported from Canada—evidence that domestic supplies could not meet the demand.

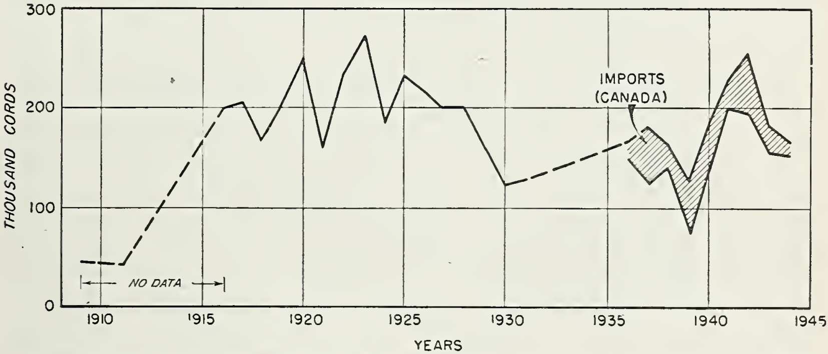

Figure 2.—Annual consumption of spruce pulpwood in Minnesota. It is estimated that 85 percent of this was black spruce. (Compiled from Bureau of the Census and U. S. Forest Service data.)

In addition to the spruce pulpwood that is consumed in Minnesota, large quantities are shipped to pulp mills in other States, particularly Wisconsin (figs. 3 and 4). In 1930 this amounted to 200,000 cords of pulpwood, chiefly spruce.[6] During the period 1936 to 1943, annual shipments of spruce pulpwood from Minnesota ranged from 44,000 to 110,000 cords.[7]

The spruce pulpwood volumes reported above include white spruce as well as black spruce. However, it is estimated that at least 85 percent of the spruce pulpwood produced in Minnesota comes from black spruce. The survey of forest resources of Minnesota made by the United States Forest Service between 1933 and 1936 showed that 82 percent of the cubic volume of spruce was black spruce. Some of the larger white spruce is cut into lumber, so it is unlikely that white spruce comprises more than 15 percent of the spruce pulpwood resources.

Black spruce seldom is cut into lumber because of its small size, except in box lumber operations where a limited amount sometimes is mixed with jack pine, balsam fir, white spruce, and second-growth

[6] Cunningham, R. N., and Moser, H. C. the forests of minnesota. U. S. Forest Serv., Lake States Forest Expt. Sta., 122 pp., illus. 1938. [Multilithed.]
[7] Data compiled by Lake States Forest Experiment Station.

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Figure 3.—Spruce pulpwood decked for shipment by rail north of Two Harbors, Minn. Most pulpwood produced in Minnesota is transported by truck to the nearest railway. Wood produced within 50 to 75 miles of the consuming mill is delivered directly by truck.

white pine (*Pinus strobus*) and sold as "northern pine." Small quantities of black spruce also are used for mine lagging, mine poles, fence posts, and farm construction work. However, the total amount used for all of these purposes is negligible compared with that cut for pulpwood.

F-415226

FIGURE 4.—Spruce pulpwood in the harbor at Grand Marais, Minn., ready for loading and shipment by boat to an out-of-State destination. Much of the region north of Lake Superior has no nearby railway facilities. Pulpwood from this district is transported by boats to Pennsylvania and Michigan, rafted across Lake Superior to Wisconsin, or trucked to railway loading points at or near Two Harbors and Duluth.

Black spruce is cut rather extensively for Christmas trees in Minnesota because of its abundance and ability to withstand rough handling and tight packing, as well as its straightness, symmetry, close branching, comparatively blunt needles, and dense foliage (fig. 5). It has one drawback, rapid shedding of the needles upon drying, which, however, can be corrected by standing the base of the tree in water (*23*),[8] or, as is done by some Christmas tree processors, by dipping or spraying the trees with a film of paint. In recent years, the annual cut of Christmas trees in Minnesota has amounted to about 2,600,000 trees (*26*). The majority of these were black spruce cut from swamps where growth is too poor to produce trees of pulpwood size.

It is clear that black spruce is a natural resource that should, if possible, be maintained at a high level of production. From the forest-management standpoint black spruce has another feature that makes it a valuable species. It is the chief one of the very few economically useful trees or other plants capable of growing reasonably well on more than two million acres of peat swamps in northern Minnesota. It is true that growth of black spruce is low in the swamps, but in the absence of this tree species many swamps are barrens.

[8] Italic numbers in parentheses refer to Literature Cited, p. 54.

FIGURE 5.—Black spruce Christmas trees cut from a nearby low-site swamp that is incapable of producing pulpwood. This load contains several thousand small "table trees" 30 inches in height. They were cut under the supervision of the Minnesota Forest Service from State-owned land. These Christmas trees are top sections from trees about 20 feet in height and 80 years of age.

Black spruce is able to grow also on upland soils where frequently it forms one of the important components in variously mixed stands.

The Lake States Forest Experiment Station has been studying the reproduction, growth, silvicultural requirements, and harvesting of black spruce since 1932. The bulk of the experimental work has been conducted within the Superior National Forest in northeastern Minnesota but a considerable amount also has been carried out elsewhere in northern Minnesota, particularly in Koochiching County in cooperation with the Minnesota State Forest Service. These studies are the basis for this report.

RANGE AND OCCURRENCE

Black spruce has an exceedingly wide natural range, being one of the very few North American conifers that reaches from the Atlantic Ocean to the Pacific Ocean. It occurs in Newfoundland and within practically all of the forested portions of Canada, except the western and southern parts of British Columbia and the southern part of Alberta (*27*). Only a small fraction of the natural range lies within the United States. In the eastern States, where black spruce extends as far south as West Virginia in the Appalachian Mountains, it is of little commercial importance. It is relatively much more abundant in the northern portions of Wisconsin, Michigan, and particularly Minnesota.

The natural distribution of black spruce in Minnesota is rather well depicted by figure 6, which shows the original coniferous swamp forests. Black spruce was the principal tree species in the majority of these swamps. Of course, some of the swamps were stocked with tamarack (*Larix laricina*), some with northern white-cedar (*Thuja occidentalis*), or with various mixtures of black spruce, tamarack, white-cedar, and balsam fir. Black spruce probably did not extend quite to the extreme southern and western outposts as shown on the map.

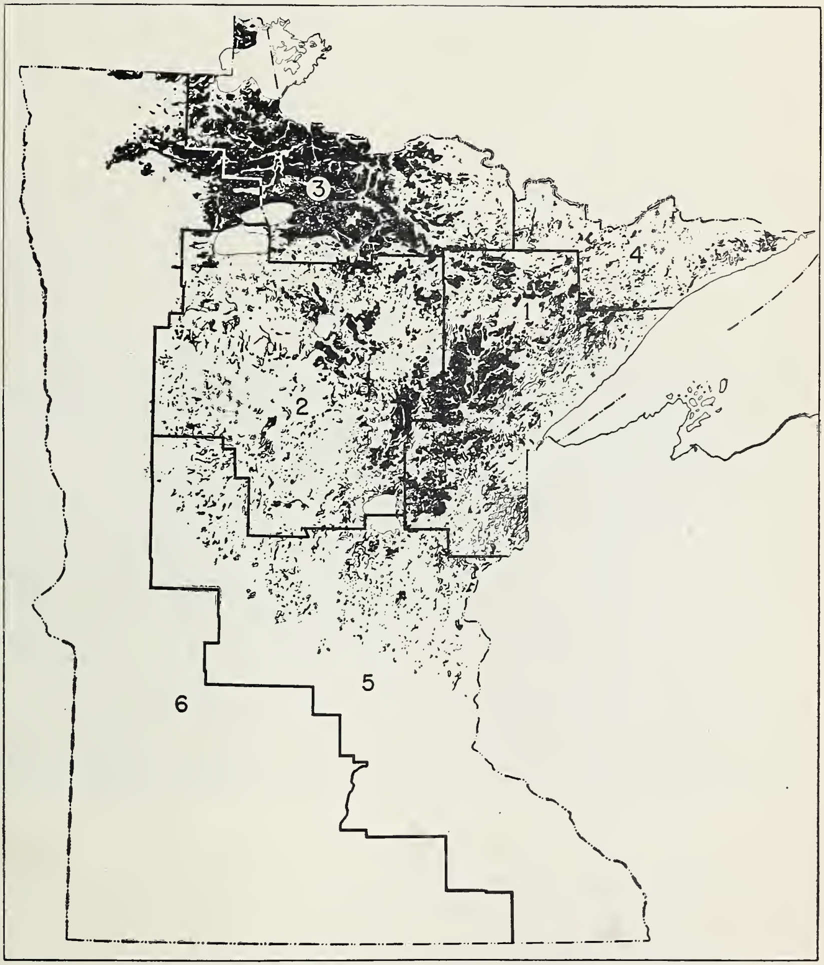

FIGURE 6.—Original coniferous swamp forests in Minnesota. Forest Survey units: (1) Cloquet, (2) Central Pine, (3) Rainy River, (4) Superior, (5) Central Hardwood, (6) Prairie. (From a map compiled from General Land Office field notes by F. J. Marschner, Bureau of Agricultural Economics, U. S. Department of Agriculture.)

The area of the original conifer-forested swamps in Minnesota has been estimated to have been 6,000,000 [9] acres. In addition, the original forests were estimated to include 6,300,000 acres of the so-called spruce-fir type. Black spruce occurs rather generally in this type.

Present Area and Volume

Land clearing for agriculture, logging, and indiscriminate burning have greatly reduced the area and volume of black spruce timber (fig. 7). In 1934 only about half of the original coniferous swamp supported a forest type similar to the original forest, and only one-sixth of the original spruce-fir type could still be so classified (table 1).[9] In the coniferous swamp type 1,529,800 acres were classified as having a cover mainly composed of black spruce. Until the deforested and aspen-covered swamps are restored to black spruce—a very slow process at best—the timber in the remaining 1½ million acres of black spruce swamp, together with the black spruce timber intermingled in the spruce-fir type, must serve as the principal Minnesota source of black spruce wood.

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Figure 7.—Burned out peat land in northern Minnesota.

It was estimated in 1934 that Minnesota had 5,429,000 cords of merchantable black spruce pulpwood—i. e., trees large enough to produce two 100-inch bolts to a 4-inch top inside bark—distributed in Forest Survey economic units as follows: (1) Cloquet, 305,000; (2) Central Pine, 398,000; (3) Rainy River, 1,911,000; (4) Superior, 2,653,000; (5) Central Hardwood, 17,000; and (6) Prairie, 145,000. The great bulk

[9] See footnote 6, p. 3.

of this—over 5 million cords—was situated in a comparatively narrow band in the northernmost part of the State. These districts are thinly settled and, to a large degree, poorly accessible. During the 10 years subsequent to 1934, roughly 2 million cords of black spruce have been cut for pulpwood, and there have been appreciable losses caused by fire, wind, snow, glaze, decay, drought, and senility. To some extent the depletion has been offset by growth, but the net result has been a substantial reduction in supplies of merchantable timber. The most recent Forest Survey estimate (1945) indicates a volume of 4,400,000 cords.

TABLE 1.—*Status of original coniferous swamp and spruce-fir types in 1934* [1]

Status or cover in 1934	Original forest type	
	Coniferous swamp	Spruce-fir
	Thousand acres	*Thousand acres*
Nonforest use	900. 4	1, 978. 3
Deforested	1, 608. 3	617. 5
Aspen	260. 9	2, 615. 9
Spruce-fir		1, 088. 3
Coniferous swamp:		
Black spruce	1, 529. 8	
Cedar	380. 6	
Tamarack	656. 9	
Nonproductive [2]	763. 1	
Total	6, 100. 0	6, 300. 0

[1] See footnote 6, p. 3.
[2] Stands of spruce or tamarack in which it is estimated that trees will not attain a 5-inch d. b. h. by the age of 100 years.

DESCRIPTION OF STANDS AND GROWING CONDITIONS

SWAMPS

Black spruce occurs most commonly in peat swamps (fig. 8). On such sites in Minnesota it usually is found in nearly pure stands although it also grows in mixture with a number of other species. Tamarack was once a very common associate, but is much less abundant now as the result of devastating attacks by the larch sawfly (*Pristiphora erichsonii*) about 1910 to 1915. Mixtures containing northern white-cedar occur, although black spruce and white-cedar tend to segregate into different types of swamps. Almost all black spruce swamp forests contain a light sprinkling of balsam fir and paper birch (*Betula papyrifera*).

The swamps of Minnesota, in which black spruce and associated tree species grow, can be found in many stages of development. They range from the relatively primitive ones with excessively wet, poorly decomposed peat where black spruce is barely able to survive, up to the more mature ones having drier, humuslike, surface peat where growing conditions for spruce seem to be similar to those on moist mineral soil.[10] The natural development of the peat has also been disturbed repeatedly and extensively by a number of factors, both natural and man-caused, including forest fires, and raising or lowering of the water tables. Therefore, swamps are exceedingly complex and diverse formations as to site quality for the growth of black spruce or other trees. No other native Minnesota tree, except tamarack, can endure such a wide range of growing conditions as that regularly exhibited by black spruce in different swamps or different parts of the same swamp.

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FIGURE 8.—Black spruce stand in a swamp. The wide right-of-way is caused by an agricultural drainage ditch at the right. The ditch has been abandoned, as have many similar ones in Minnesota.

The characteristic pattern of productivity in swamps is for the best growth to be at the border and progressively poorer growth toward the center. Unless the slope of the adjoining upland is abrupt, there usually is a border transition zone which is neither true upland nor true swamp. In northeastern Minnesota the swamp border types sometimes are as much as 30 or 40 acres in size. In such instances they commonly are underlain with boulders. Almost invariably the best growth occurs in this band of "swamp border." The decline in growth rate toward the center of a swamp may be steplike or regular, slow or fast. In small pocket swamps, which are common in northeastern Minnesota, the average heights of dominant trees about 80 years in age often range from 60 feet down to 20 feet within a distance of 150 feet. In larger swamps, the transition in site quality ordinarily

[10] The term "swamp" is used throughout this paper to include all peat forming areas, as has been advocated by Waksman (*29*), in the belief that attempts to differentiate between swamps, bogs, muskegs, moors, etc., are inexact and confusing.

is much more gradual. For example, on three plots taken at intervals of about 300 feet in a 140-year-old stand in Koochiching County, dominant trees were found to have average heights of 68 feet, 52 feet, and 24 feet.

Changes in productivity of site from place to place within a swamp usually can be associated with some discernible physiographic condition such as depth of peat, or drainage, but no satisfactory method has been worked out for accurate determination of the productivity of swamps except by measurement of the trees. Merchantable stands[11] most often are found on peat less than 2½ feet in thickness, less often on peat 2½ to 5 feet in thickness, and occasionally where the peat is 18 or 20 feet deep. Some attention was given to the possibility of finding associated plants that would serve as indicators of site quality but none were detected.

The actual average volume of pulpwood per acre found over any considerable area is small, due to the inclusion in the statistical compilations of many poorly stocked and comparatively low site swamps. For example, in the Rainy River district, the average volume per acre in the 3- to 9-inch or "cordwood" size-class in 1934 was as follows:

Species:	*Cords*[1]
Black Spruce	7.6
Tamarack	.8
Northern white-cedar	.7
Others[2]	.6
	9.7

[1] Volume in trees 5.0 inches d. b. h. and over to a 4-inch top diameter inside bark.
[2] Chiefly balsam fir, paper birch, and quaking aspen.

Well-stocked stands of cordwood size, of course, contain much larger volumes than the average given above—up to about 35 cords per acre.

UPLANDS

Black spruce occurs to some extent in practically all upland forest types in northern Minnesota, but generally is of little importance except in the mixed forests classed as spruce-fir type. For the State as a whole, black spruce constitutes about 7 percent of the volume in trees 5 inches and larger d. b. h. in the spruce-fir type. In northeastern Minnesota there are occasional nearly pure stands of black spruce on the rock outcrop formations of the Laurentian Shield and the species often is present in considerable numbers in the jack pine type (fig. 9). For example, on the Kawishiwi Experimental Forest near Ely, Minn., 6 percent of the area was classed as upland black spruce type. Eight percent of the merchantable volume in jack pine types on the experimental forest was black spruce.

When black spruce is found growing in mixed forests, it usually is smaller in size than its associates, such as paper birch, quaking aspen, and jack pine. However, the principal components of these stands, including the black spruce, are even-aged.

[11] Under current logging practices in Minnesota, spruce pulpwood seldom is cut unless at least 4 or 5 cords per acre can be taken mainly from trees that will yield two or more 100-inch bolts to a top diameter of 3 inches inside bark.

F-290076

FIGURE 9.—Nearly pure stand of 65-year-old black spruce growing on upland in northeastern Minnesota. This stand contained 25 cords per acre in trees over 5.5 inches d. b. h.

TRENDS IN FOREST SUCCESSION

Considerable information has been gained concerning the possibilities of black spruce for forest management by studying its development under natural conditions and its responses to destructive agents, such as fire and logging. Some factors aid its perpetuation and others definitely retard it.

Succession in Natural Stands

SWAMPS

Black spruce occupied extensive areas of swamp prior to settlement and logging in Minnesota, chiefly because very few other tree species were adapted to the poorly drained peat soils. This was quite the reverse of the situation on uplands, where trees of many kinds grow vigorously and display rather definite patterns of ecological succession.

Black spruce is one of the first trees to invade primitive treeless swamps, although it usually is slightly preceded by tamarack. Black spruce also generally continues as the dominant kind of vegetation in swamps through later stages when the peat soil is gradually elevated by the further accumulation of organic matter and fertility conditions are improved. In these more mature stages of swamps in Minnesota, there is some increase in the occurrence of balsam fir and paper birch, but they seldom are of importance. Black spruce and its generally less numerous associate tamarack form a remarkably stable forest type with no effective competitors over a wide range of conditions of peat swamps.

In some swamps tamarack seems to become established more readily than black spruce. Although the fundamental reason for this difference is not apparent, tamarack sites in their most distinct phases almost always can be distinguished by a rather abundant occurrence of speckled alder (*Alnus incana*) in contrast to black spruce sites that have shrubby vegetation composed mainly of heath plants, the most common of which are leatherleaf (*Chamaedaphne calyculata*) and Labrador tea (*Ledum groenlandicum*). Gradations between spruce and tamarack sites are common. Black spruce grows well on tamarack sites but does not become established readily. The distinction is important because it accounts for many of the examples where spruce has failed to regenerate on deforested or poorly stocked swamp land.

There is another class of swamps in which black spruce occurs but where northern white-cedar predominates. Since white-cedar is unable to endure as acidic soil conditions (*7*), it is rather sharply limited in occurrence. White-cedar is longer-lived and more shade-tolerant than black spruce; accordingly, black spruce has little chance of reproducing under natural conditions in swamps where vigorous white-cedar is present.

UPLANDS

In the spruce-fir type, where black spruce occurs most frequently on upland soil, almost all native tree species are present to some extent, but balsam fir, paper birch, quaking aspen, and white spruce are most common. It was concluded by Cooper (*9*) that on Isle Royale, Lake Superior, balsam fir, paper birch, and white spruce together formed the dominant elements of the plant association that succeeded all other tree species under natural conditions. More recently, Lee (*24*) in studying forest successions at Lake Itasca, Minn., decided that balsam fir and white spruce would form the climax forest in that locality.

It is significant that black spruce has not been considered a member of the climax forest. It indicates that black spruce has less natural ability for self-perpetuation in the spruce-fir type than it has in swamps.

In northeastern Minnesota where black spruce frequently grows in mixture with even-aged stands of jack pine on loamy soils, the majority of the spruce trees, although smaller, are of the the same age as the jack pine. Not infrequently there is a fair stocking of black spruce reproduction. It is believed that in such stands, when the jack pine succumbs to old age, it will be replaced by black spruce, white spruce, balsam fir, and paper birch (*11*).

The Effect of Forest Fires

Swamp forests ordinarily are not subject to fire but during drought periods when water levels are low they can burn very fiercely, and when they do spruce timber is killed almostly entirely. Peat samples containing charcoal, sometimes in different strata, have been found at widely scattered points throughout northern Minnesota, showing that fires occurred in swamps long before this region was settled by white men (*28*).

A rather surprising characteristic of black spruce is its ability to regenerate promptly and abundantly after forest fires (*3*, *18*, *25*). This is accomplished in a manner not unlike that in which jack pine reproduces itself. The serotinous and persistent cones are largely

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Figure 10.—Close-up view of fire-blackened but still sound cones.

situated near the tips of the trees where they are least likely to be consumed by the flames from a forest fire (figs. 10 and 11). After a forest fire, the seeds fall from the cones to the soil where competing vegetation and much of the dry litter has been destroyed.

A large quantity of seed is stored in the serotinous cones of black spruce. Collections made in stands near Ely, Minn., over a period of 4 years showed that usually half or more of the viable seeds still remained in the cones 1 year after the cones have ripened (table 2). It has been found in Ontario that about 40 percent of the seeds were

F-372672

FIGURE 11.—Fire-killed stand 2 years after burning. This swamp stand has reproduced successfully from seeds stored in the clusters of serotinous cones at the tops of the trees. The young seedlings are too small to be visible in the picture.

present in the cones 2 years after ripening, but less than 2 percent at the end of 3 years.[12] Thus, whether or not the seed crop for the current year is abundant, there is likely to be a rather large quantity of

[12] MILLAR, J. B. THE SILVICULTURAL CHARACTERISTICS OF BLACK SPRUCE IN THE CLAY BELT OF NORTHERN ONTARIO. 1936. [Unpublished thesis, University of Toronto.]

seed stored on the trees. Observations extending over a period of 12 years indicate that total seed crop failures are infrequent, and failures for as many as 2 or 3 successive years are likely to occur only rarely.

It has been observed that by striking recently fire-killed trees with an ax large numbers of seeds can be shaken from the scorched and dried cones. Recent instances of the regeneration of black spruce stands following fires are numerous throughout northern Minnesota.

TABLE 2.—*Viability of seed and number of viable seeds per acre in newly ripened and 1-year-old black spruce cones*

Year of collection [1]	Viable seeds per acre		Viability [2]	
	New cones	1-year-old cones	New cones	1-year-old cones
Swamp Stand				
	Number	*Number*	*Percent*	*Percent*
1936	194, 648	125, 548	52	38
1937	292, 909	238, 097	76	76
1938	51, 583	91, 094	63	62
1939	181, 521	92, 794	69	90
Average	180, 165	136, 883	65	66
Upland Stand				
1936	1, 651, 284	384, 253	64	50
1937	281, 542	392, 311	75	84
1938	595, 132	371, 750	81	73
1939	95, 999	183, 330	78	89
Average	655, 989	332, 911	74	74

[1] Cones gathered in September or October. Each collection included the cones from 25 trees selected to represent all crown and size classes in the stand. Since it was necessary to cut the trees to gather the cones, a new sample was taken each year.

[2] Germination in 16 to 32 days.

Black spruce has regenerated extensively following fires on both uplands and swamps. Although fire is not necessary for the reproduction of spruce in swamps, the exposed moist peat surfaces and the temporary absence of competing vegetation are conditions especially favorable for reseeding. Fires account for the large areas of even-aged black spruce swamp forests, including some areas where otherwise it appears that white-cedar or tamarack will replace the spruce. The presence of black spruce in even-aged upland stands, either pure or in association with other species, is explained by its specialized method of reseeding after forest fires.

It has been stated that the best stands of black spruce in Quebec and Ontario have arisen after forest fires (*3*, *25*) and the same seems to be true in Minnesota. Old stands in swamps that have not been rejuvenated by fire usually support less timber than do somewhat younger stands. The ground is covered by a dense growth of Labrador tea which hinders reproduction. Furthermore, there is often a general infestation of dwarf mistletoe (*Arceuthobium pusillum*) which stunts and deforms the trees. Fire is, of course, an effective means for controlling dwarf mistletoe because, as Weir (*30*) has pointed out, the mistletoe can spread only by seeds from plants growing on living hosts.

F–325884

FIGURE 12.—Black spruce does not regenerate after slash fires in clear-cut areas because the seeds in the cones and on the ground are consumed by the intense and prolonged heat. An upland stand of black spruce with some paper birch and aspen in mixture. All of the spruce and the larger birch were cut. The slash burned accidentally soon after logging.

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The essentially even-aged character of the overstory in stands that originated after fires often is obscured by later reproduction which intensified the density of stocking in lightly stocked areas and filled in unstocked spots.

Despite the ability of black spruce to regenerate when seed-bearing stands are burned, it does not reproduce after slash fires in clear-cut areas because the seed on the ground and in cones in the slash piles is consumed (fig. 12).

The Effect of Logging Practices

The method commonly employed in cutting spruce for pulpwood has considerable influence upon spruce regeneration in swamps. Although some new mechanical logging devices are now undergoing trial and development, the ordinary method differs little in essential principles from that used by pulpwood cutters 40 or 50 years ago.

The unit working area is the cutter's "strip," which is 60 to 80 feet in width and several hundred feet in length. The pulpwood cutter fells the merchantable trees within the strip, trims them, saws them into 100-inch bolts.[13] The bolts are then carried by hand to an 8- to 10-foot wide skid road that is cut through the center of the strip. The cutter clears the skid road as cutting progresses.

In order to keep effort to the minimum, the cutter fells the trees in directions that will (1) minimize carrying of the bolts and (2) avoid throwing tops and limbs into the cleared skid road. As a result, the tops and limbs accumulate in rather regular windrows 20 to 30 feet in width and up to 6 feet in depth along both sides of the skid road (fig. 13).

F–400363

Figure 13.—Clear-cutting operation in a black spruce swamp. The logging debris—tops, limbs, and bark—make much of the ground surface unfavorable for reseeding.

[13] Some mills require 96-inch bolts, one mill 50-inch bolts.

Cutting may be done at any season of the year but the bulk of it is performed in the periods November 1 to January 31 and May 10 to July 31. Peeled pulpwood is produced only during the latter period. Most of the bolts are peeled, for convenience, in the skid road and the sheets of bark are dropped there where they often form an almost continuous carpet.

Within the skid roads, which occupy 10 to 15 percent of the logging area, all trees large and small are destroyed by the clearing, but the leveling, trampling, and skidding make the surface favorable for germination and establishment of seedlings. However, if the bolts are peeled and the bark is thrown on the ground, this carpet seriously interferes with reproduction.

In the area between the skid roads, a good many of the unmerchantable smaller trees are cut, broken off, or otherwise damaged. Much of the damage is needless. Seedlings and saplings up to 6 feet in height often are bent down and smothered by the tangled mass of tops and limbs. Wherever the accumulation of branches is heavy, the spruce needles which quickly drop from the twigs make a coarse, dry layer of material that is decidedly unfavorable for the establishment of seedlings.

Despite the extensive damage to advance reproduction and the unfavorable reproduction conditions created over much of the area, black spruce is persistent and prolific. The result is that most cut-over areas regenerate rather well if they are not burned. A survey made in northeastern Minnesota in 1931 of cut-over spruce swamps showed that four-fifths of the areas were reasonably well stocked with black spruce.[14] O nthe average, 66 percent of the milacre quadrats examined had one or more black spruce trees present.

Pulpwood logging on upland follows the same general system as in swamps. However, black spruce in upland types tends to be replaced by other species subsequent to logging (table 3).

TABLE 3.—*Effect of clear cutting on black spruce reproduction in mixed upland forest in northeastern Minnesota*

Species	Trees per acre	
	Overstory stand before cutting [1]	Reproduction 3 years later [2]
	Number	*Number*
Black spruce	135	[3] 0
Jack pine	265	409
Paper birch	33	500
Aspen	23	1,000
Total	456	1,909

[1] Trees over 3.5 inches d. b. h.
[2] Basis, 40 milacre quadrats.
[3] The initial reproduction included 192 black spruce seedlings per acre but these were killed by a severe drought. Ordinarily some can be expected to survive.

[14] United States Forest Service. How to cut black spruce. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Notes 54, 1 p. May 1932. [Mimeographed.]

CONDITIONS AFFECTING REGENERATION

The ease and certainty with which a species regenerates are considerations of paramount importance in forest management. Hence, the ability of black spruce to reproduce and the requirements controlling reproduction have been studied in detail.

SEED SUPPLY AND DISSEMINATION

The seeds in black spruce cones in the absence of fire are not all freed for 2 or 3 years after ripening[16] (*18*). It has been established by means of seed trap collections that during this period the seeds are disseminated slowly throughout practically the entire year (table 4). This slow rate of dissemination has the effect of assuring that a considerable amount of freshly deposited seed is almost always present on the ground. It also provides for some scattering of seed practically every year regardless of the success of the current seed crop. The annual seed fall for a 5-year period in an upland stand is shown below. Comparison of these data with those on seed production (table 2, column 2, upland stand, p. 16) shows that there was substantially less fluctuation in annual seed fall than in annual seed production.

Year:	*Seeds per acre, number*
August 1, 1934–July 31, 1935	286, 222
August 1, 1935–July 31, 1936	198, 224
August 1, 1936–July 31, 1937	439, 110
August 1, 1937–July 31, 1938	265, 312
August 1, 1938–July 31, 1939	227, 328

TABLE 4.—*Black spruce seed fall in upland and swamp stands, by months, in northeastern Minnesota*

Period	Average fall of seeds per acre [1]			
	Upland		Swamps	
	Number	*Percent*	*Number*	*Percent*
August	21, 602	7	16, 050	9
September	44, 998	14	36, 483	19
October to April and monthly average	130, 151	41	71, 433	38
	(18, 593)		(10, 205)	
May	42, 486	14	24, 067	13
June	43, 590	14	26, 667	14
July	30, 262	10	13, 017	7
Total	313, 089	100	187, 717	100

[1] Basis, 33 seed traps 3.3 feet square, for periods of 3 to 5 years. Two germination tests with different lots of seed both showed a viability of 31 percent.

Undoubtedly some black spruce seeds are carried by the wind or driven along the surface of hard-packed snow for considerable distances, but the great majority of them come to rest surprisingly close

[16] See footnote 13, p. 15.

to where they were produced. In one test it was found that hardly any were blown 300 feet into a clearing from the edge of a forest (*18*). The distribution of seeds in a 100-foot cleared strip and in adjoining uncut black spruce timber is shown in figure 14. Near the center of the strip, only 50 feet from the timber, seed fall was about one-third as much as that 50 feet inside the stand.

Black spruce cones rather frequently are found to have been damaged by insects. The small yield of seed from upland trees in 1939 (table 2) was at least partly the result of extensive insect damage to the cones. The insects had departed before the cones were collected and hence could not be indentified. The cones also are commonly gathered by red squirrels (*Sciurus hudsonicus*). Large masses of chewed and separated cone scales accumulate around stumps and logs where squirrels have a habit of extracting the seeds. When squirrels gather black spruce cones, they clip off entire twigs with the cones attached. Sometimes this results in a considerable amount of pruning near the tops of the trees where the cones are borne. Examinations of the upper portions of numerous trees has shown that the characteristic "bunchy" appearance of black spruce tops (fig. 15) is caused by such pruning. This has been observed in Ontario [16] as well as in Minnesota.

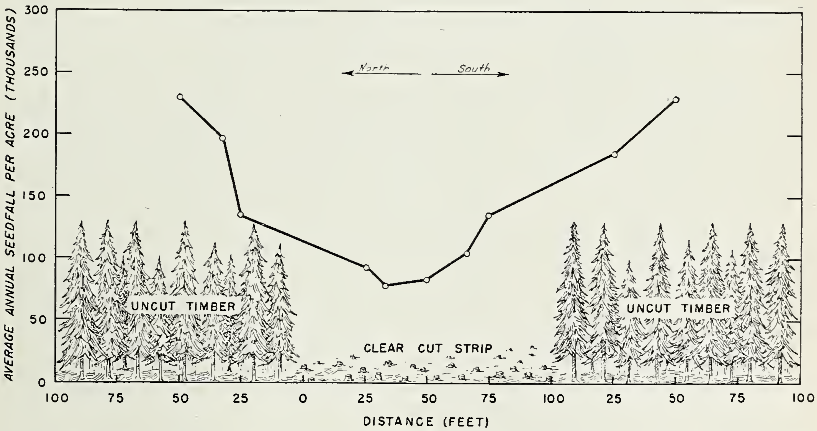

FIGURE 14.—Dispersal of black spruce seed into a cleared strip from adjoining uncut timber. Kawishiwi Experimental Forest, August 1, 1934 to July 31, 1939. The prevailing wind, which is from the southwest, accounts for slightly greater drift of the seed toward the north.

GERMINATION AND ESTABLISHMENT OF SEEDLINGS

Black spruce germinates rather promptly when temperature and moisture conditions are favorable. Seeds sown in a nursery seedbed in July and covered with one-eighth inch of sand commenced to germinate on the tenth day and practically completed their germination on the nineteenth day. Under natural conditions where moisture is likely to be less continuously available, germination is considerably slower. In a test designed to determine the relationship between date of seed fall and date of germination, seeds were sown in a freshly clear-cut

[16] See footnote 13, p. 15.

F-372687

FIGURE 15.—Eighty-year-old black spruce stand showing the characteristic "bunchy" appearance of the tops which results from pruning by squirrels.

area on torn-up duff surfaces shaded with sticks to simulate light logging slash. The results were as follows:

Time of sowing:	*Main period of germination*
May 1	June.
May 15	June–July.
June 1	June.
June 15	July.
July 1	July.
July 15	July–August.
August 1	August.
August 15	October and May.
September 1	May.
October 1	May.
November 15	May.

Germination and early survival under natural conditions are strongly influenced by the kind of soil surface material. On a recently cleared upland forest in northeastern Minnesota, mineral soil, from which vegetation and organic materials had been stripped, was found to be the best of four kinds of surfaces that were tested, and natural undisturbed duff the poorest (table 5) (*20*).

TABLE 5.—*Germination and early survival of black spruce in relation to soil surface on a loamy upland soil, northeastern Minnesota*

Soil surface	Germination	First-year survival in terms of—	
		Seedlings germinated	Seed sown
	Percent	*Percent*	*Percent*
Mineral soil	47	66	31
Scarified and shaded duff	30	19	6
Burned duff	30	15	4
Undisturbed duff	9	8	1

The same principles apply in swamps although the surface materials are quite different. Peat that has been exposed either mechanically or by burning makes a very favorable seedbed if its surface is not subject to flooding. The effect of the removal in various ways of a heavy cover of Labrador tea and sphagnum moss in a swamp having only a scattered overstory of trees is shown below. The seedlings originated from natural seed fall.

Treatment:	*Seedlings per acre after 6 years,[1] number*
None	0
Shrubs cut with brush hook	544
Shrubs uprooted by pulling	3, 049
Shrubs, litter, and mosses stripped off with hoe	8, 385

[1] Trees present when plots were established are not included. Basis, 16 plots each 10 by 10 feet.

Rotten wood is a good medium for seedling establishment and in some swamps is sufficiently abundant to be a considerable aid (fig. 16).

F-377813

FIGURE 16.—Vigorous 3-year-old seedlings, up to 12 inches in height, established on rotten wood the summer following clear-cutting of the original stand. Sphagnum moss also has invaded the area but cannot engulf such fast-growing seedlings.

The common hypnum moss (*Calliergon schreberi*) which often forms as almost continuous ground cover under densely stocked merchantable black spruce stands, both on uplands and in swamps, creates a dry, poorly decomposed organic layer that practically precludes establishment of seedlings. However, this moss can exist only under heavy overhead shade, and it quickly disappears when the timber is thinned or clear-cut.

F-372658

FIGURE 17.—Several types of sphagnum mosses collected on the Kawishiwi Experimental Forest. They illustrate the great variation in rates of height growth among sphagna. The tallest one at the right is approximately 7 inches high.

Sphagnum mosses (*Sphagnum* spp.), of which there are several distinct kinds in spruce swamps (fig. 17), occur in places that are too wet for hypnum, in openings in stands, and most abundantly in deforested or thinly stocked areas. Although seeds frequently germinate on the moist live sphagna, the seedlings seldom survive for long because they are engulfed by the faster growing mosses. There is, however, one kind of sphagnum that grows much slower than the others on which seedlings may become successfully established.

After a swamp stand has been thinned, cut clear, or burned, sphagnum mosses quickly invade and cover hummocks of moist peat and decayed stumps. These sphagna are the smaller varieties. They do not appear to offer too serious competition to the black spruce seedlings that germinate on the same places. One or 2 years later the taller, faster growing varieties commence to invade the wetter parts of the swamp surface. These spread rapidly and soon cover small plants, including many spruce seedlings, shorter varieties of sphagna, and slash. Thus, the most favorable time for successful establishment of seedlings is the first year after the opening of the stand.

Black spruce usually becomes successfully established somewhat more readily in clearings than under tree cover (*20*). In a test based on 128 small artificially sown plots, ten two-year-old seedlings were produced per 100 seeds in a recently cleared area in comparison to 7 seedlings of the same age under a moderate cover of jack pine, black spruce, and aspen. In this respect, black spruce differs somewhat from white spruce and balsam fir that seem to be benefitted more by partial shade (table 6). Of course, during years of severe drought such as 1936, small shallow-rooted black spruce seedlings in clearings are largely destroyed (table 3).

TABLE 6.—*Establishment of black spruce, white spruce, and balsam fir seedlings under partial tree cover and no tree cover*

Tree cover	5-year-old seedlings [1]		
	Black spruce	White spruce	Balsam fir
	Number	*Number*	*Number*
None	118	107	103
Thinned to 40 percent of original stand [2]	72	170	149

[1] Basis, 400 seeds for each table entry. Seeds dropped on freshly scarified mineral soil. No artificial watering or weeding.

[2] Timber overstory predominantly jack pine with some black spruce and aspen.

Studies of reproduction in northeastern Minnesota have revealed that insects sometimes destroy the tiny new seedlings and some losses are caused by frost-heaving on mineral soil and ashes, but no direct injury by frost was discovered. Black spruce begins its shoot growth in the spring about 7 to 10 days later than white spruce.

Black spruce seedlings grow most rapidly when they are wholly free from vegetative competition (*20*). Seedlings on upland soil that

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had been kept continuously weeded average 12 inches in height at 3 years. Seedlings of the same age on unweeded plots under partial tree cover averaged 3 inches. Early growth in the better quality swamps is at about the same rates under corresponding degrees of cover.

Reproduction by Layering

Black spruce propagates by layers as well as by seed (*8*). Some writers have, in fact, advanced the opinion that reproduction by means of layers is more common than by seed (*17*, *3*). Although there is no question that layers are common, the widespread occurrence of stands of fire origin, where seed is the sole means of reproduction, gives cause for doubting that layers are more abundant than seedlings. Even in typical mature pulpwood stands, seedlings outnumber layers although the layers are of somewhat larger average size and hence have comparatively better chances for survival (table 7).

Table 7.—*Comparative abundance of seedlings and layers, by height class in a mature stand of black spruce in a swamp on the Kawishiwi Experimental Forest, northeastern Minnesota*

Height class (feet)	Reproduction per acre		
	New seedlings	Older seedlings	Layers
	Number	*Number*	*Number*
0	133	3, 517	83
1	0	633	283
2	0	183	33
3	0	50	17
4	0	50	0
5+[1]	0	100	117
Total	133	4, 533	533

[1] 4.6 feet up to 3.5 inches d. b. h. Actual average height about 10 feet.

Layers are capable of developing into well-formed vigorous trees when they are released (fig. 18). In understocked stands where live branches persist near the bases of the trees layers are of some significance in increasing the density of the forest. On uplands, layers are more common on the drier sites and shallower soils than on moist soils where competing vegetation shades out the lower limbs on spruce trees.

In open stands of young trees it would be possible to encourage layering by weighting down low-hanging branches with sticks or a shovelful of earth or peat. However, for forest management practices in general, seedling reproduction has much wider application for several reasons: (1) their ability to reproduce at a distance from the parent, (2) their tendency to establish themselves rapidly, and (3) the fact that they occur much more frequently than layers.

F-377810

FIGURE 18.—Black spruce layers that originated from stumps in foreground. The "Mother" trees were felled 6 years previously. The young trees are now growing vigorously.

GROWTH AND YIELD

Black spruce is a small and slow-growing but moderately long-lived tree (fig. 19). A height of 85 feet is exceptionally tall for this species in Minnesota and diameters seldom exceed 17 inches at breast height. The greatest ages attained are about 250 years. However, most trees are considerably shorter, smaller in diameter, and younger than these near-maximum figures. Typical merchantable trees are 40 to 65 feet tall, 6 to 12 inches d. b. h., and 60 to 150 years old.

The height growth rate of upland black spruce while young is slower than those of its common competitors but a little faster than that of white spruce. In a planting experiment using 2-year-old seedlings, on the Kawishiwi Experimental Forest, black spruce and white spruce had average heights of 1.9 and 1.4 feet respectively 4 years after field planting. In an 18- to 20-year-old mixed natural stand in the same locality, the average height of the black spruce was 9 feet and the white spruce 8.1 feet. Many of these trees had been overtopped by aspen and birch of the same age. The tallest individual black spruce was 21.5 feet in contrast to 14.5 feet for white spruce. After the age of 20 years, white spruce gradually catches up with and finally outstrips black spruce on upland soils. At the age of 70 years, white spruce is likely to exceed black spruce in height by about 10 or 15 feet.

Growth of unsuppressed trees at early ages in the more fertile swamps is only slightly slower than on typical upland sites. Numerous counts of annual rings at d. b. h. and at the ground line have shown an average difference in age of 13 years. Under heavy shade or on poor sites height growth is much slower; it is not at all unusual to find seedlings 15 years old that are only 6 to 12 inches tall.

F-372659

FIGURE 19.—A typical mature swamp-grown black spruce. Height 65 feet, d. b. h. 10 inches, age about 120 years.

In well-stocked stands on average sites some trees reach 5 inches d. b. h., the minimum merchantable size, in about 50 years. Thereafter, diameter growth continues at a fairly steady rate for 60 to 80 years or more on the trees that are not seriously crowded or suppressed by their neighbors (*19*). Crowded trees continually succumb to competition, and such trees, of course, have diminishing rates of growth.

A peculiarity of swamp black spruce is that ring counts made at ground level oftentimes do not reveal total age (*22*). This is due to the continual raising of the peat surface by accumulation of litter, which results in development of adventitious roots on the stem above the original root crown. Sometimes several successive strata of roots can be detected. The number of annual rings that are "buried" in this manner is variable, but may amount to 20 years on the slower growing trees. It accounts for some of the seeming variation in ages in stands that are actually even-aged.

Growth in Relation to Site Quality

Classifications of site quality based upon age-height ratios for black spruce stands have been prepared by several workers. The earliest of these site classifications, constructed by Averell and McGrew (*2*), dealt only with swamp forests. As a consequence, some of the very best sites—swamp border and upland—were not taken into account and many sites too poor to produce merchantable stands were included (fig. 20). Nevertheless, the trends conform with those found by Fox and Kruse (*12*) for merchantable black spruce stands in northeastern Minnesota.

Bowman (*4*) pooled data for balsam fir, white spruce, and black spruce. Hence, the growth trends do not necessarily reflect accurately the behavior of black spruce. The somewhat faster diminution in rate of growth after 60 to 80 years suggests that balsam fir, a shorter-lived and more quickly maturing species, had considerable influence on the form of the curves.

In Millar's [17] classification, which was developed in Ontario, the plots were segregated into Type I, "Spruce Hardwood Association"; Type II, "Spruce Flats and Swamp Association"; and Type III, "Spruce Muskeg Association." The upper line plotted in Millar's curves (fig. 20) is his Type I, the lower line Type III. Type II, not shown in figure 20, is only slightly lower

[17] See footnote 13, p. 15.

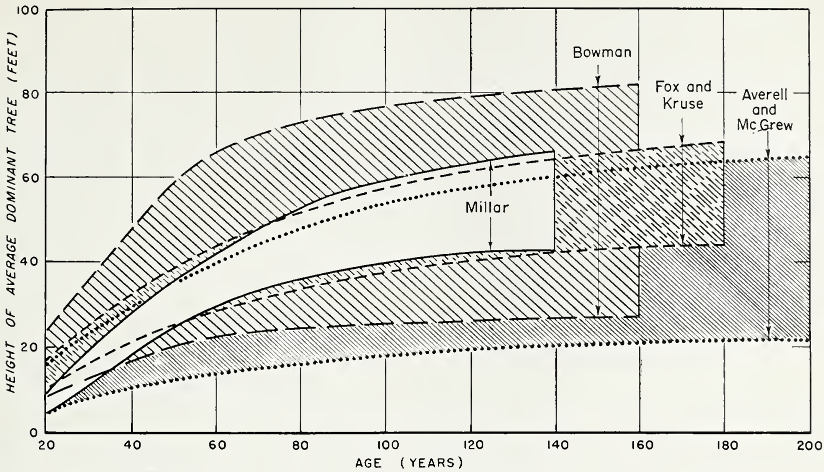

FIGURE 20.—Height-over-age site classifications for even-aged well-stocked black spruce stands. (Bowman's classification is an average for black spruce, white spruce, and balsam fir. Averell and McGrew's report indicated the range in height for each quality of site rather than the averages or midpoints as shown by other authors. Midpoints for best and poorest sites were obtained by interpolation and plotted in this figure.)

than Type I. Beyond the age of 80 years the data are in remarkably close agreement with those of Fox and Kruse (*12*). Since the two classifications were worked up independently, the close agreement lends strength to both. The marked differences in the younger age classes cannot be accounted for. However, various observations indicate that the Fox and Kruse growth rates for younger age classes are more representative of conditions in Minnesota. Therefore, it may be concluded that the site classification and growth rates reported by Fox and Kruse are the best estimates available for black spruce in Minnesota (table 8).

Fully stocked stands on good sites will yield 42 cords per acre from trees over 5.5 inches d. b. h., at 100 years, the age when mean annual growth is at a maximum (table 8). The corresponding values for medium sites are 35 cords at 140 years; for poor sites 17 cords at 160 years. When yields of all trees over 3.5 inches d. b. h. are considered, a somewhat different pattern of growth is shown, in which mean annual growth culminates at an earlier age. However, the yields based upon a minimum tree size of 5.5 inches d. b. h. are more realistic in view of current cutting practices.

The maximum yield shown in the table for trees over 5.5 inches d. b. h. is 54 cords at 180 years. It is interesting to note that the largest volume per acre of spruce pulpwood that has been recorded in Minnesota in a well-authenticated report is 63.5 cords.[18] A deviation from the yield table of such magnitude for a single limited area is not at all improbable. In fact, it tends to demonstrate that the average value in the yield table is about right for the average of good sites.

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[18] Area and volume measured by William Heritage, February 2, 1910, Township 158 North, Range 26 West.

TABLE 8.—*Yields per acre for fully stocked stands of black spruce in northeastern Minnesota* (*12*)

GOOD SITE

Age of main stand (years)	Dominant trees		Trees over 0.5 inch d. b. h.	Basal area of trees over 0.5 inch d. b. h.	Volume,[1] trees over—		Mean annual growth, trees over—	
	Average height	Average d. b. h.			3.5 inches d. b. h.	5.5 inches d. b. h.[2]	3.5 inches d. b. h.	5.5 inches d. b. h.[2]
	Feet	*Inches*	*Number*	*Square feet*	*Cords*	*Cords*	*Cords*	*Cords*
20	17	2. 2	5, 741	84				
30	26	3. 4	3, 478	129	8	0	0. 27	
40	33	4. 2	2, 529	149	17	4	. 42	0. 10
50	39	4. 9	1, 957	159	26	12	. 52	. 24
60	44	5. 5	1, 520	162	32	20	. 53	. 33
70	49	6. 0	1, 277	153	37	28	. 53	. 40
80	52	6. 3	1, 157	164	41	34	. 51	. 42
100	58	6. 9	959	166	47	42	. 47	. 42
120	62	7. 3	849	168	52	48	. 43	. 40
140	65	7. 6	775	169	54	51	. 39	. 36
160	67	7. 8	748	170	56	53	. 35	. 33
180	69	8. 0	688	170	57	54	. 32	. 30
MEDIUM SITE								
20	14	1. 4						
30	22	2. 4	5, 310	91	1		0. 03	
40	28	3. 2	3, 675	123	6		. 15	
50	33	3. 9	2, 916	142	14	2	. 28	0. 04
60	37	4. 5	2, 350	155	22	7	. 37	. 12
70	41	4. 9	1, 957	159	27	12	. 39	. 17
80	44	5. 2	1, 714	161	31	17	. 39	. 21
100	48	5. 7	1, 422	162	36	25	. 36	. 25
120	52	6. 0	1, 277	163	40	30	. 33	. 25
140	54	6. 3	1, 157	164	43	35	. 31	. 25
160	56	6. 5	1, 086	166	45	38	. 28	. 24
180	57	6. 7	1, 022	167	47	41	. 26	. 23
POOR SITE								
20	11	0. 8						
30	17	1. 6						
40	22	2. 3	5, 502	86				
50	26	2. 9	4, 338	110	3		0. 06	
60	29	3. 3	3, 575	123	6		. 10	
70	32	3. 7	3, 077	136	12	1	. 17	0. 01
80	34	4. 1	2, 691	146	16	4	. 20	. 05
100	38	4. 5	2, 275	155	24	8	. 24	. 08
120	41	4. 8	1, 985	158	27	11	. 22	. 09
140	43	5. 0	1, 837	160	30	15	. 21	. 11
160	44	5. 2	1, 714	161	31	17	. 19	. 11
180	45	5. 3	1, 626	161	32	18	. 18	. 10

[1] Unpeeled merchantable volume in standard cords from a 1-foot stump to a 3-inch top d. i. b.

[2] Volumes of trees over 5.5 inches d. b. h. compiled at Lake States Forest Expt. Sta. by means of stand structure data shown in table 12, Appendix.

The ages given above for the culmination of mean annual growth, 100 years, 140 years, and 160 years respectively, for good, medium, and poor sites should not be regarded as rotation ages at which stands necessarily should be clear cut and regenerated. There are several reasons why recommendations for fixed rotations should be guarded against: (1) the possibilities of making partial cuttings leading to the selection system of silvicultural management; (2) the varying conditions of individual stands; and (3) standards followed in the utilization of products. These considerations are discussed more fully later. The chief significance of the mean annual growth figures shown in the yield table is the evidence they supply as to the growth potentialities of undisturbed even-aged natural stands. They show that such stands can produce from 0.11 to 0.42 cord per acre per year depending upon site quality.

Experience has shown that comparatively few stands cut out volumes as large as those given in the yield table for ages greater than 80 to 100 years. As stated previously, the actual average volume of cordwood stands in one of the better districts is only 9.7 cords per acre. These low actual yields reflect many factors including patchy distribution of the trees, and understocking resulting from poor initial reproduction or more recent injury by wind, snow, glaze, insects, and diseases.

Yields of Understocked and Uneven-Aged Stands

Black spruce, particularly in swamps, has a decided tendency to become uneven-aged (fig. 21). The records for the stands on which table 8 is based included many that had younger trees in the understory, although the overstories were even-aged (*12*). Hence, the growth predictions given are generally applicable to any fully stocked stand that has an even-aged overstory.

When the stand is understocked or the dominant trees vary considerably in age, future growth can be only roughly estimated. Understocked stands, of course, tend to increase in density. Bowman (*4*) has reported that the average rates of increase in density for uniformly distributed understocked stands of black spruce, white spruce, and balsam fir are about as follows:

Site index[1] at 50 years (height in feet):	*Increase per year in density of understocked stands (percent)*
39	0.9
33	.7
26	.5

[1] These site indices were chosen to correspond with good, medium, and poor sites—records shown in table 8.

For example, a stand on medium site only 50 percent stocked (in terms of total basal area) at present probably will be 57 percent stocked 10 years hence (50 percent plus 0.7 percent times 10 years equals 57 percent). For stands where distribution of trees is patchy, the annual rates of increase are cut in half—0.45 percent, 0.35 percent, and 0.25 percent for good medium, and poor sites, respectively.

F-262776

Figure 21.—Black spruce tends to become uneven-aged. This stand has an even-aged overstory but later seeding and layering have created an understory of younger trees up to 50 or 60 years old.

Gevorkiantz and Duerr have suggested another method for estimating the approach toward normality of understocked stands.[19] It calls for the following procedure: (1) Determine the percent stocking of the area; (2) ascertain from the tabulation below what percentage of normal growth the stand can be expected to grow during the subsequent 10-year period; (3) find in the yield table (table 8) the 10-year growth of a normal or fully stock stand of the same age; and (4) apply the percentage found in following step 2.

Density of stand (percent):	*10-year growth compared with normal (percent)*
10	19
20	36
30	51
40	64
50	75
60	84
70	91
80	96
90	99
100	100

In estimating future growth in stands that do not have a reasonably even-aged overstory, the best solution for practical purposes is to assume annual rates of growth the same as those for even-aged stands on comparable sites. Of course, appropriate allowances should be made for degree of understocking, and the presence of cull trees, diseased trees, and other discernable conditions that have the effect of materially reducing the area available for production of merchantable wood.

Longevity

Most black spruce trees, even when not crowded by larger neighbors, succumb to various destructive agents long before they attain their maximum possible age of 250 years or more. One of the principal causes of the loss of otherwise vigorous trees is butt rot. Such rot causes little loss in volume because it seldom extends upward more than 2 or 3 feet but by weakening the bases of the trees it makes them susceptible to breakage by the wind (*19*). In a study made in a medium site swamp in Koochiching County the following relationship between age and presence of advanced stages of decay was found:

Age class (years):	*Trees with advanced decay at base of stem (percent)*
46–65	0
66–85	0
86–105	34
106–125	41
126–145	47
146 and over	71

These data do not tell the whole story because undoubtedly many of the older trees already had been broken off. The decay appeared to begin weakening the trees appreciably at about 120 years.

Trees beyond the age of 100 or 120 years in swamp stands usually are noticeably less thrifty in appearance than younger trees. The

[19] Gevorkiantz, S. R., and Duerr, W. A. Methods of predicting growth of forest stands. U. S. Forest Serv., Lake States Forest Expt. Sta. Econ. Note 9, 59 pp. 1938. [Processed.]

crowns become thin and ragged, and many branches die. One of the surest signs that a tree will die soon is a dead tip. Oddly enough, stands on poorer site swamps often maintain their appearance of thrift somewhat longer than stands on better site swamps. In general, the ages at which pronounced decadence in swamp stands occurs correspond rather well to the ages when mean annual growth culminates; good site 100 years, medium site 140 years, and poor site 160 years.

Although outward symptoms of the decline in vigor, such as thin foliage, dead branches, and dead tips are easily observed, the causes have not been determined. Black spruce is known to be susceptible to a number of wood-decaying organisms. Lorenz and Christensen have listed *Fomes pini*, *Armillaria mellea*, and *Stereum sanguinolentium* as common in occurrence and *Polyporus schweintizii* as occasional.[20]

Upland black spruce trees are much shorter-lived than swamp trees. Black spruce is a common associate of jack pine in northeastern Minnesota in even-aged stands up to 80 or 90 years old, but in older jack pine stands black spruce of the same age as the jack pine seldom is seen. The comparatively early disappearance of upland black spruce is caused partly by windthrow and partly by breakage resulting from butt rot. Advanced decay is common at the bases of the stems among trees 60 to 80 years old, an earlier age than in swamps. A tree with serious butt rot collapses at the base like a thin-walled tube when subjected to wind pressure. Upland trees, and particularly those in the poorly drained swamp borders, are readily uprooted by strong or severe winds.

The conclusion that butt rot becomes serious earlier in upland stands than in swamp stands is in agreement with similar findings by Watson, who examined black spruce stumps for evidences of decay on a wide range of sites.[21]

The Effect of Insect and Disease Enemies on Growth

Black spruce is susceptible to attack and injury by a large number of insects (*5*), but the injuries of few of these have been found to be of major economic importance. In their normal endemic condition, such insects cause slight reductions in growth and occasionally the death of a tree here and there. The inappropriately named "spruce budworm" (*Cacoecia fumiferana*) indirectly has caused rather extensive damage to black spruce growing in mixture with balsam fir in Minnesota. The budworm, by killing the balsam fir, exposed the black spruce to windthrow (*13*). Spruce budworm feeds on black spruce only to a limited extent. The European spruce sawfly (*Gilpinia hercyniae* Htg.), which caused widespread damage to spruce in eastern Canada, thus greatly decreasing yield of merchantable timber, has been found on black spruce in Minnesota within recent years but as yet has shown no signs of becoming epidemic.[22] The spruce needle miner

[20] Lorenz, Rolland C., and Christensen, C. M. a survey of forest tree diseases and their relation to stand improvement in the lake and central states. U. S. Dept. Agr., Bur. of Plant Ind., 52 pp., 11 plates. 1937. [Mimeographed.]

[21] Watson, Russell. silviculture of black spruce in minnesota. U. S. Forest Serv., North Central Region, 26 pp. 1937. [Mimeographed.]

[22] Hodson, A. C., and Christensen, C. M. minnesota forest insect and disease survey for 1943. Minn. Agr. Expt. Sta. Paper No. 2194, Scientific Journal Series, 9 pp. [No date, mimeographed.]

(*Epinotia nanana*) at times has made black spruce unfit for use as Christmas trees.[23] Thus, it is of some economic importance.

The principal diseases affecting growth of black spruce are dwarf mistletoe and the wood rots mentioned earlier. The main harm caused by the wood rots is the weakening of the stems and roots which makes the trees susceptible to breaking and uprooting. They cause a limited amount of direct loss, also, through their destruction of merchantable wood. The dwarf mistletoe has caused great damage in some localities by deforming and stunting the trees (fig 22). Since it infests small

FIGURE 22.—(*A*), Typical forking and brooming caused by dwarf mistletoe on black spruce. (Picture is property of and used with permission of E. L. Mowat.) (*B*), Close-up of mistletoe plants on an infested black spruce twig. The inconspicuous plants, which are greenish yellow or greenish brown in color, seldom attain a height of more than ½ inch.

seedlings as well as larger trees, it is difficult to eradicate once it has become established. Suggestions for its control are given in a later section.

Aside from the heart rots and dwarf mistletoe, black spruce has few common diseases. The most conspicuous one is spruce leaf rust

[23] HODSON, A. C. MINNESOTA FOREST INSECT SURVEY FOR 1940. Minn. Agr. Expt. Sta. Paper 448, Misc. Journal Series, 8 pp. [No date, mimeographed.]

(*Chrysomyxa cassandrae*) which causes little injury to the health and growth of the trees,[24] but like the needle miner temporarily spoils them for use as Christmas trees.

Response of Black Spruce to Swamp Drainage

About 1915, after the best farm lands in Minnesota had been settled, extensive areas of swamp lands were drained for agricultural purposes. In many instances the projects failed even before the forest cover had been removed (fig. 8). Later, studies were undertaken to determine to what extent forest growth had benefitted from the lowering of the water tables (*2*).

It was found that black spruce, as well as the other swamp trees, tamarack and white-cedar, had accelerated in both height and diameter growth rates close to the ditches, but the drainage effect did not extend on the average more than about 330 feet from the ditches. Immediately adjacent to the ditches, where the greatest stimulation occurred, volume growth of black spruce after drainage averaged 0.48 cord per acre per year in contrast to 0.21 cord before drainage. However, most of the areas studied were on poor or submerchantable sites and a large part of the volume was contained in very small trees. Hence, these volumes must be scaled down considerably to conform with usual standards of timber utilization.

It was concluded that the widely spaced deep agricultural drainage ditches needed to be supplemented by shallower lateral ditches spaced from one-eighth to one-quarter mile apart in order to accomplish a general, effective lowering of the water table. However, the estimated additional expenditure could not be justified on the basis of the increased growth.

More and more of the ditches are being dammed by beavers and it is expected that in time the drainage systems in forested swamps will become almost totally inoperative. Considerable areas of spruce timber have been killed as the result of flooding by water that has backed up behind beaver dams. The restoration of natural conditions on drained areas evidently is not a simple matter. Some ditches also have been dammed by work relief organizations as a conservation measure, although the wisdom of this may be questioned in view of the harm that has resulted from the activities of beavers.

SILVICULTURAL OPERATIONS—CUTTING AND REGENERATION

The previous sections on the occurrence, natural succession, reproduction, and growth rates of black spruce provide the basic information from which recommendations for silvicultural management of the species have been developed. The more important features of black spruce that have a direct bearing on its management for timber production are: (1) It occurs on two sharply different kinds of habitats, swamps and upland; (2) it reproduces readily following forest fires

[24] Hodson, A. C., and Christensen, C. M. MINNESOTA FOREST INSECT AND DISEASE SURVEY FOR 1941. Minn. Agr. Expt. Sta. Paper No. 1997, Scientific Journal Series, 12 pp. [No date, mimeographed.]

in uncut stands, hence there are many even-aged stands; (3) in swamps it forms a stable type that is not commonly invaded or succeeded by other trees, but on upland it gives way to the white spruce-balsam fir-paper birch association in the absence of periodic forest fires; (4) although the best growth is made in full sunlight, the species can endure rather heavy shade, and thus stands tend to become uneven-aged; and (5) growth, although slow, is well-sustained up to about 100 years on the best sites and 160 years on the poorest sites, not taking into account the submerchantable nonproductive swamps.

Thrifty Swamp Stands

APPLICATION OF PARTIAL CUTTINGS

The term "partial cutting" as used in this paper is not synonymous with the selection system of silvicultural management. The selection system presupposes a distribution of age classes within a single stand such that equal volumes of wood can be removed at each successive cut. Although the natural stands of black spruce in Minnesota usually have even-aged overstories, they become more or less uneven aged and quite commonly are two-storied in appearance as a result of later seeding-in or layering. Rarely, however, do they have such a nicely balanced series of age classes as called for under the selection system. Hence, these partial cuttings should be regarded as preliminary steps in converting wild, unimproved stands into managed stands with better size and age-class distribution and improved thriftiness (fig. 23).

Unless a wild stand is in unusually favorable condition, the first cutting can do little more than take out the most decadent and unthrifty trees. To try to do more would reduce the growing stock unduly and thus lower future yields. Many stands are seriously understocked and others have such a high proportion of overmature trees that nothing can be done except to cut the overmature material and wait until the growing stock has been built up. Sometimes this means practically clear cutting, but at other times it may be possible to save some younger, healthy merchantable trees that ordinarily would be removed in an unregulated operation.

It is a prerequisite of partial cutting that the proper trees be marked for cutting in advance of the logging operation, in order to retain those having best prospects for growth. The cost per cord of marking small trees such as black spruce is a considerable expense, but by no means prohibitive in view of the benefits derived. On the Superior National Forest many thousands of cords of spruce have been marked at an average cost of 10 cents per cord (*19*).

Fortunately, it is possible to recognize the vigor of black spruce trees with a fair degree of accuracy on the basis of outward appearance as shown by a test with 84 trees chosen at random (table 9) (*19*). In most instances the trees ranked as "progressive" grew best and "regressives" the poorest. The good growth of the 10- and 11-inch d. b. h. trees that were ranked as "stable" and "regressive" indicates that, although these trees have grown well in the past, they are now showing outward signs of decline in vigor. Accordingly they should be cut

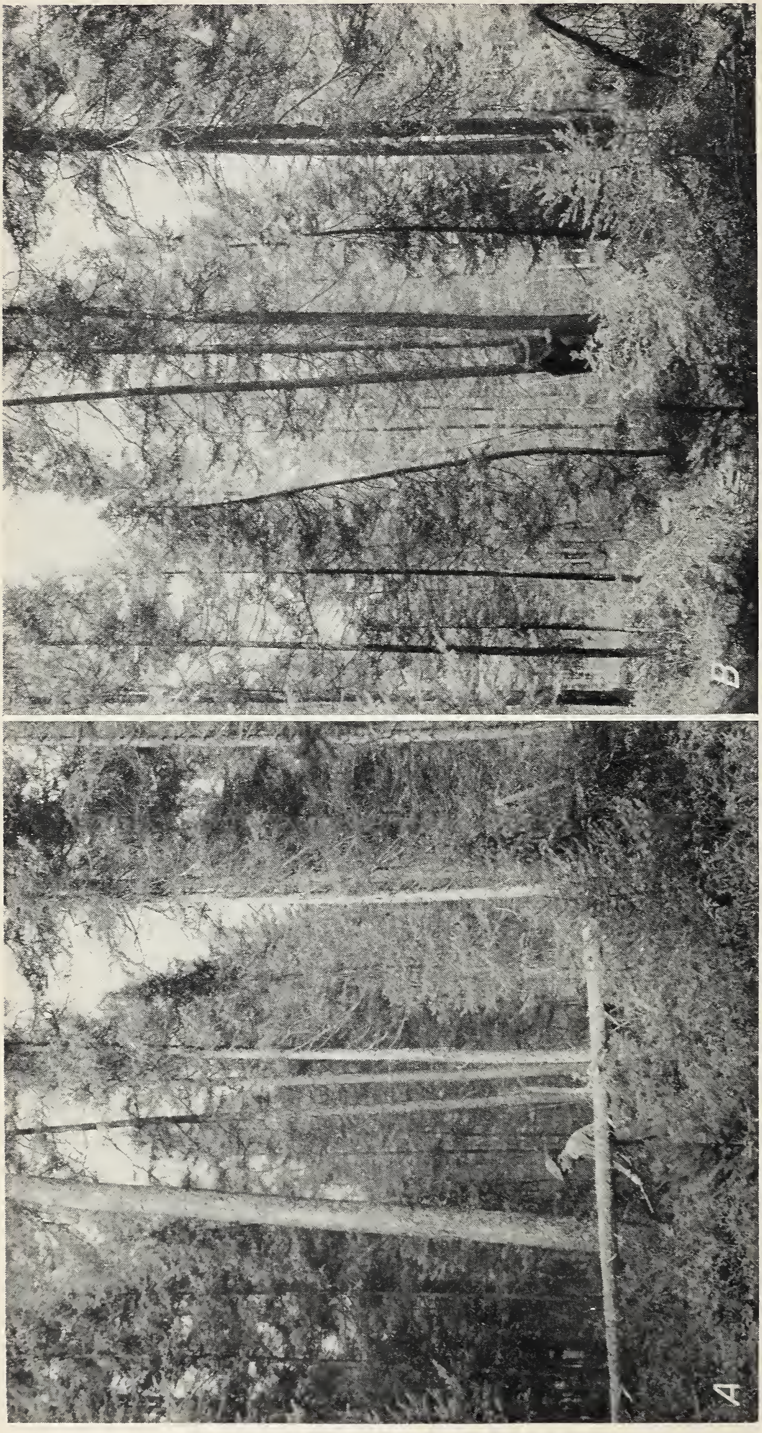

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FIGURE 23.—An experimental partial cutting on land administered by the Division of Forestry, Minnesota Department of Conservation. (*A*), Before cutting; (*B*), after cutting.

soon. The trees were judged as to vigor chiefly on the basis of the following characteristics:

1. Dead tip (upper 1- to 5-foot portion of crown).—This indicates a distinctly unthrifty condition.
2. Length and density of crown.—A long and dense crown is evidence of good growth. Conversely thin foliage and numerous dead branches or a short crown indicate poor growth.
3. Appearance of bark.—Dark bark with small tightly attached scales is characteristic of younger and more vigorous trees. Cracks in the bark to accommodate larger diameters are evidence of good growth. Gray, shaggy bark is a distinguishing feature of trees over 100 to 125 years old.

Several methods for reserving part of the trees without incurring the expense and trouble of marking have been used on timber sales on public lands. All of these methods are based on the principle of leaving trees that are smaller than a stated size. The minimum sizes specified may be related to d. b. h., stump diameter, or number of merchantable pulpwood bolts. The stump diameter limit specification has the advantage that the stumps provide tangible and easily proved evidence of violations of cutting regulations. It also encourages the cutting of low stumps. On the other hand, the taper of black spruce trees near the ground line is both rapid and variable, so that it is difficult to set a limit that will give consistent results.

TABLE 9.—*Diameter growth rates of black spruce for the period 1931–1940, by vigor and 1-inch d. b. h. classes*

D. b. h. class (inches)	Average d. b. h. growth for 10 years by vigor classes		
	Progressive	Stable	Regressive
	Inches	*Inches*	*Inches*
4	0. 71	0. 58	0. 24
5	1. 02	. 63	. 22
6	. 71	. 75	. 20
7	. 68	. 51	. 29
8		. 54	
9	. 79	. 59	. 25
10			. 80
11		. 74	
Average	. 78	. 62	. 33

All the systems of minimum size designation—d. b. h., stump diameter, and number of bolts—generally require close supervision of the cutters and frequent inspection in order to get adherence to the rules, because there is a widespread inclination to "chisel" on such specifications. Sometimes, also, cooperatively inclined operators fail to cut all of the trees that are permitted. For example, one farmer-logger operating on State forest land, who was anxious to do a good job, left 50 trees per acre that were above the minimum diameter of 9 inches at the stump. It is evident that minimum size designation requires extra supervision. However the chief objection to size designation is that at best it only approximates good marking, and frequently results in the removal of many vigorous trees and the leaving of decadent, smaller ones. In thinly stocked spots, where the individual trees are large, cutting is heavy; in dense patches, cutting is light.

The length of time between partial cuts depends upon the quantity of growing stock left, its rate of growth, the size of the individual trees, and the volume that is needed to make a satisfactory cut per acre. Obviously, frequent light cuts will result in the greatest recovery of wood since comparatively few trees will die and be wasted, and the growing space will be kept more continuously occupied.

In accessible easily logged areas where settlers or individual loggers sometimes are willing to take as little as 3 or 4 cords per acre, cuts can be made at intervals of perhaps 8 to 10 years on average sites. In poorly accessible districts where considerable outlays for roads and camps are required, few operators can be induced to log less than 60 percent of the volume, or about 12 to 18 cords per acre in good stands. In such instances, second cuts equal in volume to the first ones probably cannot be made in less than 70 to 100 years without still further depleting the growing stock. The presence of farmer-loggers and a road system in forested areas greatly improves the opportunities for full utilization and good forest management.

No special measures are needed to obtain reproduction in swamps where partial cutting is being practiced. Uncut stands generally have considerable numbers of seedlings and saplings present (table 7). Thinning of the overstory aids the growth of these and disturbance of the soil by logging often encourages the establishment of still more. An example of the stocking of reproduction 6 years after partial cutting in a mature swamp stand is shown below:

Height class (feet):	*Black spruce reproduction per acre (number)*
0	1,472
1	1,288
2	320
3	48
4	88
5+ [1]	512
Total	3,728

[1] Trees from 4.6 feet in height to 3.5 inches d. b. h.

Sometimes open stands have a heavy cover of Labrador tea that seriously retards both the establishment and growth of seedlings, but in which careful counts will show that stocking actually is reasonably good. Since Labrador tea cannot endure heavy shade, the spruce eventually will suppress most of it and reproduction conditions will improve.

The occasional swamp, where speckled alder invades the site strongly, probably cannot be kept in spruce type because the heavy leaf-fall from the alder smothers the tiny spruce seedlings. As mentioned previously, it is believed that spruce became established on such sites only by means of forest fires. No silvicultural measure that appears to be economically practicable has been proposed for regenerating spruce in alder swamps.

Some black spruce stands have considerable white-cedar or balsam fir reproduction. White-cedar and balsam fir are not particularly desirable to have in mixture with black spruce. Neither one grows well in true spruce swamps and the balsam has the further drawback of being the chief host for spruce budworm (*13*). Such reproduction can be prevented by cutting the trees that produce the seed. Since many white-cedars and balsam firs are culls, their removal may have to be conducted as a stand improvement operation which does not always pay its way.

The slash created by light partial cutting is so scattered as to be of little consequence either as a fire hazard or a factor in reproduction. In heavier cuttings the slash is proportionately more dense and hence is more of a problem. On State land, loggers are required to lop the tops as a fire hazard reduction measure. The practice on national forest timber sales is to require lopping or piling. The latter method is being tested as a means of reducing the amount of area covered by slash in order to favor reproduction. In an experiment designed to test the effect of several kinds of slash disposal on reproduction in a moderately heavy partial cutting on the Superior National Forest, the results 7 years after logging were:

	Black spruce seedlings per acre[1] *(number)*
Slash disposal method:	
No disposal	1, 860
Lop and scatter	1, 500
Pile	3, 184
Pile and burn	2, 533

[1] ROE, E. I. SLASH REMOVAL AN IMPORTANT FACTOR IN RESTOCKING CUT-OVER SPRUCE SWAMPS. U. S. Forest Serv., Lake States Forest Expt. Sta., Technical Note 249, 1946. [Mimographed.]

Even the lowest stocking, that which resulted from no slash disposal, is satisfactory. In theory, piling and burning should give the best results of all because the burned spots are particularly favorable for seedling establishment. However, piling and burning is not recommended, because of the additional cost and the probability of scorching residual trees.

POSTCUTTING MORTALITY

The variations in size among the trees in a black spruce stand and the shade-tolerance of this species naturally suggest the possibility that it can be managed by the selection system (*7*). On the other hand, the reputation black spruce has for lack of windfirmness has caused many to believe that partial cutting would lead to serious windthrow losses. Hence, no attempts at partial cutting were undertaken in spruce swamps in Minnesota until 12 or 15 years ago (fig. 24).

In recent years evidence has been gathered which shows that windthrow and other postcutting mortality in black spruce swamp stands are not nearly so serious as once was supposed. In 1939 a series of plots was established in recently cut-over black spruce swamps scattered widely over northern Minnesota. Cuttings on private, State, and Federal lands were sampled indiscriminately wherever they could be found. On some areas all of the merchantable volume and up to 93 percent of the basal area in trees over 2.5 inches d. b. h. had been

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FIGURE 24.—View along winter haul road in an experimental partial cutting in a State-owned black spruce swamp. About 35 percent of the merchantable volume was cut from this stand 6 months earlier. Koochiching County.

removed. On others as little as 33 percent of the volume and 24 percent of the basal area had been cut. The plots were remeasured approximately 5 years after cutting (*21*).

The plots showed that in areas where up to about 50 percent of the volume (or 40 percent of the basal area) had been removed, total mortality during the 5 years subsequent to logging amounted to 32 trees per acre or only 6 percent of the trees over 2.5 inches d. b. h. in the residual stand. In areas where all of the merchantable trees had been cut (over 75 percent of the basal area) the losses were 56 trees per acre or 54 percent of the residual stand.

Uprooting, which accounted for 24 percent of the mortality, increased with severity of cutting but in nearly all instances was of secondary importance (figure 25). Breaking accounted for 12 percent of the mortality. It was not appreciably influenced by the intensity of cutting. The remainder of the mortality, 64 percent, was among trees that had died standing. Such mortality increased with the degree of cutting.

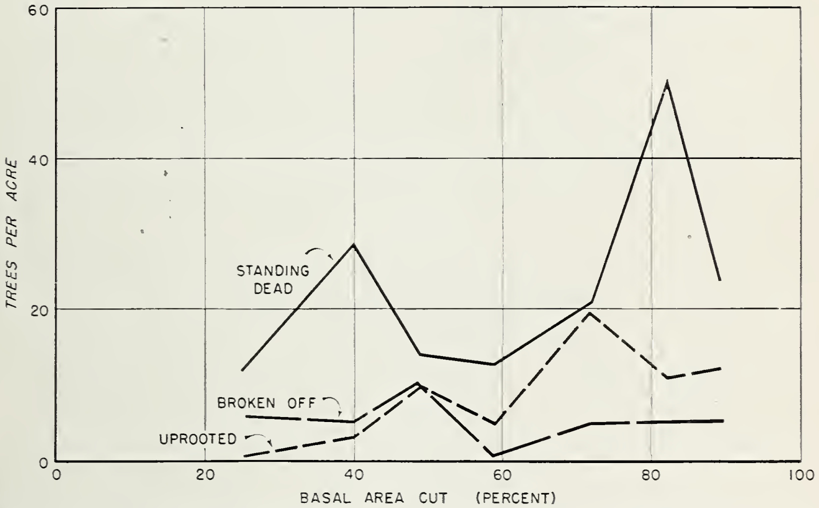

FIGURE 25.—Losses in trees per acre in 5 years in relation to severity of cutting.

Uprooting, of course, is caused almost wholly by wind pressure but breaking can be caused by wet snow, glaze, and rot as well. Thus, windthrow was responsible for something less than one-third of the mortality. It can be concluded that windthrow has been overrated as a cause of loss subsequent to logging in swamp spruce.

Black spruce has shallow roots and peat does not provide very solid footing, but the resilient quality of the peat apparently allows the roots considerable motion without actually tearing them loose. Occasional storms of exceptional violence uproot many spruce trees but this occurs in uncut stands as well as thinned stands. Further evidence of the relatively high windfirmness of swamp spruce was supplied by the July 1932 windstorm in northeastern Minnesota. Upland black spruce sustained approximately twice as great losses as black spruce growing in swamps.[25]

The causes of death among the trees classified as standing dead could not be completely diagnosed. In the most lightly cut areas they ap-

[25] EYRE, F. H. WHEN A TORNADO STRIKES A FOREST. THE SUPERIOR BLOWDOWN OF 1932. U. S. Forest Serv., Lake States Forest Expt. Sta. Original manuscript. 1933. [An article bearing the same title appeared in the Minn. Conservationist, July 1933, but essential information was omitted.]

peared to have died chiefly as the result of long extended suppression. In the heavily cut stands many small trees of seemingly good thrift died for no obvious reason. Sudden exposure apparently has some harmful effect. Probably insects, mistletoe, disease organisms, senility and mechanical injuries also contributed to the undiagnosed causes of death. But, whatever the causes of mortality may have been, the losses following light cutting were not sufficiently serious as to make such cutting impracticable.

GROWTH IN CUT-OVER STANDS

In another phase of the analysis of response of black spruce to various degrees of cutting, it was found that the total growth, not taking into account mortality, was almost directly proportional to the volume of timber left (table 10) (*21*). The most lightly cut plots grew nearly one cord per acre per year for the 5-year period and the most heavily cut plots about one-tenth cord per acre per year. The fact that growth percents, before deducting mortality, were as high in light cuttings as in heavy cuttings, is evidence that the trees left in the light cuttings were wisely chosen for their vigor, in contrast to the "choppers' choice" on the heavy cuttings where only small trees were left.

TABLE 10.—*Volume growth per acre in black spruce stands during 5-year period following cutting*

Basal area cut (percent)	Volume[1] left after cutting	Gross annual growth		Net annual growth [2]	
	Cords	*Cords*	*Percent*	*Cords*	*Percent*
25	20. 7	0. 98	4. 7	0. 88	4. 3
40	14. 8	. 72	4. 9	. 54	3. 6
49	12. 4	. 50	4. 0	. 02	. 2
59	9. 2	. 50	5. 4	. 20	2. 2
72	5. 5	. 28	5. 1	. 04	. 7
82	2. 5	. 10	4. 0	—. 10	—4. 0
89	1. 5	. 08	5. 3	—. 06	—4. 0

[1] Volume of trees over 3.5 inches d. b. h. from a 1-foot stump to a 3-inch top d. i. b.

[2] Growth after deducting mortality. No correction has been made for cull, but this seldom exceeds 5 percent in spruce pulpwood timber.

Net growth, after deducting mortality, ranged from almost nine-tenths cord on the lightest cuttings to negative values on cuttings heavier than 72 percent by basal area. It is unlikely that a growth rate of nearly nine-tenths cord per acre per year can be maintained indefinitely, but a considerably lower rate would still be satisfactory. Definite proof of the growth rates that will result from periodic light cuttings cannot be obtained until such successive cuttings have been made, but it appears safe to predict that one-third to one-half more wood can be recovered by this method than by clear cutting. The study indicated that initial cuts which remove about 25 percent of the basal area or one-third of the volume of trees over 5 inches d. b. h. will result in the largest net gains in volume. The reasons are simple:

1. By leaving many trees, a large volume of wood can be produced even though the individual trees do not grow rapidly.
2. Light cuttings give an opportunity to take out the more decadent trees and leave the vigorous ones; hence, the natural mortality losses should be considerably curtailed.

A clue to the possibilities for recovering additional volume by frequent light cuts is indicated by the extent of mortality in undisturbed stands. A 40-year-old fully stocked stand on medium site contains 3,675 trees per acre but a stand on the same quality of site contains only 1,277 trees per acre when 120 years old (table 8). In other words, two-thirds of the trees die during this 80-year period. This is a great waste of wood. Obviously, many of these trees die long before they attain merchantable size, but some of them reach merchantable size first and some of the more promising ones could be saved for further growth by the harvesting of over-topping decadent or unthrifty trees.

Existing standards of utilization have considerable effect in determining the extent to which small unthrifty trees can be salvaged. At present few pulpwood buyers accept bolts smaller than 3 inches inside bark at the small end and some in Minnesota hold to a 4-inch top. In a utilization study conducted near Big Falls, Minn., it was found that where both large and small trees were removed, the gain in volume when tops were utilized down to 1½ inches instead of the usual 3½ inches amounted to 22 percent (*1*). In a later study [26] the cord volume increase for 2½-inch utilization was 27 percent and for 3-inch utilization 21 percent, compared with 4-inch top cutting. About 10 percent of this increase came from small trees between 4 and 5 inches d. b. h., and the remainder from the additional usable sticks per tree. Bolts smaller than 3 inches in diameter have, in the past, been considered by some mills to be more difficult to bark than standard pulpwood. It was concluded, however, following a recent mill test [27] that there is no loss in the barkers of sticks down to 2½-inch top diameter, and the average barking time is not excessive for spruce which is not frozen. Even without barking, small bolts can be used for certain products, such as insulating material. There is, of course, less solid wood in a stacked cord of small wood. However, the main objection to small wood is the greater cost of handling the greater number of sticks per cord. Nevertheless, the trend is toward closer utilization practices. As a result, the quantities of wood to be recovered and the amount of stand improvement that can be accomplished in partial cuttings will be considerably increased.

STRIP CUTTING

Considerable interest has been aroused and some experimentation has been done in strip cutting, that is, clear cutting in alternate strips. Perhaps its chief appeal lies in the ease of administration. The

[26] ZASADA, Z. A., HUBBARD, JOHN W., and ADAMS, EARL J. A STUDY TO DETERMINE THE VARIATION IN VOLUME AND COSTS OF BLACK SPRUCE CUT TO DIFFERENT TOP DIAMETERS. Lake States Forest Expt. Sta., Minn. Forest Service, and Minnesota and Ontario Paper Company. 33 pp. 1947. [Mimeographed.] (Revised Feb. 27, 1948.)

method consists simply of clear cutting parallel strips and leaving the intervening areas uncut to provide seed. The tests of strip cutting reported here all dealt with thrifty stands.

One of the earlier trials of strip cutting was undertaken by the Minnesota Forest Service. The alternate clear-cut and uncut strips were each 330 feet in width—too wide to insure adequate seeding. No systematic follow-up of results was made, but some rather casual inspections about 10 to 12 years later led to the conclusion that reproduction had been only moderately successful and that the timber in the uncut strips had suffered considerable mortality.

A similar experiment was begun at the Cloquet Experimental Forest in 1927, but the strips were made only 75 feet wide (*16*). Strips were laid out in a northeasterly direction, at right angles to the prevailing wind. Within 3 years both the cleared strips and the uncut strips were abundantly stocked with seedlings. Unfortunately, the results as to success of reseeding were somewhat clouded because much of the live sphagnum had been picked from the area for nursery packing material. The uncut strips suffered serious mortality—32 percent in the first 3 years. A little over half of these trees were lost through windthrow and the remainder had died standing.

It was thought that locating strips parallel with the prevailing wind might give the uncut timber greater protection; hence, a strip-cutting experiment was tried on the Kawishiwi Experimental Forest with strips that ran east and west. In this instance the strips were made 100 feet in width. Six years later there were about 2,600 black spruce seedlings per acre in the cleared strips and 3,200 in the uncut strips. About half as much reproduction was present on the area immediately prior to logging. In the same 6-year period the trees in the uncut strips made a net gain in volume of 2.1 cords per acre or 9 percent despite some losses from windfall and exposure along the edges. The results in this instance were favorable although the stand was also well adapted to partial cutting.

Another strip-cutting test was tried more recently in Koochiching County. It was similar in lay-out to the preceding one but the west ends of the strips adjoined a new clear cutting. Within a few weeks after clearing the strips a hard wind struck the area and caused extensive uprooting in the uncut strips. The new windfalls and remaining live trees were salvaged immediately.

On the whole, the results of these four tests of clear cutting in alternate strips were rather discouraging, although further trials may bring out more information in favor of strip cutting. The method is not suited to badly overmature stands that must be cut at once to obtain the maximum recovery of merchantable material. The kinds of stands where it has greatest promise are likely to be reasonably well adapted to partial cutting, a method that should give higher yields in the long run.

Recently another type of strip cutting—the removal of a 50- to 75-foot strip along the leeward side of the stand at 1- to 3-year intervals—has been suggested for the management of black spruce in Michigan (*10*). In principle, this method appears to be just about ideal for the growth of black spruce in even-aged stands under a simple form of management. It provides for abundant seed on freshly cleared soil, gives maximum wind protection to the exposed edge of the timber, and permits easy and relatively prompt salvaging of any trees that may blow down along the edge.

However, it would require 600 to 800 feet of timber "frontage" to furnish 1 acre of cutting area. Therefore, cutting would have to be spread over a very large area to obtain a substantial quantity of pulpwood—a considerable disadvantage from a practical standpoint.

CHRISTMAS TREE OPERATIONS

In 1940 black spruce Christmas tree stumpage from stagnant swamps made up 6 percent of the receipts for sales of State-owned timber in Minnesota (26). Accordingly, it is evident that not all "nonproductive" swamps are valueless despite their classification.

Most of the trees cut in low-grade swamps are used for table-size Christmas trees, 18 to 30 inches in height. However, these marketable sections are usually the tops of trees that stand 12 to 25 feet in height and range in age from 80 to 140 years old.

The stands that produce the tree tops which meet the rather exacting requirements of the table-tree market are exceedingly dense.[27] Since they usually support 3,000 to 5,000 stems per acre, the trunks on the trees are bare of live limbs for half or more their length, and only a few feet at the tips are free-grown. The 30-inch top sections are from 8 to 12 years old.

In sales of Christmas tree stumpage made by the Minnesota Forest Service, the cut is restricted to a maximum of 10 percent of the total stems on the area. However, few stands contain that large a percentage of acceptable trees. Cuts of from 150 to 200 trees per acre are about average and 400 trees per acre is exceptionally high. Since the merchantable top sections are only about 10 years old, it is expected that many of the trees which are unacceptable at the time of a cutting operation will by later growth produce an acceptable top. Furthermore, it is believed that the thinning brought about by the removal of up to 10 percent of the trees will result in improved growth on the remainder. In a few instances second cuts have been made. The results have fully met expectations.

There is good reason to believe that at least 5 or 6 cuts can be made at intervals of 10 years before the present even-aged stands will have been too much culled or thinned for further production. There has not been sufficient time to show whether the stands will reseed naturally and change gradually into all-aged forests that can be managed by the selection system for Christmas tree production.

When black spruce is cut with a stump 3 to 5 feet high so as to leave several of the lower branches, one of them may turn up to form a new leader. In stagnant swamp forests of the kind described above, there seldom are opportunities to encourage growth of new tops for future Christmas trees by this method. The trees are too crowded and the lower branches are too suppressed. But where Christmas trees are cut from reproduction on more fertile swamps or uplands, it is suggested that stumps be cut sufficiently high to leave about three whorls of thrifty branches to produce one or more new leaders unless there are neighboring trees that will crowd and suppress them.

[27] Information on Christmas-tree-cutting operations on State lands was largely received from Mr. Raymond Clement and other members of the Division of Forestry, Minnesota Dept. of Conservation.

Christmas tree operations on better sites compete with pulpwood production to some extent, but generally so few trees are acceptable for Christmas trees that the future pulpwood supplies are not seriously endangered. The total harm caused by cutting Christmas trees is slight compared to the needless damage caused to small trees in pulpwood cutting operations.

Decadent Swamp Stands

CLEAR CUTTING

Many old stands in swamps are so overmature and defective that there is no choice in cutting other than clear cutting. Such stands may be well stocked with advance reproduction or poorly stocked. Almost never is reproduction totally absent (fig. 26).

The proper action in such cases is to harvest all the overmature timber, using care in logging to prevent needless damage to the advance reproduction. Some additional reproduction usually comes in immediately after clear cutting on the skid roads and other places where peat or rotten wood has been exposed. Probably chopping and felling of the trees causes a temporary increase in the dispersal of seeds from the cones.

Both the survival of advance reproduction and the establishment of new reproduction can be materially assisted by piling or piling and burning the slash, since the accumulation of tops and limbs is much heavier from clear cuts than from partial cuts. Seedlings seldom are found under layers of slash in clear cuttings. Instead they usually are seen in places exposed to full sunlight. Any method of slash disposal that will increase the area of exposed soil surface will be helpful to reproduction. The effect upon reproduction of lopping slash depends upon the volume of the slash. Where the slash is so heavy that lopping and scattering creates a continuous, dense layer of debris, the effect is likely to be unfavorable. However, if lopping reduces the slash to a light sprinkling of limbs through which much of the ground surface is visible, it appears to be helpful. For example, in an experiment near Big Falls, Minn., where three methods of slash disposal were compared with no disposal in a clear cutting, stocking of black spruce 5 years after cutting was as follows:

Slash disposal method:	*Seedlings per acre* [1] *Number*
No disposal	730
Pile	1,435
Pile and burn	1,540
Lop and scatter	1,960

[1] Measured and reported by Paul Zehngraff, Lake States Forest Experiment Station.

Instances have been observed of rather carefully lopped and scattered slash that created a layer that appeared to be about as unfavorable to seedling establishment as undisturbed slash. Lopping, of course, is helpful for hastening the reduction of fire hazard because it brings the slash closer to the moist peat where it is soon overgrown by sphagnum moss. Lopping also hastens decay of the slash.[28]

[29] Djerf, Harvey E. THE EFFECT OF SLASH DISPOSAL METHODS ON REPRODUCTION AND FIRE HAZARD IN THE BLACK SPRUCE SWAMP TYPE OF NORTHERN MINNESOTA. 1947. [Unpublished thesis, University of Minnesota.]

Figure 26.—Most black spruce swamps that were not burned subsequent to logging have restocked. This area was clear cut about 20 years prior to the time this photograph was taken. The present stand is composed partly of advance reproduction that survived the logging operation and partly of reproduction that seeded-in later.

CONTROL OF DWARF MISTLETOE

The dwarf mistletoe of black spruce sometimes causes great damage in open-grown swamp stands. In such instances, trees of all sizes are likely to be parasitized. Probably the only way to accomplish satisfactory control is to cut or burn all the trees, including small seedlings. Broadcast burning of logging slash in favorable weather would have the desired effect. Prompt planting of the burned area with tamarack would insure continued productivity without the danger of reinfestation.

There is some possibility that dwarf mistletoe may become more widespread and damaging in managed forests where fire is kept out than it has been in wild forests that have burned periodically. Since its rate of spread is slow, a considerable degree of control can be accomplished by destroying infected trees whenever they are detected.

Upland Stands

Most black spruce trees growing on uplands occur in mixture with other species. The black spruce usually is only a minor although valuable element in such stands. There are two exceptions: the occasional nearly pure stands on well-drained upland soils, and the nearly pure swamp border type which occupies the fringe of poorly drained land around swamps.

PURE TYPE ON WELL-DRAINED UPLAND

Pure stands of black spruce on well-drained upland soil, although neither common in occurrence nor extensive in area, have been given some special attention because of their high productivity. In rate of growth, they usually correspond to Good Site as shown in table 8.

Experimental attempts to manage such stands have not yielded wholly conclusive results. They do, however, indicate that there is little possibility of maintaining a pure spruce type on upland soil. Moreover, these stands do not lend themselves to partial cuttings leading to a selection system such as has been recommended as the goal for swamp forests.

In 1934 a series of experimental plots was established in a 65-year-old even-aged stand on the Kawishiwi Experimental Forest. The stand contained a small admixture of jack pine, quaking aspen, paper birch, red pine (*Pinus resinosa*), and white pine. On one plot, 25 percent of the volume was removed. The jack pine was cut heavily, the spruce very lightly, and other species were left intact. On another plot alternate 100-foot strips were cleared of all merchantable spruce and jack pine. A third plot was cut clear, and the fourth was left undisturbed as a check.

After cutting had been completed the duff and humus on parts of the plots were scarified or removed with mattocks to determine the effect of such treatment on reproduction. Seven years later all of the logged areas had considerable tree reproduction, but in most instances the species composition was considerably different from that of the original stand (table 11). Most of the black spruce seedlings were much smaller than the young aspen, jack pine, and paper birch; despite the rather generous numbers of black spruce, therefore, this species will not dominate the future stand unless released by the cutting out of competing trees.

The responses of the residual stands, both after partial cutting and after clear cutting in alternate strips, were unsatisfactory. The partially cut plot sustained a net loss of 4.4 cords per acre in the first 7 years, or 19 percent of the volume left after cutting. During the following 4 years losses continued at about the same rate. Thirty-seven percent of the mortality during the first 7 years was caused by uprooting and breaking. The remainder of the loss was in trees that died standing. Most of this latter type of mortality seemed to be associated with the severe droughts of 1934 and 1936, although the uncut check plot lost comparatively few trees and made a net gain in volume of 2.2 cords per acre during the same 7-year period.

TABLE 11.—*Reproduction per acre by species in an upland black spruce stand 7 years after treatment*

Overstory and soil treatment	Seedlings per acre						Basis, mil-acre quad-rats
	Black spruce	Jack pine	Aspen	Paper birch	Others [1]	Total	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Clear-cut area:							
Duff undisturbed [2]	2, 500	200	2, 200	150	100	5, 150	20
Duff removed	425	2, 656	2, 356	27	68	5, 532	73
Clear-cut strips:							
Duff undisturbed	1, 570	247	1, 591	591	97	4, 096	93
Duff torn up	1, 282	294	1, 553	659	47	3, 835	85
Duff removed	3, 190	600	1, 390	1, 420	10	6, 610	100
Partially cut area:							
Duff undisturbed	300	0	0	0	0	300	20
Duff torn up	1, 353	0	517	418	217	2, 505	60
Duff removed	750	0	950	400	0	2, 100	20
Uncut strips: Duff undisturbed	2, 180	130	470	450	40	3, 270	100
Check plot: Duff undisturbed	770	------	10	------	150	930	100

[1] White pine, red pine, and a very few balsam fir.
[2] Low poorly drained spot—not a good sample of upland conditions.

The uncut strips in the strip cutting suffered a net loss of 8.2 cords per acre or 24 percent in 7 years. In the following 4 years over 8 cords per acre more were lost. Uprooting and breakage were the chief kinds of injury. In upland black spruce these causes of loss are greater than in swamps.

The conclusion from these studies is that upland black spruce should be clear cut around 70 to 90 years old, whenever the stands show signs of opening up and becoming subject to breakage and uprooting. It is probable that in the future light thinnings could be made at an age of 35 to 50 years, by taking out merchantable jack pine, aspen, and balsam fir. This would help materially to increase the yield of spruce and encourage the establishment of advance reproduction of black spruce.

SWAMP BORDER TYPE

Black spruce frequently grows in swamp borders but does not occupy extensive areas. In northeastern Minnesota are a good many low-lying poorly drained areas underlain with boulders in which the humus layer and mosses are so shallow that they should be classified as swamp border rather than as true swamp. The trees in such stands are very susceptible to uprooting because of the wet condition of the soil. There is no alternative to clear cutting when the timber commences to uproot and break or adjoining forest types are cut heavily.

The success of spruce reproduction in swamp borders seems to depend chiefly upon the negative factor of what competing tree species are present. For example, aspen, when present, suckers very vigorously after clear cutting in swamp borders and paper birch and balsam fir seed-in aggressively. The young aspen and birch quickly overtop spruce seedlings. Care in logging prevents damage to advance reproduction of spruce and will help in maintaining a representation of this species.

MIXED TYPES

In stands where black spruce is outnumbered by other species, the management requirements of the major species will be the ruling considerations in deciding how to handle the spruce. Efforts thus far made to favor black spruce over jack pine have failed because the spruce, especially on uplands, lacks windfirmness (fig. 27) (*11*). The logging of jack pine is, of course, an entirely different process from the gradual natural breaking up of an overmature stand. The reactions that occur are considerably different from the successional changes in stands left in a natural condition. Hence, black spruce must be cut when jack pine is mature. There is reason to believe that the same thing is true for black spruce associated with paper birch or quaking aspen. Of course, the spruce could well be favored by releasing it from overtopping trees during improvement or intermediate cuttings while the stands still were young. Release cuttings have been advocated in Michigan (*32*), and in the northeast the release of young spruce has proven highly successful (*31*).

SUMMARY

Black spruce, a tree having exceptionally good qualities for pulpwood, forms the principal cover on 1½ million acres of productive swamplands in northern Minnesota. It is also the principal species adapted to a large area of deforested swamps. Spruce pulpwood is in much demand, and timber stands are being depleted rapidly. Considerable numbers of black spruce Christmas trees can be obtained from swamps where growth is too poor for the production of pulpwood. Black spruce grows well on upland soils but usually occurs there only in mixture with other species of trees.

In swamps, black spruce has few competitors and forms stable types that regenerate naturally from seedlings, and to some extent by layering. Many swamp stands are even-aged because of regeneration after forest fires. On uplands black spruce reseeds most successfully following forest fires. In the absence of periodic burns it tends to be replaced by balsam fir, white spruce, and paper birch.

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Figure 27.—Understory black spruce left after a 65-percent cutting in 85-year-old jack pine was uprooted within 3 months by the first strong wind. Kawishiwi Experimental Forest.

Its serotinous cones, borne at the tops of the trees, disperse the enclosed seeds slowly over a period of 2 or 3 years after ripening. The seeds stored in the cones account for the success of black spruce in reseeding after forest fires. The slow dispersal of the seed also is of value in assuring a supply of freshly scattered seed when stands are cut over.

Seedlings as well as older trees can endure much shade but are most successful in sunlight. The seeds germinate best on exposed mineral soil, rotten wood, and peat.

Black spruce trees grow slowly and in Minnesota rarely attain breast high diameters larger than 17 inches. Growth is well-sustained up to about 100 years on good sites, 140 years on medium sites, and

160 years on poor sites. As a result of the exceedingly large numbers of trees in fully stocked stands, pulpwood production is fairly good despite the slow growth of the individual trees. Fully stocked stands on average sites grow at the rate of about one-fourth cord per acre per year. Upland trees become infected with butt rot and succumb to breakage or uprooting at around 80 to 90 years.

It is recommended that thrifty swamp stands be given a series of periodic light partial cuttings leading to the creation of all-aged forests adapted to the selection system. The initial cut should preferably remove not over one-third of the merchantable volume. Such cuts should eventually result in increasing the growth by one-third to one-half. Windthrow has been found to be less of a risk than formerly supposed.

Badly decadent overmature swamp stands must be clear cut. Although reproduction usually is reasonably adequate, it can be improved by slash-disposal measures such as piling that cause exposure of more of the soil surface. Prevention of logging damage to advance reproduction also helps to maintain satisfactory stocking.

Nearly pure types on uplands and the fringes of swamp borders should be clear cut when they become mature or show signs of opening up due to wind damage. Reproduction on uplands is likely to include such species as quaking aspen, paper birch, jack pine, and balsam fir, although black spruce will continue as a more or less important element that can be encouraged by release cuttings or in connection with commercial thinnings.

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APPENDIX

Identification Characteristics of Black Spruce

Although trees of black spruce and white spruce usually can be distinguished at first glance by persons who are familiar with these species, newcomers often experience considerable difficulty in correctly identifying them. The taxonomic characteristics as given in botanical keys and descriptions provide positive means of identification, but these are not always easy or convenient to check. Several characteristics that have proven useful in making quick determinations are described below:

1. *Cones.*—Black spruce cones are borne in a cluster at the top of the tree, are egg-shaped before they open and remain on the tree for many years. They are purple in color before ripening, rich reddish brown after ripening, and finally become gray or blackened. White spruce cones fall within 6 to 12 months after maturing and, accordingly, can be found in large numbers on the ground under cone-bearing trees; and are borne scattered over the top and sides of the crown, are rather cylindrical in shape before opening, green in color before ripening, and straw-colored to brown afterwards. These differences are positive.

2. *Crown form.*—Young black spruce are conical in shape and very symmetrical, but older trees have slender, comparatively unsymmetrical crowns with irregularly spaced branches (figs. 15 and 19). White spruce have broader crowns with regular symmetrical branches. Crown form differences do not give positive identification but are helpful in viewing trees from a distance.

3. *Twigs.*—The 1-year-old twigs on black spruce are dull brown. On white spruce they are smoother, almost glossy, and straw-colored. Twig differences are useful for small trees before cones are borne. Rarely a doubtful twig is found that cannot be identified with certainty.

4. *Bark.*—The freshly exposed bark surface on mature or nearly mature black spruce as determined by peeling off a bark scale with a knife is greenish-yellow. On white spruce it is pink or pinkish-yellow. This is a positive test for use on logs or tall trees where twigs or cones cannot be examined.

5. *Odor of crushed needles.*—Some persons find a marked difference between the pleasant resinous odor of crushed black spruce needles and the pungent, disagreeable odor of white spruce (skunk spruce, cat spruce). Since the acuteness of the sense of smell of individuals differs greatly, one should not rely on this test until he has determined by trial that he can unfailingly detect the difference in ordor. One difficulty is that in checking several trees, the fingers soon become impregnated with the odors of both species.

6. *Seedlings.*—Most newly germinated black spruce seedlings (76 percent) have four cotyledons, 3 percent have only two or three seed leaves, and 21 percent have five or six. Most white spruce seedlings have six cotyledons (82 percent), and the remainder have four or five cotyledons. Thus, by checking the number of seed leaves on new reproduction a reasonably accurate estimate can be made of the species or species mixture. This is the only method for ocularly distinguishing new seedlings.

PEELED PULPWOOD BOLTS

Peeled spruce and balsam fir pulpwood bolts can be distinguished on sight only after long experience, and perhaps even then with some margin of error. Black spruce and white spruce bolts are even more difficult to differentiate.

Studies made in Canada (*14*, *15*) have shown that balsam fir and spruce pulpwood can be separated with reasonable accuracy on the basis of the following characteristics:

1. *Resin ducts.*—Spruce wood contains resin ducts that can be seen with a hand lens on a freshly cut end surface. Sometimes exudations of resin are visible on the ends of bolts. Balsam fir has no resin ducts.
2. *Knots.*—Spruce knots usually do not tend to be nodal in arrangement. Balsam fir knots are likely to be arranged in whorls. There is no swelling at the base of spruce knots but some occurs in balsam fir.
3. *Grain.*—In spruce the grain, as shown by drying checks, tends to be spiral. In balsam fir it usually is straight.

Black spruce bolts tend to be smaller on the average than white spruce bolts (*14*). Black spruce usually has narrower annual growth rings. The wood is also said to be somewhat harder than the wood of white spruce.

Stand and Volume Tables

Table 12 shows the distribution of trees by diameter and crown classes in fully stocked stands of black spruce. It can be used for calculating yields above different minimum tree sizes than those shown in table 8.

Table 13 gives volume of unpeeled wood and table 14 gives volume of peeled wood in cords.

TABLE 12.—*Stand table for fully stocked stands of black spruce in northeastern Minnesota (12)*[1]

Average diameter of dominant stand (inches)	Crown class[2]	Distribution of total number of trees in each crown class by diameter breast high in inches—												Average number of trees per acre
		1	2	3	4	5	6	7	8	9	10	11	12	
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
2	D	24.0	64.1	11.6	0.3									2,413
	I	92.0	8.0											1,343
	S	99.0	1.0											2,188
3	D	.9	27.1	53.5	16.6	1.8	0.1							1,732
	I	24.0	70.0	6.0										847
	S	86.8	12.6	.6										1,402
4	D		2.4	29.4	43.2	20.0	4.3	0.6	0.1					1,232
	I	2.0	45.0	48.7	4.3									562
	S	60.0	34.8	4.9	.3									880
5	D			4.3	30.7	38.0	20.7	5.2	1.0	0.1				888
	I		11.5	57.0	29.3	2.2								361
	S	38.0	43.3	16.5	2.1	.1								548
6	D			.2	6.3	30.5	35.8	19.7	6.1	1.2	0.2			657
	I		2.5	29.5	52.8	14.3	.9							228
	S	24.0	41.0	28.0	6.3	.7								380
7	D				.6	8.0	28.4	35.2	19.4	6.5	1.5	0.4		522
	I		.5	11.5	48.0	35.0	4.8	.2						139
	S	15.3	36.4	33.4	12.7	2.0	.2							246
8	D					1.3	9.5	25.5	33.8	20.3	7.2	2.0	0.4	426
	I			4.2	35.8	56.3	2.6	1.1						80
	S	10.1	31.9	37.7	16.5	3.4	.4							164

[1] Data collected in 1933–36 on the Superior National Forest. Stands are relatively pure and even-aged.
[2] D, dominant and codominant; I, intermediate; S, suppressed trees.

TABLE 13.—*Unpeeled merchantable volume of black spruce, Minnesota and Wisconsin (6)* [1]

Diameter breast high (inches)	Volume by total height in feet—												Basis, trees
	20	25	30	35	40	45	50	55	60	65	70	75	
	Cords	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Number*
4	0.008	0.010	0.011	0.013	0.015	0.017							62
5	.013	.017	.020	.024	.028	.031	0.035	0.038	0.042				100
6		.025	.030	.036	.041	.046	.052	.057	.062	0.068			92
7			.044	.051	.058	.064	.071	.078	.085	.092	0.099		54
8				.067	.076	.084	.093	.102	.111	.119	.128	0.136	48
9					.094	.105	.115	.125	.135	.145	.154	.165	33
10					.114	.125	.138	.151	.162	.175	.187	.199	10
11						.148	.161	.176	.190	.203	.218	.231	8
12						.171	.187	.202	.219	.234	.250	.265	3
13						.208	.214	.232	.248	.273	.284	.300	1
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	
Basis, trees	4	36	38	42	66	67	59	44	34	13	4	4	411

[1] Volume of unpeeled stem above a 1-foot stump to a 3-inch top diameter inside bark.

Compiled at the Lake States Forest Experiment Station by alinement-chart method.
Data collected in 1929–1934.
Aggregate deviation, −0.05 percent.
Average deviation, ±7.9 percent.

Table 14.—*Peeled merchantable volume in standard cords of black spruce (4),*[1] *Minnesota and Wisconsin*

Diameter breast high (inches)	Volume by total height in feet—							Basis, trees
	20	30	40	50	60	70	80	
	Cords	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Number*
4	0. 007	0. 01	0. 013					62
5	. 012	. 018	. 024	0. 03	0. 036			100
6		. 025	. 034	. 042	. 051			92
7		. 038	. 05	. 062	. 074	0. 085		54
8			. 066	. 081	. 096	. 11		48
9			. 081	. 099	. 116	. 133		33
10			. 098	. 118	. 14	. 161		10
11				. 14	. 164	. 188	0. 212	8
12				. 161	. 188	. 214	. 24	3
13				. 185	. 215	. 244	. 273	1

[1] Volume of peeled stem above a 1-foot stump to a 3-inch diameter inside bark.

Conversion of volumes from table 124 (cu. ft.), Technical Bulletin 39, Rev. 1934, University of Minnesota.
Compiled at the Lake States Forest Experiment Station by alinement-chart method.
Data collected in 1929–1934.
Aggregate deviation, 0.02 percent.
Average deviation, ± 8.6 percent.

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