STAND CHANGES
In the First 10 Years After Seedbed Preparation
FOR PAPER BIRCH

by John C. Bjorkbom

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-238
1972

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

THE AUTHOR

JOHN C. BJORKBOM received his forestry training at Pennsylvania State College. After working several years in state and industrial forestry, he joined the Northeastern Forest Experiment Station in 1948. His research work has been with timber management of northern hardwoods and with the regeneration of paper birch in New Hampshire and Maine. He is now on the staff of the Station's Forestry Sciences Laboratory at Warren, Pennsylvania.

MANUSCRIPT RECEIVED FOR PUBLICATION 28 SEPTEMBER 1971.

CHANGES MAY take place rapidly in young forest stands. Stands that appear good may deteriorate unexpectedly: stands that hold little promise initially may suddenly show great potential. The ability to understand and predict such changes increases our ability to prescribe effective silvicultural treatments.

In 1958, the Northeastern Forest Experiment Station began a study of the influence of seedbed-preparation methods on paper birch (*Betula papyrifera* Marsh.) regeneration in Maine. The initial results indicated that, the greater the soil disturbance, the greater the amount of paper birch regeneration. However, this effect was short-lived. Ten years after the study was begun, there was a substantial reduction in the total number of stems per acre, accompanied by significant changes in species composition and dominance. Mortality and slow growth rate of the paper birch seedlings diminished the relative importance of this species in the developing stand.

THE STUDY AREA

The study was made in a 70-year-old second-growth stand in the Penobscot Experimental Forest near Orono, Maine. The stand contained 8 cords per acre of all species. Paper birch accounted for 75 percent of the volume and for 26 percent of the number of trees. Other species representing significant proportions of the total number of stems included red maple (*Acer rubrum* L.), which made up 35 percent; American beech (*Fagus grandifolia* Ehrh.), which made up 22 percent; and softwood species, which made up 11 percent.

The softwoods were principally balsam fir (*Abies balsamea* (L.) Mill.), white spruce (*Picea glauca* (Moench) Voss), red spruce (*Picea rubens* Sarg.), and eastern white pine (*Pinus strobus* L.). Minor numbers of other hardwoods were also present, including gray birch (*Betula populifolia* Marsh.), pin cherry (*Prunus pensylvanica* L. f.), northern red oak (*Quercus rubra* L.), and eastern hophornbeam (*Ostrya virginiana* (Mill.) K. Koch).

The terrain on the study area slopes slightly to the northeast. The soil is the Thorndike stony silt loam, well-drained and shallow to a fractured shale bedrock.

STUDY METHODS

Four seedbed-preparation methods were tested: (1) disking after winter logging, (2) burning after winter logging, (3) summer logging only, and (4) winter logging only. Each treatment was applied to two 0.45-acre plots.

Before any logging was done, paper birch seed trees were selected. Reserved from cutting, they were evenly distributed at a density of 14 trees per acre.

Winter logging was done in March 1958 when snow was still on the ground. Summer logging was done in June 1958. The merchantable wood was stump-cut and tractor-yarded with a rubber-tired flat trailer. The unmerchantable trees, the saplings, and the advance growth over 3 feet tall were cut and left. In effect, the only trees remaining after logging were the seed trees and the advance growth less than 3 feet tall.

The disking was done in August 1958. To facilitate this operation, the stumps were cut to ground level; and all the slash was removed from the plots. Even so, repeated passes with a harrow were required for complete scarification of the soil.

The burning treatment also was carried out in August 1958. To confine the fire within prescribed limits, the slash was pulled back from the plot boundaries. Most of the smaller slash was consumed in the burning.

In April 1959, the hardwood sprouts—except for paper birch and gray birch—were cut back; and the stubs were treated with 2, 4, 5-T.

Each plot contained 100 randomly located milacre subplots on which species composition and dominance were determined. Estimates of the number of stems per acre were based on ¼-milacre samples of 20 randomly selected milacre subplots. These measurements and observations were made on all plots at the end of each growing season from 1958 to 1963.

In 1968, each treatment plot was divided into 18 subplots, each 0.5 by 0.5 chains. At the end of the growing season, a 100-percent tally of all stems of seedling origin taller than 4.5 feet on each subplot was made by species and by 1-inch diameter classes. This choice of height was arbitrary but seemed to be the lower limit of the main crown canopy in all plots and included all species. Estimates of the number of stems less than 4.5 feet tall were based on tallies of the same ¼ milacres used in the 1958-63 inventories. These smaller stems were tallied by species only.

The height and diameter of the tallest tree of seedling origin on each subplot were measured and were recorded by species. Height was measured to the nearest ½ foot; diameter was tallied by 1-inch classes. If the tallest tree was not a paper birch, then the tallest paper birch was also measured.

All stump sprouts were tallied by species, and the number of stems per clump was recorded. The diameter at breast height and the height of the tallest sprout were measured in each clump.

EARLY RESULTS

The 1958 paper birch seedfall was an estimated 1.3 million seeds per acre, with an average germination of 13 percent (*1*). This seed, fairly evenly distributed over the study area, regenerated most of the new stand. Succeeding seed crops contributed relatively little to the total regeneration except through seeding the open areas left from the previous year.

Much of the paper birch seed falling on the disked plots and on the burned plots found a favorable seedbed—70 percent or more of these areas were in exposed mineral soil (*1*). On the other hand, only about 5 percent of the summer-logged and winter-logged areas was exposed mineral soil.

Temperature and moisture conditions during the first growing season (May through September 1959) seemed favorable for seed germination and seedling survival. Records from the U. S. Weather Bureau station at Old Town, Maine—9 miles northwest of the study area—indicated that both temperature and rainfall in this period were above their long-term means (*15, 16*). No extended periods of excessively high temperatures were recorded, and rain fell at rather regular and frequent intervals. (*10, 11, 12, 13, 14*).

At the end of the first growing season (1959), the number of paper birch seedlings per acre by treatment and the ratio of seeds to seedlings by treatment were as follows:

Treatment	*Seedlings per acre*	*Ratio, seeds to seedlings*
Disking	245,400	6 : 1
Burning	50,100	14 : 1
Summer logging	65,700	28 : 1
Winter logging	33,700	36 : 1

STAND CHANGES

During the 10-year period of observation, a number of changes occurred that have drastically altered the stands. The total number of stems per acre peaked in 1959, dropped sharply the following year, and then continued in a downward trend at a diminishing rate. The species composition changed; and paper birch lost its early supremacy, thus giving the other species a relatively greater prominance.

Number of Stems

Regardless of treatment, most of the decrease in number of stems per acre was in the hardwood seedlings (table 1). The softwood seedlings, most common after the logging-only treatments, were fairly stable in number. Hardwood sprouts, also most common after logging only, decreased after 1959 as a result of a sprout-control program to eliminate all but paper birch and gray birch sprouts. However, this program was only partly successful, and sprouts of other hardwood species were also present.

The greatest decrease in numbers of stems occurred on the disked plots. However, considering the great number of stems (primarily hardwood germinants) that regenerated on these plots, high mortality was to be expected in this treatment. Then, too, the disking itself probably contributed to the mortality. Most seedlings survive best in partial shade and with

Table 1.—Total number of stems per acre by treatment, origin, species group, and year of observation
[In thousands of stems]

Origin and species group	Year of observation 1958	1959	1960	1961	1962	1963	1968
				DISKING			
Seedlings:							
Hardwood	1	282	138	101	75	65	11
Softwood	(1)	1	(1)	1	1	1	(1)
Sprouts	11	2	2	(1)	(1)	(1)	1
Total	12	285	140	102	76	66	12
				BURNING			
Seedlings:							
Hardwood	2	62	30	26	(2)	25	9
Softwood	0	(1)	0	(1)	(2)	0	1
Sprouts	7	2	(1)	(1)	(2)	(1)	1
Total	9	64	30	26	(2)	25	11
				SUMMER LOGGING			
Seedlings:							
Hardwood	2	77	26	24	21	21	4
Softwood	5	5	3	4	5	4	3
Sprouts	8	7	4	3	3	2	2
Total	15	89	33	31	29	27	9
				WINTER LOGGING			
Seedlings:							
Hardwood	10	43	18	19	11	10	4
Softwood	3	2	2	2	2	2	2
Sprouts	22	6	8	6	8	4	2
Total	35	51	28	27	21	16	8

Note: Increases shown in the table after 1959 are due to rounding off estimates and to sampling procedures.
[1] Fewer than 500 stems per acre.
[2] Remeasurement errors gave unreliable estimates.

adequate moisture. This is particularly true of paper birch (*6*).

However, the seedbed after disking had little micro-relief and no logging slash or woody vegetation to provide shade sufficient to reduce surface soil temperatures and to help conserve moisture. In addition, some grasses were able to establish themselves in this rather harsh environment and subsequently choked out some of the new seedlings (fig. 1).

Both disking and burning after logging appear to have stimulated the ingrowth of sweetfern (*Comptonia peregrina* (L.) Coult.). Occurring characteristically in large openings and on dry sites, this shrub forms dense patches in which the competition appears so severe that only a few tree seedlings have been able to struggle up through the canopy (fig. 2).

The magnitude of the changes in number of stems per acre on the burned, summer-logged, and winter-logged plots were remarkably similar. Accumulations of slash, advance growth, or unburned materials on these plots served to moderate the environment and probably contributed to the relative equality in numbers.

Seedling Species

Based on the number of stems of seedling origin per acre, paper birch was the predominant species in all plots in most years. But there were obvious differences by treatment in the other species.

Seedbed preparation after logging led to a preponderance of the pioneer species. In the disked plots, aspen ranked second in number to paper birch for the first 5 years. But by the end of the second 5-year period, aspen predominated. On the burned plots, gray birch was initially second to paper birch, but was replaced eventually by aspen. Softwood species were least common on all these plots; trees of these species were advance growth, and most were destroyed by the disking and burning.

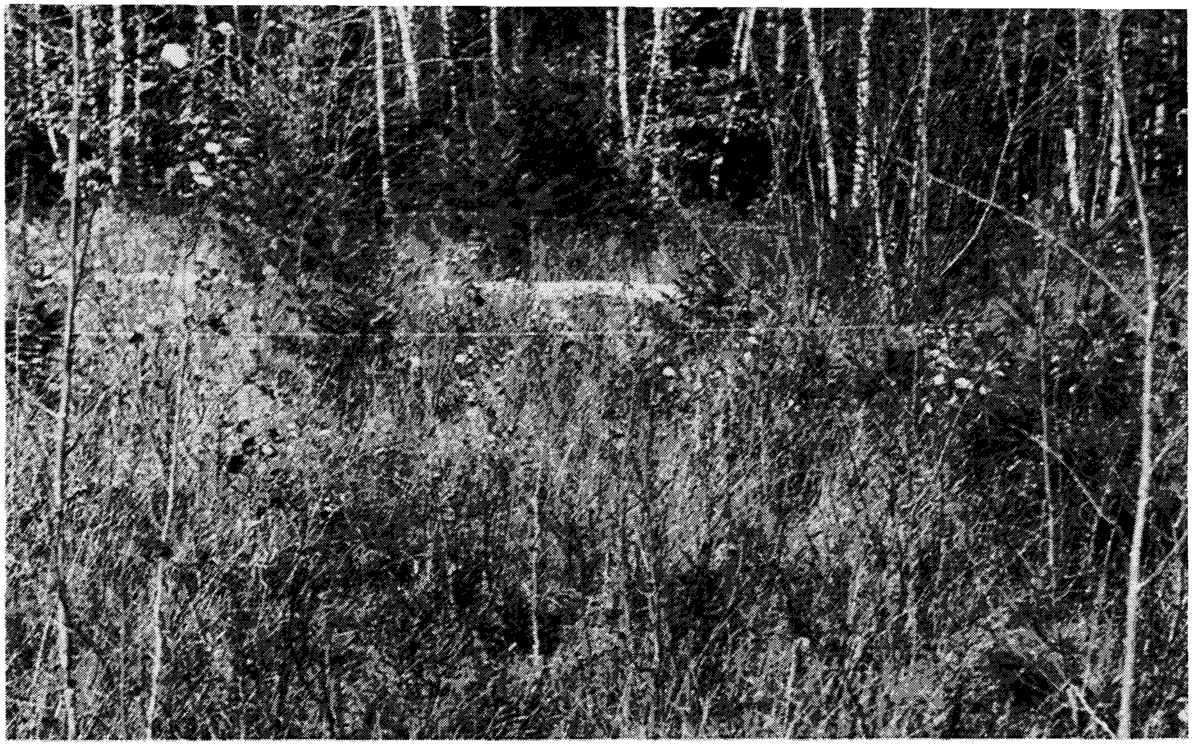
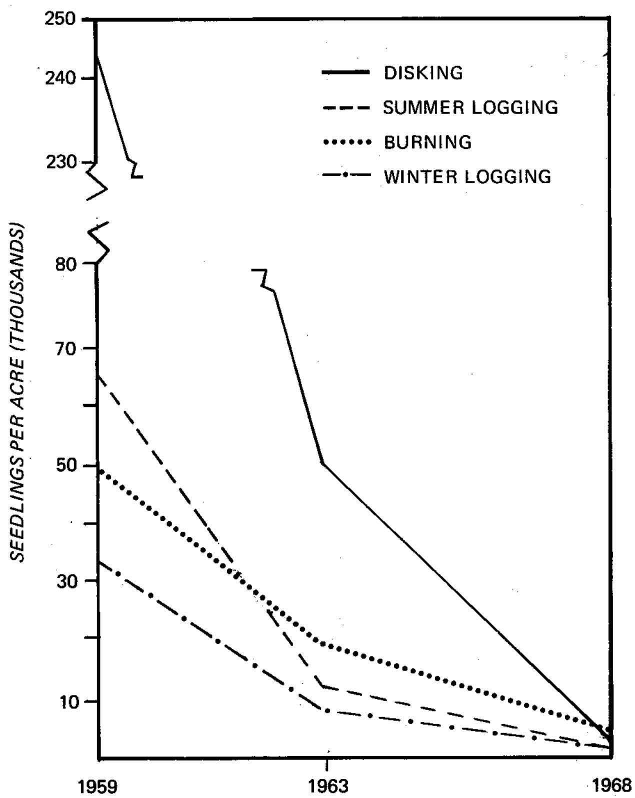


Figure 1.—Some portions of the disked areas are still not satisfactorily regenerated after 10 growing seasons. Here only a few scattered aspens and advance growth of softwoods are visible.

Figure 2.—Competition from sweetfern is sometimes so severe that tree species are slow to regenerate. Here, after 10 growing seasons, only an occasional aspen has been able to break through a cover of sweetfern 3 feet high.

Figure 3.—Softwoods present in the stand before treatment and not destroyed by treatment are a major component of the new stand.

Figure 4.—In all treatments, the number of paper birch seedlings decreased rapidly over the 10-year period.



In plots that were logged only, paper birch ranked first in abundance; and softwood species ranked second for almost the entire 10-year period. The softwoods were present at the start of the study as advance growth (fig. 3).

Although the relative ranking of paper birch did not vary, there were substantial decreases in the number of stems of this species (fig. 4), the greatest decreases occurring on the disked areas. After 10 growing seasons, there were about 4,800 paper birch seedlings per acre on the burned plots, 3,300 on the disked plots, 1,900 on the winter-logged plots, and 1,700 on the summer-logged plots. Changes in the other species were relatively small on all plots.

The proportion of paper birch seedlings also declined. But despite the decreases, 10 years after the start of the study, paper birch still accounted for at least 25 percent of the stems and up to as much as 48 percent (table 2), depending on the treatment.

Tree Height

Height of the paper birch trees of seedling origin is important in evaluating the results of this study. If the paper birch trees are in the main crown canopy (at least 4.5 feet tall), then they have a better opportunity to survive and grow well. Otherwise, they will gradually

Table 2.—Seedling distribution as a percent of the total number of seedlings after 10 growing seasons, by treatment and species, September 1968

Species	Treatment			
	Disking	Burning	Summer logging	Winter logging
	Pct.	*Pct.*	*Pct.*	*Pct.*
Paper birch	29	48	25	35
Aspen	38	26	7	7
Gray birch	12	13	17	3
Pin cherry	3	2	2	(1)
Other hardwoods	14	5	11	24
Softwoods	4	6	38	31
Total	100	100	100	100
Total number of seedlings per acre	11,300	10,100	6,900	5,500

[1] Less than 0.5 percent.

fall behind and eventually will drop out of the stand.

Although abundant paper birch regeneration was obtained on all plots, 12 percent or fewer seedlings had reached 4.5 feet in height by the end of the tenth growing season (table 3). In general, the proportion of taller trees on the disked areas was only one-third to one-fourth that on the other areas; in actual numbers per acre, the burned areas exceeded all others.

Within the main crown canopy, paper birch occupied a subordinate position. Faster growing species and advance reproduction were nearly twice as tall as the paper birch (table 4). Treatment made a difference in which species were dominant. Where disking or burning was used, 87 percent of the dominant trees were aspen, 10 percent were softwoods, and 3 percent were other hardwoods. On areas that were logged only, 58 percent of the taller trees were softwoods, 36 percent were aspen, and 6 percent were other hardwoods.

Table 3.—Number and percent of paper birch seedlings per acre after 10 growing seasons, by height class and treatment, September 1968

Treatment	Height class				
	4.5 feet and taller		Less than 4.5 feet		Total
	No.	*Pct.*	*No.*	*Pct.*	*No.*
Disking	100	3	3200	97	3300
Burning	500	10	4300	90	4800
Summer logging	200	11	1500	89	1700
Winter logging	200	12	1700	88	1900

Table 4.—Average height of the tallest trees[1] of seedling origin, after 10 growing seasons by species or species group and treatment, September 1968

Species	Treatment			
	Disking	Burning	Summer logging	Winter logging
	Feet	*Feet*	*Feet*	*Feet*
Paper birch	5.0	7.1	6.4	6.7
Aspen	13.2	15.0	22.6	18.2
Other hardwoods	9.0	10.5	16.0	16.7
Softwoods	9.7	13.0	14.0	14.3

[1] Based on the tallest tree on each subplot.

Tree Diameter

Most of the trees taller than 4.5 feet were less than 0.5 inch d.b.h. However, there were treatment and species differences (table 5).

In a large measure, these differences were a reflection of the presence or absence of advance growth. The logging-only treatments have a higher proportion of large-diameter trees simply because these trees were left after the treatments were applied. Aspen is an exception. Although this species regenerated only after treatment, its rapid growth has resulted in a substantial proportion of the aspen component

Table 5.—Distribution of trees[1] of seedling origin by diameter class and treatment after 10 growing seasons, September 1968

Species	Diameter class	Treatment: Disking	Burning	Summer logging	Winter logging
		Pct.	Pct.	Pct.	Pct.
Paper birch	under 1-inch	98	96	96	98
	1-inch	2	4	4	2
	over 1-inch	0	0	0	0
Aspen	under 1-inch	74	65	70	68
	1-inch	26	34	22	28
	over 1-inch	0	1	8	4
Pin cherry	under 1-inch	90	92	89	95
	1-inch	10	8	11	5
	over 1-inch	0	0	0	0
Gray birch	under 1-inch	95	100	100	93
	1-inch	5	0	0	7
	over 1-inch	0	0	0	0
Other hardwoods	under 1-inch	85	78	65	61
	1-inch	15	22	34	38
	over 1-inch	0	0	1	1
Softwoods	under 1-inch	59	57	47	41
	1-inch	39	39	45	52
	over 1-inch	2	4	8	7

[1] Includes only trees that were at least 4.5 feet tall.

in the 1-inch diameter class. In general, the regeneration of other species—principally paper birch—was slower growing; so it remained in the lowest diameter class.

Hardwood Sprouts

Sprouts were very common on all plots at the end of the 1958 growing season. Because they might obscure the effects of seedbed preparation on paper birch regeneration, the hardwood sprouts—except paper and gray birch—were cut; and the cut surfaces were treated with 2,4,5-T in the spring of 1959. Although this treatment was not entirely successful in killing off all the sprouts, the number was greatly reduced.

Sprouts were still present in 1968. They were most common on the summer-logged and the winter-logged plots, where they represented 25 percent (2,000 per acre) of the total number of stems (fig. 5). Even though disking and burning killed some stumps outright and reduced the sprouting capacity of others, weak sprouting occurred. About 5 percent (500 per acre) of the total number of stems on these plots were of sprout origin.

Red maple sprouts outnumbered all other sprouts combined, and paper birch sprouts were the tallest; gray birch had more sprouts per stump than did any other species (table 6).

POTENTIAL CROP TREES

To be a potential crop tree, a paper birch tree should be well up in the crown canopy and should have a good chance of reaching merchantable size. But after 10 growing seasons, relatively few of the paper birches exceeded the arbitrary lower limit (4.5 feet) of the main crown canopy; so most cannot qualify as potential crop trees. The paper birch reproduction in the burning-treatment plots shows the most promise. There are twice as many potential crop trees of seedling origin in these plots as there are on the logged-only plots and nearly 5 times as many as there are on the disked plots.

Table 6.—Growth characteristics of sprouts after 10 growing seasons, by species, September 1968

Species	Sprouts— Per acre	Sprouts— Per stump	Diameter distribution[1] 1.5 inches and smaller	Diameter distribution[1] more than 1.5 inches	Average height tallest sprout per stump
	No.	*No.*	*Pct.*	*Pct.*	*Feet*
Red maple	2881	6.3	97	3	11.3
Paper birch	1482	5.7	69	31	12.7
Beech	565	4.1	100	—	9.3
Gray birch	94	9.4	73	27	12.2
Other hardwood	14	2.6	80	20	11.9

[1] Based on diameter of the tallest sprout in each clump.

Figure 5.—Logging-only treatments have resulted in many paper birch sprouts; but many of these are of poor form, and all are relatively small. The largest sprout seen here is only 1 inch d.b.h. and 14 feet high after 10 growing seasons.

Paper birch sprouts at least 4.5 feet tall should also be included in an estimate of the number of potential crop trees. A conservative estimate of this number would be one sprout per sprouting stump. On this basis, the logged-only plots have the greatest number of potential crop trees of sprout origin—100 to 120 per acre. The burned plots had less than one-third of this number, and the disked plots had less than one-fifth.

In total, after 10 growing seasons, the greatest number of potential crop trees per acre was found on the burned plots—about 500 per acre (table 7). The logged-only plots had about 300 per acre, and the disked plots had about 100 per acre.

Table 7.—Number of paper birch potential crop trees after 10 growing seasons, by treatment and origin, September 1968

Treatment	Origin: Seedling	Origin: Sprout	Total
	No.	*No.*	*No.*
Disking	94	13	107
Burning	482	27	509
Summer logging	190	99	289
Winter logging	222	121	343

DISCUSSION

Different seedbed-preparation methods make a difference in the amount of paper birch regeneration developing soon after treatment. But under the conditions of this study, the initial effects were short-lived.

Disking stimulated far more paper birch regeneration than did any other treatment. After one growing season, the number of seedlings after disking was roughly five times the average number in the other three methods combined. Mortality was also higher. At the end of the tenth growing season, there were fewer paper birch seedlings after disking than after burning and not quite twice as many seedlings as after the summer- and winter-logging treatments.

Burning did not regenerate as much paper birch as did disking or summer logging, but seedling survival was better than in any other treatment. After 10 growing seasons, there were 1.5 times as many paper birch seedlings on the burned areas as on the disked areas and 2.7 times as many as on the summer-logged and winter-logged areas.

Improved birch regeneration after scarification or burning to break up the humus cover or expose mineral soil has also been reported for paper birch in New Hampshire (*4*) and for *Betula verrucosa* Ehrh. and *Betula pubescens* Ehrh. in Finland (*8*).

Summer logging and winter logging resulted in less paper birch regeneration. After five growing seasons, these treatments had only one-half as many seedlings as the burning treatment and only one-fifth as many as the disking treatment. Yet these relative amounts were rather substantial: 12,000 seedlings per acre after summer logging and 8,000 per acre after winter logging (*1*). These amounts were somewhat larger than might have been expected, based on the results of a clearcutting in New Hampshire (*5*). Presumably, seed trees made the difference: they were retained in the study reported here but not in New Hampshire. Nevertheless, at the end of 10 growing seasons, there were fewer than 2,000 paper birch seedlings per acre on these logged-only areas.

Despite the number of paper birch seedlings, their growth was disappointing. After 10 years, 88 percent or more of the total number of these seedlings were less than 4.5 feet tall. The tallest birch seedlings over 4.5 feet in height averaged only 5 to 7 feet, depending on treatment. Most of these trees were less than 0.5 inch in diameter. Paper birch sprouts ranged up to 13 feet in height, and most were less than 1.5 inches in diameter. Observations of height and diameter growth elsewhere in Maine and in New Hampshire show that, at age 10, seedlings might be expected to be about 10 feet high and 1 inch in diameter, and sprouts might be expected to be about 19 feet high and 2 inches in diameter (*3*).

The reasons for this poor growth are not entirely clear. Although paper birch occurs on a wide range of soil and moisture conditions, the soil in the study area was not the fresh, well-drained sandy loam on which this species reaches its best development (*9*). This alone very likely accentuated the effects of those factors detrimental to the growth of paper birch. Then, too, browsing probably had a significantly adverse effect on tree height because paper birch appeared to be a favored browse species.

Seedbed-preparation methods have also influenced the other forest tree species. Aspen, gray birch, and pin cherry—pioneer species of little or no commercial value now—were much more abundant after disking and burning than after logging only. On the other hand, a relatively high proportion of commercially valuable hardwoods and softwoods was present after both summer and winter logging.

Both disking and burning tend to favor the regeneration of pure stands of paper birch. If this is the management objective, then the regeneration areas should be so prepared. But because these treatments add to the management costs, their use should probably be limited to the best sites or to those sites that, for some compelling reason, must be regenerated with paper birch.

If the maximum amount of paper birch regeneration is to be produced without extra effort to expose mineral soil, then the regeneration area must be effectively seeded, and the undisturbed seedbeds must not become excessively hot and dry. Effective seeding between seed crops can be achieved by leaving seed trees on the regeneration area or by keeping the regeneration area within the zone of adequate seed dispersal (*2*) from the residual stand. Or it can be achieved by logging in the winter after the bulk of the seed crop has been dispersed. The temperature of the seedbed can be moderated, and the soil moisture can be maintained at higher levels by using cuttings that provide at least partial shade (*7*).

Regardless of what methods are used to get paper birch regeneration on the ground, these seedlings must be retained in the developing stand. The key to this is likely to be silvicultural treatments beginning early in the life of the stand. Although paper birch generally asserts dominance over most other tree species, it is sometimes overtopped by advance growth, by less valuable species, and by sprouts. Carefully selected paper birch potential crop trees should be released from such competitors and then maintained in a free-to-grow position by a series of release treatments. (7). Such treatments will increase the proportion of paper birch in the stand and will accelerate and concentrate the growth on the most desirable trees.

LITERATURE CITED

(1) Bjorkbom, John C.
1967. Seedbed-Preparation Methods for Paper Birch. USDA Forest Serv. Res. Pap. NE-79, 15 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

(2) Bjorkbom, John C.
1971. Production and Germination of Paper Birch Seed and its Dispersal into a Forest Opening. USDA Forest Serv. Res. Pap. NE-209, 14 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

(3) Dana, S. T.
1909. Paper Birch in the Northeast. USDA Forest Serv. Circ. 163, 37 pp., illus.

(4) Marquis, David A.
1965. Regeneration of Birch and Associated Hardwoods after Patch Cutting. USDA Forest Serv. Res. Pap. NE-32, 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

(5) Marquis, David A.
1967. Clearcutting in Northern Hardwoods: Results after 30 Years. USDA Forest Serv. Res. Pap. NE-85, 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

(6) Marquis, David A., John C. Bjorkbom, and George Yelenosky.
1964. Effect of Seedbed Condition and Light Exposure on Paper Birch Regeneration. J. Forest 62: 876-881, illus.

(7) Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A Silvicultural Guide for Paper Birch in the Northeast. USDA Forest Serv. Res. Pap. NE-130, 47 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

(8) Sarvas, Risto.
1948. A Research on the Regeneration of Birch in South Finland. Comm. Inst. For. Fenn. 35(4): English summary 82-91.

(9) USDA Forest Service.
1965. Silvics of Forest Trees of the United States. U.S. Dep. Agr., Agr. Handbk. 271, 762 pp., illus.

(10) U. S. Weather Bureau.
1959. Climatological Data, New England. May 1959: 111.

(11) U. S. Weather Bureau.
1959. Climatological Data, New England. June 1959: 135.

(12) U. S. Weather Bureau.
1959. Climatological Data, New England. July 1959: 167.

(13) U. S. Weather Bureau.
1959. Climatological Data, New England. August 1959: 191.

(14) U. S. Weather Bureau.
1959. Climatological Data, New England. September 1959: 215.

(15) U. S. Weather Bureau.
1960. Climatological Data, New England. Annual summary 1959: 314, 318.

(16) U. S. Weather Bureau.
1963. Climatological Data, New England. Annual summary 1962: 300, 304.

■

☆U.S. GOVERNMENT PRINTING OFFICE: 1972-707-488/355