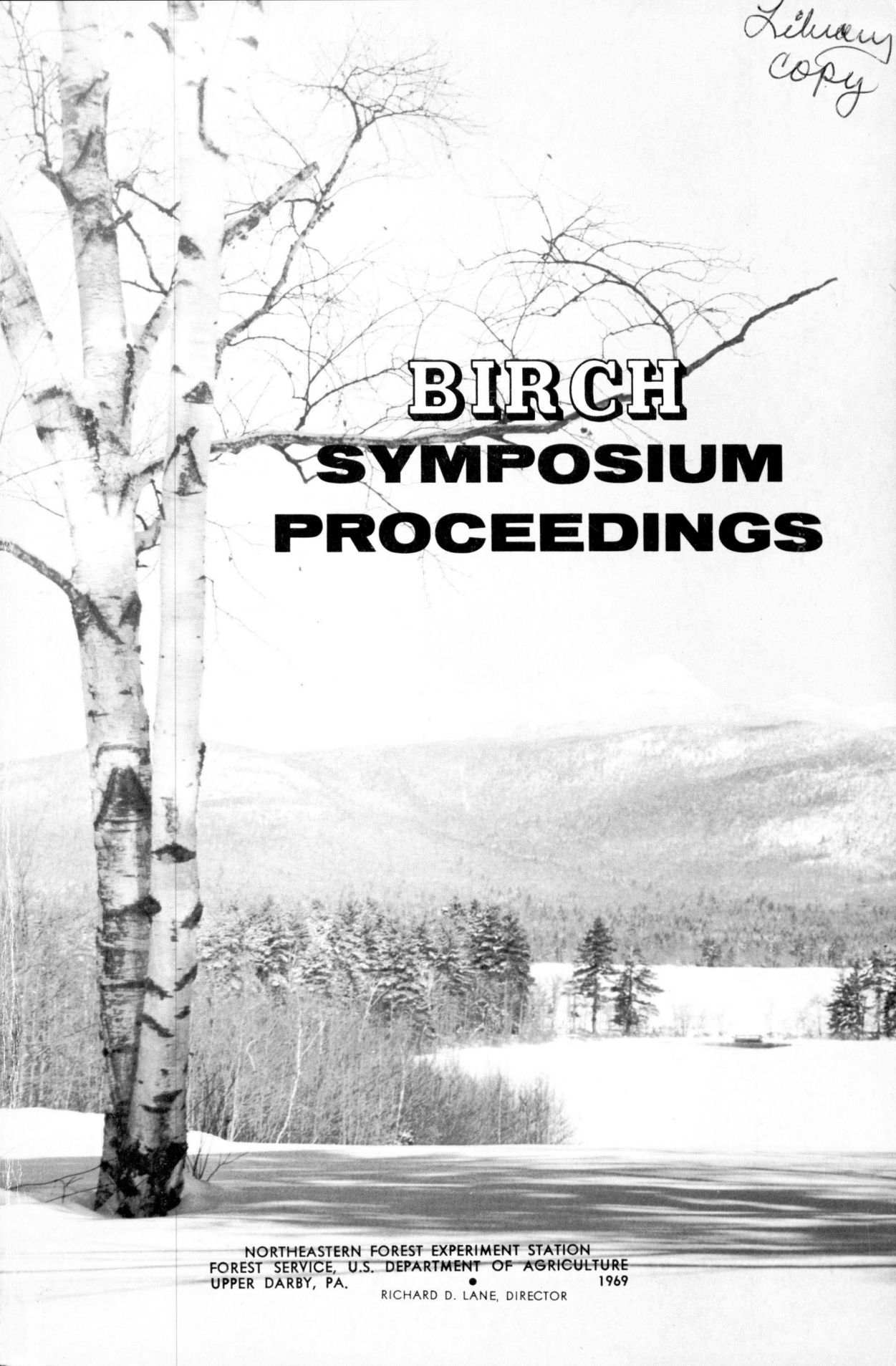


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BIRCH SYMPOSIUM PROCEEDINGS

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
UPPER DARBY, PA.

•
RICHARD D. LANE, DIRECTOR

1969

THE BIRCH SYMPOSIUM

Held at the University of New Hampshire, Durham, N. H.

19-21 August 1969

SPONSORED BY —

Department of Forest Resources, University of New Hampshire.

U.S.D.A. Forest Service:

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Entertainment: D. S. Solomon and B. B. Foster.

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Publicity: H. G. Marx, J. R. Falge, and H. W. Corrow, Jr.

Field Trips: R. P. Sloan and S. M. Filip.

Editor: E. vH. Larson.

THE SPECIES and THEIR NAMES

Here are the common and scientific names of the species mentioned often in these Proceedings:

<i>Common Name</i>	<i>Scientific Name</i>
Ash, white	<i>Fraxinus americana</i> L.
Aspen, large-tooth	<i>Populus grandidentata</i> Michx.
Aspen, trembling	<i>Populus tremuloides</i> Michx.
Beech	<i>Fagus grandifolia</i> Ehrh.
Birch, paper or white	<i>Betula papyrifera</i> Marsh.
Birch, sweet or black	<i>Betula lenta</i> L.
Birch, gray	<i>Betula populifolia</i> , Marsh.
Birch, European white	<i>Betula pendula</i> , Roth
Birch, river	<i>Betula nigra</i> L.
Birch, yellow	<i>Betula alleghaniensis</i> Britt.
Cherry, pin	<i>Prunus pennsylvanica</i> L.
Hemlock, eastern	<i>Tsuga canadensis</i> (L.) Carr.
Maple, red	<i>Acer rubrum</i> L.
Maple, striped	<i>Acer pennsylvanicum</i> L.
Maple, sugar	<i>Acer saccharum</i> Marsh.
Raspberry, Blackberry	<i>Rubus</i> spp.
Spruce, red	<i>Picea rubens</i> Sarg.

To avoid needless repetition of the scientific names in the Symposium papers, only the common names are used in these Proceedings.

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FOREWORD

THIS SYMPOSIUM on yellow and paper birch is the third in a series of meetings devoted to discussion of our fine hardwood timber species. The first meeting, held at Carbondale, Illinois, in 1966, dealt with black walnut. The second, held at Houghton, Michigan, in 1968, dealt with sugar maple.

The purpose of this third meeting is to bring together our present knowledge of the silviculture, management, and utilization of the birches; and to point out the gaps in our knowledge, which research can help to fill.

From a review of the papers prepared for presentation at this meeting, it is evident that we already know much about how to grow and utilize the birches—especially those that regenerate naturally. We know enough to do a much better job of managing our birch stands than we are doing now. Nevertheless, even for natural stands we still have much to learn about spacing and thinning, and about birch nutrition and fertilization.

It is in artificial regeneration and plantation management of the birches that our knowledge is most woefully weak.

In yellow and paper birch we have two extremely versatile and valuable trees of relatively intolerant species which—if given proper spacing, freedom from competition, and optimum nutrition—show excellent promise of producing small high-quality logs and bolts in rotations as short as 40 to 60 years. And with a further boost from genetic improvement of the growth rate, quality, and pest resistance—plus improved utilization techniques—the time required to grow birch in plantations could be made even shorter.

Our experience in growing valuable birch products in plantations is just enough to whet our appetite for more information. So far, it has been like watching a baseball game through a knothole in the fence. If we could only get to the reserved seats inside the stadium, how much better we could participate and enjoy the game!

Top-grade birch veneer logs and sawlogs are now scarce, a situation that will probably result in making the birches even more valuable in the near future. And since there are practically no birch plantations in existence today, it means that we shall have to manage the existing natural stands intensively—with emphasis on thinnings, fertilization, and utilization—to see us through for at least 30 years, when we hope we will be able to begin utilizing some plantation-grown birch.

At the same time we must keep in mind that the birches, paper birch in particular, are prized for their aesthetic value in public forests and parks, in private woodlands, and as ornamental trees in cities and around homes. More and more forest land is being set aside each day for special uses other than for timber production. Aesthetics, recreation, water, and sanctuaries for wildlife are uses that may be assigned individually or in some combination with each other or with timber production.

We especially need to recognize more fully the role of forestry in planning land use in urban areas. Culturing, maintaining, and protecting trees and forests, and promoting several uses or benefits on the same land—this is a real multiple use of these precious trees and forested areas.

In summary, it is the opinion of the general chairmen that we need to mount a strong effort in research to develop sound and useful methods of birch crop-tree culture that will meet the requirements for all future uses of these two valuable species—whether it be in urban or rural areas.

—W. T. DOOLITTLE and P. E. BRUNS

OUR BIRCH RESOURCES

by EDWARD P. CLIFF, *Chief, Forest Service, U. S. Department of Agriculture, Washington, D. C.*

I AM PLEASED to be here in New England this morning to help get this birch symposium under way. It is a delight, first of all to be here to enjoy the magnificent scenery. And second, I am happy to be here because this meeting is an important link in a chain of efforts aimed at resolving one of the most critical problems facing American forestry today—the need to improve the domestic supply of high-value hardwoods available for timber harvest.

Both the quality of the landscape and timber production will receive attention during the sessions that follow, for the two are inseparably related throughout the northern hardwood regions of the United States and Canada. These forests that provide birch and other fine hardwood timber for consumer use also provide some of the finest opportunities for outdoor recreation of any area in the world. Together, the wood-using and outdoor recreation industries represent the backbone of the economy in many of the birch-growing areas. As demands for wood products increase and as pressures for recreation and other forest uses continue to grow at unprecedented rates, we shall have to be increasingly skillful to harmonize these sometimes conflicting uses.

We all know that yellow birch and paper birch are important timber species. Yellow birch is generally considered to be one of the most valuable of all trees growing within its commercial range; high-quality logs bring prices that can be matched by only a few other species in the world.

Paper birch, too, commands premium prices for the larger logs. Even paper birch boltwood, in small diameters, brings high prices, particularly in New England. Because of its rapid growth and high value in small

sizes, paper birch is especially attractive to timber growers.

I am sure you all know that good quality trees of these valuable birches are in short supply. Some of you in the birch industries are more aware of this than the rest of us, for you have been paying even higher prices for suitable raw material and hauling it from ever greater distances. And the prices keep getting higher. In the last 20 years, the prices of yellow birch veneer logs and high-quality sawlogs have nearly doubled. Prices up to \$300 per thousand for yellow birch veneer logs were reported in New Hampshire in 1968. Wisconsin also reported high-quality yellow birch saw and veneer log prices in the \$200 to \$300 range. These price increases reflect a growing scarcity of birch timber.

More Birch Needed

Our resource inventories show the extent of the decline in the supply of yellow birch. The inventory of yellow birch growing stock went down about 16 percent from 1963 to 1968. For the last year of record, 1967, total removals of yellow birch sawtimber were 204 million board feet. This was 23 percent higher than sawtimber growth. If the cut continues to exceed growth, there will be increased competition for residual supplies, higher prices, and increasing imports. Cut also exceeded growth for some of the other preferred species such as sweetgum and walnut.

Partly because of the rising prices for hardwood timber, the United States has been turning more and more to foreign sources for high-quality hardwood timber products. We estimate that for 1968, about three-fifths of the Nation's needs for hardwood plywood and veneer were supplied by imports. This

is a major change from the 1950's, when imports were insignificant. Thus the scarcity in quality hardwoods contributes substantially to our 900 million dollar deficit in balance of payments for forest products.

The current trends in timber cutting and growth indicate that, under present levels of management, we will be unable to supply prospective increases in demands for birch and some other high-quality hardwoods in the years immediately ahead. And within the next decade or so we will be faced with a similar situation for other hardwoods. We can scale back domestic consumption and exports, we can further increase imports, or we can increase our efforts to produce more timber. There is no question in my mind that we should take the last course. This means developing the know-how and investing the money to raise the productive capacity and quality of our hardwood resource. This in turn means stepping up our programs in research, in managing the public lands, and in cooperative assistance to private owners.

But how does this apply to birch? To find out, you are going to be taking a very close look at the birch situation. At the outset, we can trace the present scarcity of high-quality birch timber to past cutting and the lack of forest-management practices. The reversion of farm lands plus the heavy cuttings at the turn of the century have resulted in many second-growth birch stands that are not yet old enough to produce large veneer-quality material. Light cuttings in more recent years have gradually reduced the volume of birch in our older timber stands.

A Question of Motivation

The problem is not likely to go away in the near future. While we have some promising second-growth stands coming along, we have many others where the potential value has been lost by failure to maintain growth, quality, and species composition through thinning or other management practices. The paper birch in some of these stands has already been harvested, leaving little prospect of value for many years to come. We have failed to reproduce enough new stands of both paper and yellow birch over the past 30 or 40 years.

I am convinced that there will always be

a demand for high-quality timber of preferred species. The mellow tone and rich grain of birch cabinets or panelling are not likely to be replaced by substitute materials as long as we can provide the quantity of wood needed at competitive prices.

To do this will require vigorous action by everyone concerned. There must be more intensive management on both public and private lands. We as birch timber-growers have two major tasks. To boost the immediate and near-future supply of quality logs, we need to stimulate diameter growth and improve quality of existing stands through thinning, pruning, fertilization, or any other cultural measures required. And to insure that supplies will be adequate in the more distant future, we need to begin now to regenerate new stands of birch in an orderly and systematic manner. We have much of the knowledge needed to get the job done; we just need to get started and then continue on a significant scale.

A major problem is motivation. The owners of birch timberlands include public agencies and large wood-using industries — but most of all the hundreds of thousands of private individuals who may or may not have any interest in timber production. The latter group—small, private landowners—control about two-thirds of the commercial forest area in states where birch grows.

Owners of small forest acreages have widely varied objectives. Some want timber, and certainly forest management can serve their interests. But it can also serve those who want other things, like wildlife, recreation, or a vacation retreat. If these things can be combined, the lands will continue to serve the interests of the owner and help produce wood the Nation needs today and tomorrow.

Inform the Landowner

The small landowner *is* interested. A 1966 study by Noyes and Babeu in Berkshire County, Massachusetts, revealed that the majority of the woodland owners there considered personal recreation as the dominant reason for holding their land. Yet 41 per cent of these owners indicated they would accept cutting of mature trees and another 41 per cent indicated they would accept cutting of this type if it is controlled or done with the advice of foresters. Some owners simply were

not well informed on the advantages of harvesting timber or did not know how to go about getting it done.

A major challenge therefore is to inform the landowner. As the recreation pressure increases, city and suburban residents can be expected to purchase greater amounts of rural forest land. How do we reach these people with management information? Today we need professional assistance for those absentee owners of small forest land. Some of the states are beginning to provide these services by offering urban forestry units in metropolitan areas. In the vanguard are Georgia, which now has people in Atlanta and Savannah, and Missouri with units in St. Louis and Kansas City. These specialists serve three functions in metropolitan areas. They offer:

- Advice to city dwellers who own rural land.
- Cooperation in community planning.
- Information to the community about the need for wise management of rural wildlands.

What this means is that the target of forestry information and education programs is shifting.

Although the motivation may be different for each of the many types of owners, we need to stress the economics of management for quality hardwoods. Profit is a motive that speaks to nearly everyone, and we need to show what can be accomplished by prudent investments on the better sites. I think we have a far better story to tell here than most of us have realized.

When a landowner is both informed and motivated to the extent that he is interested in learning more and doing more about his forest resource, then he is ready for specific advice and technical assistance. Each of the birch-growing states has a staff of service foresters operating under the Clark-McNary Act of 1924 in cooperation with the Forest Service. These men are ready, willing, and able to assist landowners in planning and achieving better management and use of their birches and trees of other species. By working with consultant foresters and industry people they can make sure that the landowner has adequate professional help in growing, harvesting, and marketing his forest products. This symposium, and the follow-up that will be generated by it, will enable state forestry

organizations to provide even better technical assistance to interested landowners.

Continue Research

Of course, we need to continue our research to find better, faster, and more economical ways of producing the timber we need. We need to investigate the possibilities of very intensive culture of our quality hardwoods. I am thinking now of plantations on the very best of sites, utilizing genetically superior strains at wide initial spacings and tended on a nearly agricultural intensity to produce veneer logs on a short rotation. The existing possibilities of such tree culture are already being tested with walnut; the birches should respond to the same approach.

However, in our efforts to improve birch timber production, we will constantly need to remember the other important uses of our birch-producing forests. The birches themselves are outstanding trees from an aesthetic standpoint—especially the paper birch, with its attractive, clean white bark.

For many people, the white birches symbolize the charm that is New England. Roadside groves of paper birch, such as the one at Shelburne, New Hampshire, are significant tourist attractions marked on the roadmaps and tour-guide folders. The view of Mt. Chocorua framed by white birches along Route 16 is one of the most photographed scenes in the world. When some of these Chocorua birches died a few years back, the State of New Hampshire went to considerable trouble and expense to have them replaced, for the spot loses much of its appeal without them. Artists have the advantage over photographers here—I understand that the original birches still frame new paintings of that spot, even though they have been gone for some time!

To the tourist driving along a forest highway in this region, as in the Lake States, the paper birch adds variety and interest to the forest. The chalky whiteness contrasts dramatically with the dark greenery of the other trees. And the kaleidoscope of color in the fall—with the golden yellow of birch foliage, the oranges and reds of the maples, the dark green of the conifers, and the white birch bark—is simply unsurpassed.

In the past, we have relied heavily on nature to provide these aesthetic incentives to tourists, but I believe more and more con-

scious effort will be made in the future to establish and maintain really superior scenic focal points. Lines of birches along highways, groves of birches at picnic and camping areas or in vacation cottage developments or ski areas, clumps of birches framing vistas of lakes and mountains—these are all attractions that can be maintained or created through cultural practices. Foresters have much to contribute to this form of tree culture too.

Conflicting Demands

In all our tree-growing activities, whether it be primarily for timber, for aesthetic values, or for other purposes, we must recognize the multiple demands being made on our northern hardwood lands. Each activity invariably affects other uses to some degree. When we clearcut a mature stand and secure birch regeneration, we have at the same time influenced the water relationships of that area; we have changed the aesthetic qualities of the area and have influenced its characteristics as a site for camping or skiing or berry picking or bird watching or flower collecting; and we have altered the type and amount of food and cover available for wildlife.

The wildlife-habitat and timber-growing relationship is one that must not be overlooked. Some wildlife prefer birch for food, and this in turn creates difficulty in achieving young growth for timber. The challenge we face is to manage birch cuttings so as to grow enough young birch to provide food for reasonable wildlife populations and at the same time provide stocking for timber stands. I believe this can be done; but it will call for skill and knowledge that we may not yet have.

Although we have recognized these influences, we need to do a lot more planning and adjusting of our forest management activities to accommodate and take maximum advantage of these multiple effects. We need to plan for orderly progressions of reproduction for timber uses, for aesthetics, and for wildlife habitat.

We need to recognize that some timber-harvesting activities can create unsightly conditions. We need to alleviate this problem by planning to take the extra measures necessary to dispose of the brush and slash or otherwise clean up areas where other uses require it.

And we need to recognize that our timber management systems will have to be modified

in some areas, even at the expense of obtaining maximum timber yields.

We need to recognize that individual uses other than timber production will be paramount in some areas—that recreation uses or water-supply requirements, for example, may preclude or limit other uses. The public will insist on such single-use management in some areas, and they are willing to pay the price necessary to get it. In November 1966, for example, Maine voters passed the State's 1½ million-dollar Allagash Wilderness Waterway proposal by a 2 to 1 majority, while at the same time they defeated three other referendums calling for increased expenditures of tax money. And in adopting articles for a new state constitution in 1967, the State of New York upheld the "forever wild" policy as applied to the Adirondack Preserve, defeating even the most modest attempts to modernize the laws governing the management of this area. On a smaller scale, we as foresters need to be sensitive to this kind of demand and demonstrate leadership in recognizing and delineating areas where special or single-use management will be appropriate.

Emphasize Quality Birch

I hope that this symposium will lead to widespread improvements in the management of our birch timberlands for all uses. I feel sure that it will accomplish its primary objective of summarizing and interpreting existing knowledge on the many subjects that affect birch management and utilization. Certainly these proceedings that we have before us represent a giant step in that direction. Within these pages are the latest results of birch research and the most up-to-date recommendations for birch silviculture and management. And I have seen other published material on display here that will further supplement the proceedings.

But now I believe we should carry this one step further and provide a focus on birch as a premium, fine hardwood species—just as we did with black walnut after the symposium at Carbondale, Illinois. This promises to pay handsome dividends in the Central States. Walnut has become important to almost everyone there who has an interest in forests, from Boy Scouts to legislators.

This interest has helped foresters in that region in many ways. Research has found more

funding to intensify walnut studies. Forest nurseries are receiving more seed from more sources. The cooperative forestry programs have provided expert assistance for landowners eager to establish and manage the species on their properties.

We need a similar emphasis on quality birch, if we expect to reap these benefits. We already have the necessary cooperation. The universities, timber industries, trade associations, consulting foresters, State Foresters, extension agencies, and the Forest Service have worked together to improve forest management. It is evident in both our cooperative accomplishments and your attendance at this meeting. If we apply our cooperative force to

the task of selling the importance of producing quality birch, we should achieve the same success that resulted from the black walnut effort.

All of us will have much to carry back to the job with us—new information can be applied in management programs or in our extension and education efforts; new insight into the additional research that needs to be accomplished. We must carry back with us and sustain some of the enthusiasm generated by this meeting. We are taking part in a new era of quality tree culture that will surely be more intensive and more successful than anything that has yet been achieved.



BIRCH TIMBER RESOURCES OF NORTH AMERICA

by KENNETH L. QUIGLEY and HAROLD M. BABCOCK. *The authors are respectively Assistant Director, Northeastern Forest Experiment Station, U.S.D.A. Forest Service, Upper Darby, Pa., and Head, Resource and Resource Analysis, Forest Economics Research Institute, Department of Fisheries and Forestry, Ottawa, Ontario.*

THE GENUS *BETULA* is composed of about 40 species of trees and shrubs. This paper deals with two of the most important: paper birch and yellow birch—their geographic ranges, areas of importance, cover types in which they are found, cubic- and board-foot volumes, estimates of growth-allowable cut, removal, and future volume trends.

Our data are drawn from numerous timber-resource reports. Most information presented here is based on surveys and compilations made in the 1960's; but where no later data were available, information collected during the 1950's was used. In Canada, where no data were available, information on similar areas and conditions was used to develop approximations.

PAPER BIRCH

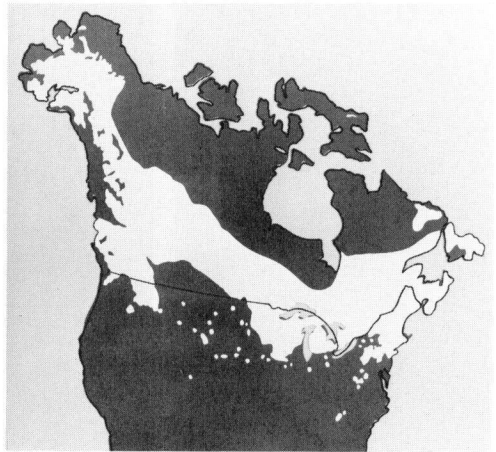
Range

Paper birch has a transcontinental range (fig. 1). It is a characteristic species of the Boreal Forest Region of Canada and Alaska, becoming shrublike as it approaches the northern limits of its range. Paper birch is also common in the states and provinces bordering the Great Lakes and the St. Lawrence River. It occurs in the United States in the northern border states, with outliers as far south as North Carolina, Colorado, and Oregon.

Cover Types

Paper birch is most commonly found in association with aspen, jack pine, red spruce, white spruce, balsam fir, hard maple, beech,

Figure 1.—The geographic range of paper birch in North America.



and yellow birch. Several birch cover types are recognized throughout its range. One of these, the paper birch type, includes forest land on which paper birch comprises a plurality of stocking. This cover type is most common in the Boreal Forest Region of Canada and Alaska. Paper birch also occurs commonly in the aspen-paper birch and maple-beech-birch types. In the United States, acreages in these types are estimated to be as follows:

	<i>Paper birch type (thousand acres)</i>	<i>Aspen-birch & maple-beech- birch type (thousand acres)</i>
Alaska	5,140	7,550
Lake States	1,600	27,270
Northeastern States	770	25,430
Other States	20	2,020
Total	7,530	62,270

Information about paper birch cover types in Canada is not available. However, the area occupied by hardwood and mixedwood stands similar to the aspen-birch and maple-beech-birch types is as follows:

	<i>(Thousand acres)</i>
Newfoundland	590
Maritime Provinces *	16,030
Quebec	65,600
Ontario	47,700
Prairie Provinces **	56,380
British Columbia	7,600
Total	193,900

* Nova Scotia, New Brunswick, and Prince Edward Island.

** Manitoba, Saskatchewan, and Alberta.

Volumes

Sawtimber.—The net volume of paper birch sawtimber in North America is estimated to be about 40 billion board feet (fig. 2). Of

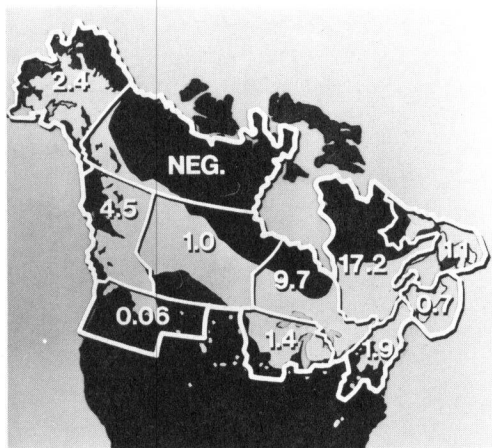


Figure 2.—Paper birch sawtimber volume, in billion board feet, by regions.

this, about 85 percent is in Canada and 15 percent is in the United States.

Approximately 42 percent of the United States volume is in Alaska, 34 percent in the Northeastern States, 23 percent in the Lake States, and 1 percent in the Pacific Northwest States. States having important sawtimber volumes of paper birch are:

<i>State</i>	<i>Million bd. ft. (Int. 1/4" rule)</i>
Alaska	2,430
Maine	990
Michigan	630
Minnesota	480
New Hampshire	360
New York	270
Wisconsin	240
Vermont	240
Other	140
Total	5,780

Half of the Canadian paper birch sawtimber volume occurs in Quebec, an additional 28 percent in Ontario, and 13 percent in British Columbia. After deductions for inaccessible stands and scattered and cull trees, the estimated paper birch sawtimber volume in Canada, in trees 10 inches d.b.h. and larger, is as follows:

	<i>Million board feet</i>
Quebec	17,150
Ontario	9,710
British Columbia	4,530
Newfoundland & Labrador	1,090
Prairie Provinces	990
Maritime Provinces	720
Total	34,190

Paper birch usually does not develop into a large or high-quality sawtimber tree. In states recently surveyed, 80 percent to almost 100 percent of the sawtimber volume was found to be in trees less than 17 inches d.b.h. Also in these states only 1 to 10 percent of the volume is in log grade 1—, and another 10 to 25 percent in log grade 2. Because of the generally low quality of the logs for lumber, most paper birch is harvested as boltwood and is used for sawed specialty products rather than for lumber.

Similar conditions are thought to prevail in Canada, where log diameter rather than defect is the controlling factor in log grade. Pockets of veneer-quality trees can be found

throughout the range, but for the most part sawlog quality is low. Cull volume increases rapidly on trees older than 100 years and the life expectancy of paper birch seldom exceeds 140 years.

Growing stock.—Paper birch growing-stock volume in North America is estimated to be about 36 billion cubic feet. Of this, about one-fifth is in the United States and four-fifths in Canada (fig. 3).

The growing-stock volume in the United States,¹ is approximately 7 billion cubic feet. Of this, 43 percent is in Alaska and is inaccessible to markets. Twenty-nine percent is in the Northeastern States, 27 percent in the Lake States and 1 percent in the Pacific Northwest States. The bulk of the volume is in poletimber-size trees. In some recently surveyed states, the distribution between the two size classes was as follows:

	<i>Poletimber</i> (percent)	<i>Sawtimber</i> (percent)
Alaska	78	22
Minnesota	88	12
New Hampshire	78	22
Vermont	72	28

¹ Growing stock is net volume of live merchantable sawtimber and poletimber trees from stump to a minimum 4-inch top diameter outside bark of central stem. Sawtimber trees are live merchantable trees 11.0 inches d.b.h. and larger. Poletimber trees are live merchantable trees 5.0 inches to 10.9 inches d.b.h.

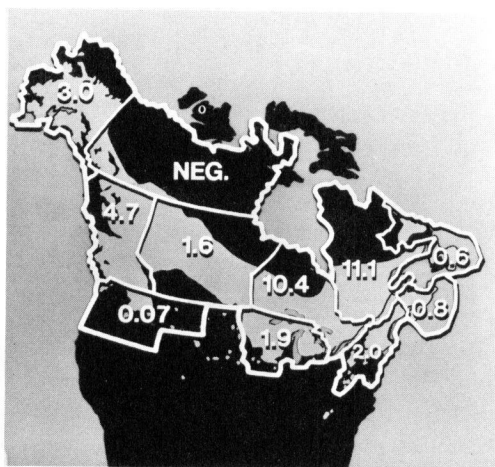


Figure 3.—Paper birch growing-stock volume, in billion cubic feet, by regions.

In addition to the growing-stock volume, rough and defective paper birch timber in the United States not now or prospectively merchantable would add another 10 to 15 percent (about 1 billion cubic feet) to the total volume figure.

In Canada the paper birch growing-stock volume² is estimated at 29 billion cubic feet. Of this total approximately 4.5 billion cubic feet are considered to be inaccessible for exploitation at present. Not included in these estimates are paper birch volumes in the Yukon and Northwest Territories, which do contain stands of small paper birch, but where both use and accessibility are extremely limited.

The bulk of the Canadian growing-stock volume, 74 percent, occurs in Quebec and Ontario, and British Columbia accounts for another 16 percent of the total. The relationship of poletimber volume to sawtimber volume varies widely across the country as a result of growing conditions, fire history, area exploitation, and prevalence of the birch dieback. The distribution between the two size classes is estimated to be as follows:

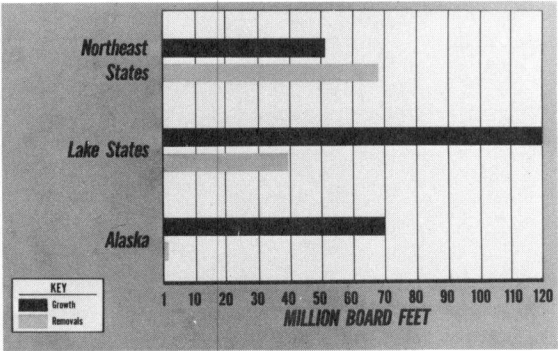
	<i>Poletimber</i> (percent)	<i>Sawtimber</i> (percent)
Newfoundland	58	42
Maritime		
Provinces	74	26
Quebec	28	72
Ontario	61	39
Prairie Provinces	79	21
British		
Columbia	42	58

Growth and Removal

The growth-removal relationship for paper birch sawtimber varies according to region (fig. 4). In Maine, the annual sawtimber removal is about double annual growth. However, in Alaska, where less than 1/2 million board feet are cut annually, the annual growth of paper birch sawtimber exceeds removal by over 100 times. Current growth on the growing stock in the United States is estimated to be at the rate of about 21 1/2 percent, and annual growth of paper birch growing stock timber is at least double the

² The Canadian Department of Forestry defines growing stock as the net volume in poletimber and sawtimber trees exclusive of top, stump, and cull. Poletimber trees are 3.5 to 9.4 inches d.b.h. Sawtimber trees are 9.5 inches d.b.h. and larger.

Figure 4.—Paper birch sawtimber growth-removal relationships for selected U.S. regions, 1967.



removal in every state (fig. 5). Overall growth of paper birch growing stock exceeds removal by about four times. Annual mortality of paper birch is of major importance; it almost equals annual removal.

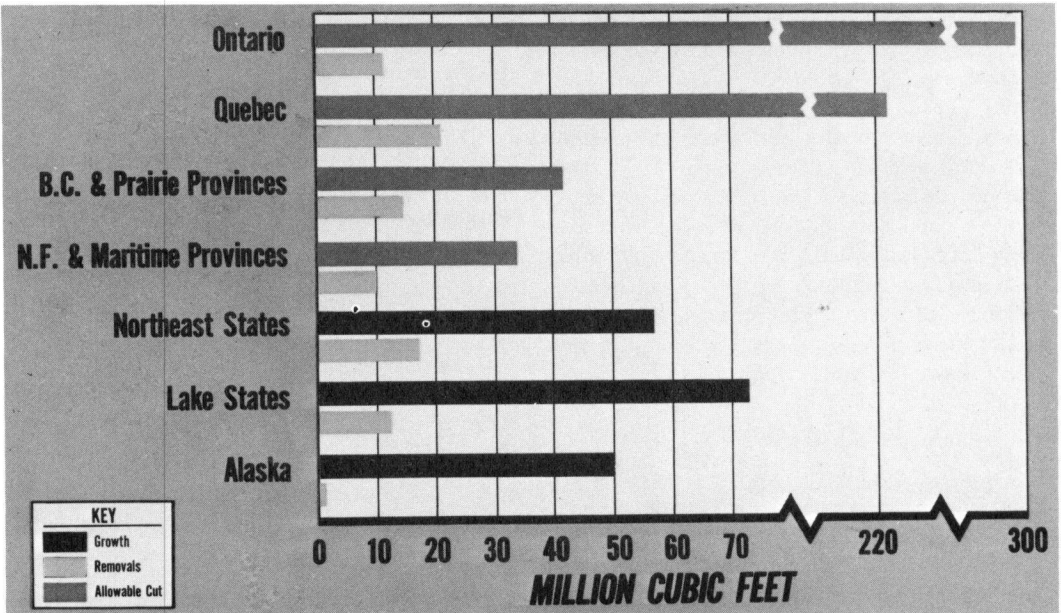
Growth data are not available for much of Canada. The fragmentary data that are available indicate that in the southern areas east of Lake Superior a 4-percent growth rate may be achieved if age-class distribution is more

or less normal. However, much of the Canadian paper birch is mature and even over-mature; therefore total net growth figures, if available, would probably indicate little net growth. For these reasons allowable annual removal has been calculated. This is related to actual removal in figure 5. Allowable annual removal for paper birch for Canada as a whole is 10 times greater than actual removal.

In Canada, present demand for paper birch is extremely limited. Besides some sawlogs and pulpwood cut in Ontario, Quebec, and the Maritime Provinces, the only product of significance is fuelwood. Generally, paper birch trees are bypassed in pulpwood and sawlog operations; and if not killed during the harvesting process, they form a major portion of many residual stands.

The steady decline during the last four decades in acreages burned in the Boreal Forest Region of Canada undoubtedly will reduce the acreage of paper birch stands in the future. The birch dieback of the 1940 era drastically reduced the sawtimber and growing-stock volumes in Quebec and the Maritime Provinces and to a lesser extent in Ontario. The total effect of the dieback has never

Figure 5.—Paper birch growing-stock relationships between annual allowable cut—actual removal and annual growth—removal, for selected Canadian and U.S. regions, 1960-68.



been calculated; however, standing dead-tree volume of paper birch on some 8 million acres of productive forest in New Brunswick in the 1950's was 2½ times larger than livetree volume. Most of the dead-tree volume was in the large diameter classes.

Outlook

Any projection of paper birch timber supply is subject to many uncertainties and must be based on a number of assumptions. The principal assumptions we are making are that: the current growth-removal relationships will remain fairly constant; forest land area that is growing paper birch will not increase or decrease significantly; and demand will increase for the better quality timber.

Our review shows that only in the Northeastern States do industrial removals have a significant effect on sawtimber volumes. In all other areas, cutting has had little effect on the size of the resource. Fire, insects, diseases, and climatic factors are likely to be the major determinants of future volume changes in these areas. A return of the die-back could result in a dramatic reduction of paper birch volumes in a short time, particularly in the sawtimber-size classes. In Alaska, expansion of population and transportation facilities will gradually bring a greater portion of the paper birch resource into industrial production.

For these reasons, we expect that in the United States both sawtimber and growing-stock volumes will increase at a moderate rate for the next 20 to 30 years. However, accessible high-quality sawtimber will be increasingly scarce.

In Canada, many of the mature and over-mature paper birch stands are approaching the end of their life expectancy. Without further disturbances by fire or heavy cutting, these stands may not be renewed. In areas now being harvested, the management objective is not to perpetuate paper birch. Because of these two factors the area and volume of paper birch in Canada may decline slowly in the future.

YELLOW BIRCH

Range

Yellow birch occurs in southeastern Canada and the northeastern United States (figure 6). In Canada, it occurs from Newfoundland and the St. Lawrence area westward through



Figure 6.—The geographic range of yellow birch in North America.

southern Quebec and Ontario to the north shore of Lake Superior. In the United States it occurs in New England, the Lake States, and southward in the Appalachian Mountains as far as eastern Tennessee and northern Georgia.

Cover Types

Yellow birch seldom occurs in pure stands. Common associates include beech, sugar maple, hemlock, red spruce, balsam fir, white pine, and a number of other hardwood species.

Much of the yellow birch timber is found in the maple-beech-birch cover type, defined by the U.S. Forest Service as forests in which maple, beech, or yellow birch, singly or in combination, comprise a plurality of the stocking. This type covers 32 million acres or about 9 percent of all the forest land in the eastern United States:

State	Million acres
New York	5.8
Michigan	5.2
Maine	5.1
Pennsylvania	3.5
Wisconsin	3.0
West Virginia	2.3
Vermont	2.0
New Hampshire	1.3
Other States	3.8
Total	32.0

In Canada, the maple-beech-birch cover type is not recognized. However, hardwood and mixedwood areas on which yellow birch may be found amount to about 74 million acres, distributed as follows:

Province	Million acres
Maritime Provinces	16.0
Quebec	34.0
Ontario	23.7
Total	73.7

Volumes

Sawtimber.—The net volume of yellow birch sawtimber in North America is estimated to be about 34 billion board feet. Of this, 25 percent is in the United States and 75 percent in Canada (fig. 7).

The largest volumes of yellow birch sawtimber are found in Quebec, Ontario, Maine, Michigan, New York, and New Brunswick. Other states and provinces having more than 100 million board feet of yellow birch sawtimber are New Hampshire, Wisconsin, Vermont, West Virginia, Nova Scotia, Pennsylvania, Connecticut, and Massachusetts.

The Canadian yellow birch sawtimber volume greatly exceeds that of the United States (fig. 7). The Province of Quebec contains more than half of the total United States and

Canadian volume. It should be noted that Canadian and United States figures are not exactly comparable because the Canadian sawtimber volumes are for trees 10 inches d.b.h. and over, while in the United States, sawtimber volume includes trees 11 inches d.b.h. and over.

Yellow birch is in strong demand for furniture, lumber, and veneer; as a result, the larger and better trees are usually the ones harvested. This results in a disproportionate volume in trees less than 17 inches at d.b.h. In several recently surveyed states, more than two-thirds of the volume was in trees less than 17 inches d.b.h.

For the same reasons, quality of yellow birch sawtimber is low. In Vermont, only 15 percent of the sawtimber volume was in log grade 1 while in Minnesota 20 percent was in grade 1. The quality of yellow birch sawtimber in Canada is also considered to be low, although there are very few statistics to bear this out. Cull studies carried out in the important yellow birch regions of Ontario show that only 12 percent of the gross merchantable volume of logs is Grade 1. Grade tends to decrease near the northern and western limits of the range.

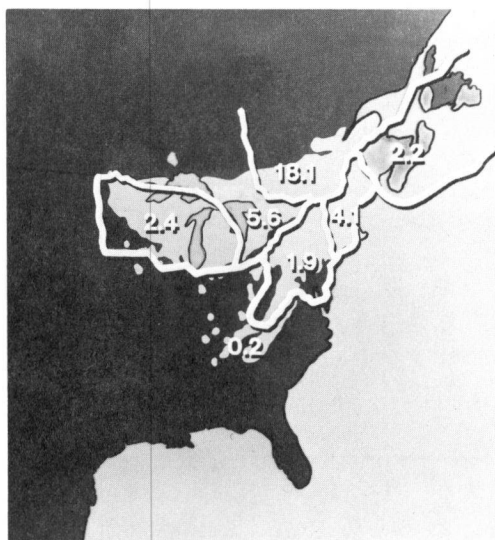
Growing stock.—Growing stock (all merchantable trees 5 inches d.b.h. and larger in the U.S.; 4 inches d.b.h. and larger in Canada) is estimated to be about 13 billion cubic feet. About 72 percent of this is in Canada and 28 percent is in the United States (fig. 8). Approximately half of the growing-stock volume in the United States is of less than sawlog size. States having more than half of their yellow birch volume in sawtimber-size trees are Michigan, Wisconsin, Maine, and New York. In other states, volume in pole-timber-size trees exceeds volume in sawtimber-size trees.

The provinces having the highest proportion of yellow birch in sawtimber-size trees are Quebec (84 percent) and Ontario (75 percent). It must be noted that growing-stock volume of Quebec accounts for about half of the total North American yellow birch volume.

Growth and Removal

Growing stock.—In the United States, yellow birch growing-stock volumes are increasing because overall the annual growth exceeds the annual removal (fig. 9). The annual rate

Figure 7.—Yellow birch sawtimber volume, in billion board feet, by regions.



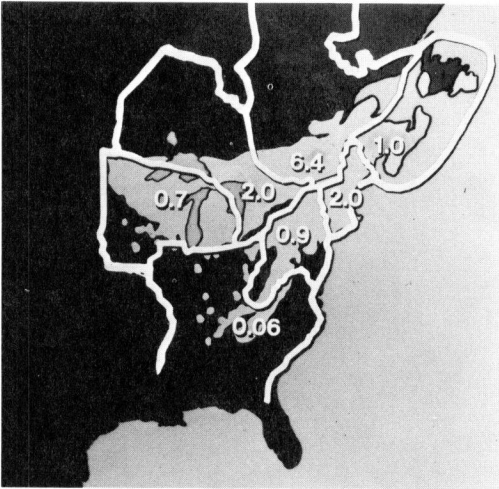


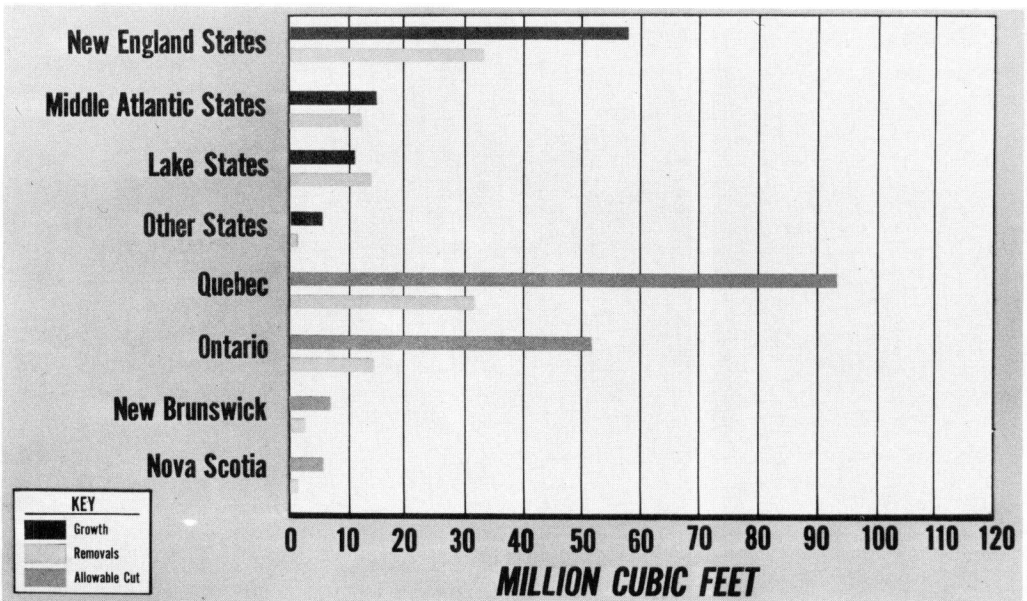
Figure 8.—Yellow birch growing-stock volume, in billion cubic feet, by regions.

of growth is approximately $2\frac{1}{2}$ percent of the volume, while annual cut is less than 2 percent of the total volume. However, the annual removals are increasing at a rapid rate and in some States — notably New York, Michigan, Wisconsin, and Vermont—removal now exceeds growth.

Limited information indicates that growth rate in Canada is about $2\frac{1}{2}$ percent in the southeastern portion of the range. The low growth rate may in part be due to premature mortality of many of the larger trees that were weakened by the dieback and are now dying from other causes. In part of Nova Scotia there has been a decided decrease in yellow birch growing stock over the last 10 years, and industrial removal does not account for all of this decrease. Throughout the remainder of the range, growing stock is either maintaining present volume or is on the increase.

Since reliable growth data are not available for Canada, allowable annual removal has been calculated. The overall actual removal-allowable removal relationship indicates that much greater annual removal could be sustained. Quebec, which accounts for the major supply of yellow birch, removed only about

Figure 9.—Annual relationships between growth—removals and allowable cut—removals for yellow birch growing stock in Canadian and U.S. regions.



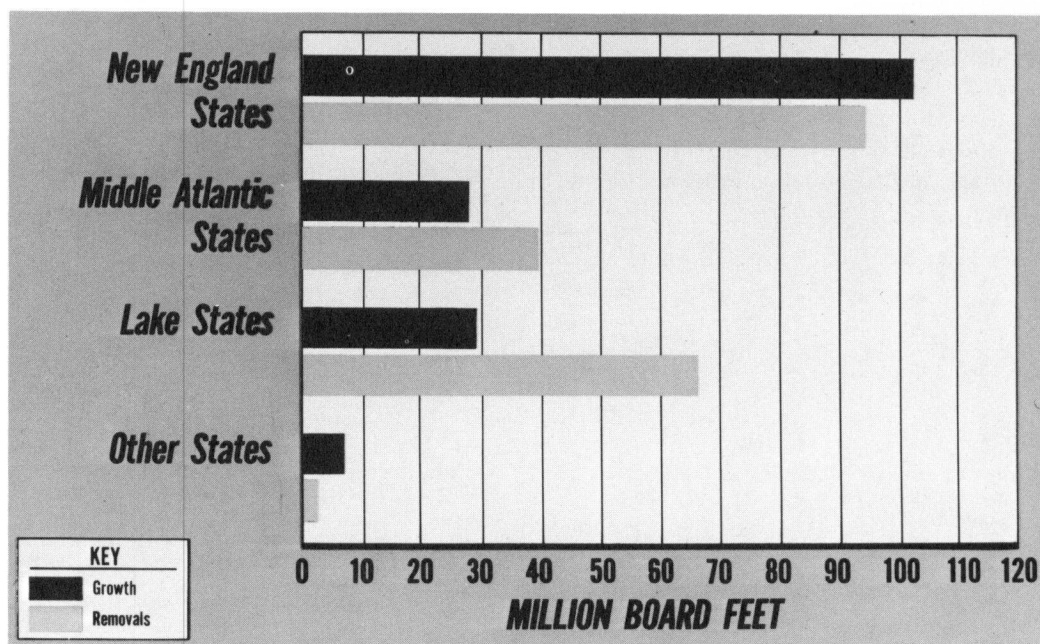


Figure 10.—Annual relationship between growth and removals for yellow birch sawtimber in U.S. regions, 1967.

35 percent of its estimated allowable removal. Ontario, New Brunswick, and Nova Scotia removed 23, 15, and 12 percent respectively of their estimated allowable removal volume.

The birch dieback dramatically reduced yellow birch growing stock, particularly in all of New Brunswick and the Gaspé and southern areas of Quebec. In 1948, it was estimated that there was a 40- to 90-percent kill of yellow birch in this area and an additional 15- to 40-percent mortality on an equal size adjacent area. Even by 1958 the volume of dead standing yellow birch in New Brunswick was more than twice that of live trees.

Sawtimber.—In contrast to the excess of annual growth over annual removal of all yellow birch growing stock in the United States, the annual removal of sawtimber-size yellow birch exceeds annual growth, according to recent estimates (fig. 10). Sawtimber growth is at a rate of about 2 percent annually while removal is estimated to be at a rate of 2½ percent annually. In Michigan, New York, Wisconsin, and Vermont annual sawtimber removal is more than double annual growth.

Outlook

Future demand for yellow birch will depend on such things as consumer preferences, population changes, consumer buying power, and substitution of other woods or material for products made of yellow birch. Changes in any of these factors will change the yellow birch supply-demand relationship.

In United States.—Yellow birch sawtimber is in strong demand for furniture and related uses. Current heavy removal is causing sawtimber volume to decline. The outlook is for increasing demand and a further reduction of volume in the areas accessible to the birch-using industries. Quality timber in accessible stands will become progressively scarcer.

In Canada.—Over the last 20 years yellow birch lumber production has shown a slightly declining trend. On the other hand, peeler log consumption is on the increase. In total it appears that the volume of yellow birch logs removed annually will be maintained at present levels at least over the short term. The quality of logs harvested appears to be declining. Undoubtedly this is a result of the dieback, which virtually eliminated all trees

above 24 inches d.b.h. and seriously depleted the other large diameter classes throughout most of the Canadian range. Thus present removal, although considerably below calculated allowable removal, is concentrated on a relatively small and abnormally distributed growing stock.

Evidence suggests a general build-up in yellow birch growing stock in Canada, and

over the long term there should be a corresponding increase of volumes in trees 10 inches d.b.h. and over. Assuming that the dieback does not recur, and given a reasonable level of management, it is conceivable that over the long term yellow birch may again become a significant feature in the forests of its Canadian range; but it is extremely unlikely that it will ever again be present in predieback volumes.

BIBLIOGRAPHY

- Alberta Department of Lands and Forests.
1961. ALBERTA FOREST INVENTORY. 40 pp. Edmonton.
- British Columbia Department of Lands and Forests.
1957. CONTINUOUS FOREST INVENTORY OF BRITISH COLUMBIA, INITIAL PHASE. 223 pp. Victoria.
- British Columbia Department of Lands and Forests.
[n.d.] FOREST INVENTORY SUMMARIES. 1 to 149. Victoria.
- Calvert, W. W.
1960. GRADING HARDWOOD LOGS FOR FACTORY LUMBER. *Timber of Canada* 18: 42-46.
- Canada Department of Agriculture, Forest Biology Division.
1953. REPORT ON THE SYMPOSIUM ON BIRCH DIEBACK; PART 1 AND 2. 188 pp. Ottawa.
- Canada Department of Forestry and Rural Development.
1966. NATIONAL FORESTRY CONFERENCE, BACKGROUND PAPERS. 35 pp. Ottawa.
- Dominion Bureau of Statistics.
1968. CANADIAN FORESTRY STATISTICS. 25 pp. Ottawa.
- Dominion Bureau of Statistics.
[n.d.] HARDWOOD FLOORING INDUSTRY. 10 pp. Ottawa.
- Dominion Bureau of Statistics.
[n.d.] VENEER AND PLYWOOD INDUSTRY. 18 pp. Ottawa.
- Dominion Bureau of Statistics.
[n.d.] SAWMILLS AND PLANING MILLS. 40 pp. Ottawa.
- Dixon, R. M.
1963. THE FOREST RESOURCES OF ONTARIO. 108 pp. Ontario Dep. Lands and Forests. Toronto.
- Ferguson, Roland H., and V. S. Jensen.
1963. THE TIMBER RESOURCES OF NEW HAMPSHIRE. USDA Forest Serv. Resource Bull. NE-1, 46 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Ferguson, Roland H.
1964. THE TIMBER RESOURCES OF WEST VIRGINIA. USDA Forest Serv. Resource Bull. NE-2, 123 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Hutchison, O. Keith.
1967. ALASKA'S FOREST RESOURCES. USDA Forest Serv. Resource Bull. PNW-19, 74 pp., illus. Pacific NW. Forest and Range Exp. Sta., Portland, Ore.
- Hyvarinen, Matti J.
1968. PAPER BIRCH, ITS CHARACTERISTICS, PROPERTIES AND USES. USDA Forest Serv. Res. Paper NC-22, 11 pp., illus. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Kingsley, Neal P., and J. E. Barnard.
1968. THE TIMBER RESOURCES OF VERMONT. USDA Forest Serv. Resource Bull. NE-12, 117 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Knight, Herbert A., and J. P. McClure.
1967. VIRGINIA'S TIMBER, 1966. USDA Forest Serv. Resource Bull. SE-8, 47 pp., illus. SE. Forest Exp. Sta., Asheville, N.C.
- Manitoba Department of Mines and Natural Resources.
1959 & 1960. THE FOREST OF MANITOBA. Provincial reports 1 to 10, 32 pp. each. Winnipeg.
- New Brunswick Department of Lands and Mines.
1958. NEW BRUNSWICK FOREST INVENTORY, A SUMMARY REPORT. 64 pp. Fredericton.
- Nova Scotia Department of Lands and Forests.
1958. THE FOREST RESOURCES OF NOVA SCOTIA. 179 pp. Halifax.
- Ontario Department of Lands and Forests.
1953, '57, '58, '59. FOREST RESOURCES INVENTORY. Reports 1 to 25, 32 pp. each. Toronto.
- Ostrander, M. D., and others.
1965. A GUIDE TO HARDWOOD LOG GRADING. 50 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Quebec Ministère de l'Industrie et du Commerce.
1966. STATISTIQUES DES PRODUITS FORESTIERS. 59 pp. Quebec.
- Rowe, J. S.
1959. FOREST REGIONS OF CANADA. Dep. N. Affairs and Natl. Resources Bull. 123, 71 pp. Ottawa.
- Saskatchewan Department of Natural Resources.
1959. SASKATCHEWAN'S FOREST INVENTORY 1947 to 1956. 125 pp. Regina.
- Stone, Robert N.
1966. A THIRD LOOK AT MINNESOTA'S TIMBER. USDA Forest Serv. Resource Bull. NC-1, 64 pp., illus. North Cent. Forest Exp. Sta., St. Paul, Minn.
- United States Forest Service.
1965. SILVICS OF THE FOREST TREES OF THE U.S. U.S. Dep. Agr. Agr. Handb. 271, 762 pp., illus.
- United States Forest Service.
1965. TIMBER TRENDS IN THE UNITED STATES. U.S. Dep. Agr. Forest Resource Rep. 17, 235 pp., illus.

BIRCH VENEER & PLYWOOD DEMAND: PROJECTED NEEDS OF THE INDUSTRY

by CLARK E. McDONALD, Managing Director, Hardwood Plywood Manufacturers Association, Arlington, Virginia.

INTRODUCTION

PRODUCTION OF HARDWOOD plywood in the United States has increased steadily from 1955 to 1967 — almost doubling during this period (table 1). The peak year for shipments of hardwood plywood was 1965, for all species (1,668,313,000 square feet surface measure) and also for birch (600,723,000 square feet surface measure). The U.S. Bureau of Census figures are not available yet for 1968; however, they should be as high as those for 1965.

In the total shipment of veneer core, birch made up from 28 percent (1961) to 38 percent (1967). In the total shipment of plywood board core, birch made up from 17 percent (1968) to 29 percent (1965).

Before 1960 Canada was the largest exporter of birch plywood to the United States. Now Japan is the largest exporter (table 2). Since 1963 Finland has shipped more birch

plywood to the United States than Canada has. Korea and the Philippines tried exporting birch plywood in 1967, but evidently they found it unprofitable compared to the exporting of lauan plywood; and in 1968 they cut down their shipments to a small amount.

Of the 16 countries that exported birch plywood to the United States during the period 1962 to 1968, the country that will bear watching in the future is the Union of Soviet Socialist Republics. Even though the U.S.S.R. pays a much higher advalorem duty on its plywood, it can still undersell other countries. Customers have said that the sanding of Russian birch plywood is not up to the quality of Finnish birch plywood. Russia has the raw material and could be a formidable exporter of birch veneer and plywood in the future.

In 1962-68 (table 2), total U.S. imports of birch plywood from all countries have increased from 161,445,140 square feet sur-

Table 1.—Hardwood plywood shipments, 1955-67
(In thousands of square feet surface measure)

Year	Veneer core		Year	Board core*	
	Total, all species	Birch		Total, all species	Birch
1955	813,480	244,896	1955	68,693	16,111
1956	820,285	254,547	1956	66,355	13,785
1957	735,174	243,285	1957	59,124	12,066
1958	752,982	256,475	1958	50,590	12,610
1959	915,404	311,051	1959	61,313	11,669
1960	791,995	277,766	1960	58,272	10,906
1961	1,048,437	299,073	1961	50,840	12,799
1962	1,156,121	392,480	1962	58,719	12,152
1963	1,353,524	485,417	1963	60,736	12,613
1964*	1,442,229	516,716	1964	73,088	15,917
1965*	1,568,835	571,768	1965	99,478	28,955
1966*	1,523,529	566,972	1966	104,856	23,058
1967*	1,441,581	547,475	1967	83,340	14,462

* Includes lumber core, particle-board core, hardboard core, etc.

Table 2.—United States imports of hardwood plywood, by country of origin, 1962-68

Year	Total hard- wood plywood (square feet surface measure)	Value	Birch plywood (square feet surface measure)	Value
FROM CANADA				
1962	56,565,774	\$ 5,708,563	54,368,700	\$ 5,502,572
1963	71,503,450	7,200,935	67,635,421	6,798,888
1964	67,375,000	6,966,849	65,661,000	6,752,109
1965	62,640,152	6,488,102	61,263,138	6,315,836
1966	61,585,000	6,426,840	58,003,000	5,937,926
1967	46,199,000	4,758,751	43,057,000	4,430,123
1968	51,169,000	5,331,597	47,356,000	4,950,555
FROM FINLAND				
1962	63,846,071	\$ 5,974,977	63,844,495	\$ 5,974,714
1963	76,576,766	7,337,320	77,531,953	7,330,411
1964	92,435,000	8,866,581	92,435,000	8,860,885
1965	103,490,534	10,103,151	103,480,934	10,099,656
1966	133,595,595	13,309,355	133,593,592	13,308,388
1967	104,721,000	11,201,626	104,721,000	11,201,626
1968	134,437,000	13,974,897	134,410,000	13,967,738
FROM FRANCE				
1962	4,446,097	\$ 413,660	12,000	\$ 1,218
1963	2,136,960	245,106	—	—
1964	2,385,000	311,739	—	—
1965	2,200,607	326,116	—	—
1966	1,804,000	245,459	—	—
1967	1,884,000	248,551	—	—
1968	1,027,000	154,704	—	—
FROM WEST GERMANY				
1962	1,756,864	\$ 290,347	—	\$ —
1963	732,903	150,632	—	—
1964	725,000	126,967	—	—
1965	434,007	166,639	28,886	2,750
1966	269,000	91,751	—	—
1967	162,000	67,906	—	—
1968	696,000	96,849	—	—
FROM JAPAN				
1962	740,103,236	\$53,731,611	43,149,848	\$ 6,880,289
1963	739,941,879	55,610,169	51,183,464	7,885,666
1964	680,986,000	50,905,470	68,847,000	9,316,488
1965	768,316,182	50,419,815	105,411,598	12,655,889
1966	765,922,000	54,856,470	119,332,000	14,511,327
1967	632,083,000	47,689,008	143,760,000	15,602,807
1968	920,714,000	71,918,638	173,077,000	20,085,483
FROM SOUTH KOREA				
1962	51,427,767	\$ 2,588,458	—	\$ —
1963	120,513,110	5,592,152	—	—
1964	205,245,000	9,414,392	—	—
1965	336,735,786	14,652,977	—	—
1966	573,626,000	25,232,188	—	—
1967	701,967,000	30,140,133	3,140,000	120,739
1968	1,167,156,000	53,438,959	101,000	9,091

CONTINUED

Table 2—continued

Year	Total hard- wood plywood (square feet surface measure)	Value	Birch plywood (square feet surface measure)	Value
FROM NANSEI & NANPO ISLANDS				
1962	45,193,347	\$ 2,098,984	—	\$ —
1963	37,420,944	1,503,668	30,912	2,894
1964	34,086,000	1,394,560	64,000	8,192
1965	42,864,682	1,768,844	—	—
1966	35,929,000	1,513,685	—	—
1967	25,858,000	994,502	—	—
1968	32,643,000	1,295,168	—	—
FROM POLAND				
1962	—	\$ —	—	\$ —
1963	—	—	—	—
1964	193,000	13,336	193,000	13,336
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	134,000	8,839	134,000	8,839
FROM THE PHILIPPINES				
1962	214,442,465	\$14,538,308	—	\$ —
1963	246,717,081	15,419,115	—	—
1964	355,691,000	21,566,510	—	—
1965	307,759,563	18,055,850	—	—
1966	398,004,000	22,362,017	29,000	3,349
1967	471,425,000	23,733,078	1,046,000	107,329
1968	602,244,000	29,879,187	154,000	15,551
FROM PORTUGAL				
1962	618,400	\$ 54,966	—	\$ —
1963	711,798	57,089	6,400	525
1964	1,057,000	91,298	—	—
1965	527,296	44,962	—	—
1966	64,000	5,579	—	—
1967	—	—	—	—
1968	—	—	—	—
FROM SURINAM				
1962	13,444,411	\$ 1,128,370	—	\$ —
1963	16,268,141	1,475,012	—	—
1964	10,340,000	1,038,627	—	—
1965	8,176,774	870,381	—	—
1966	6,846,000	737,676	—	—
1967	6,252,000	691,851	16,000	1,521
1968	5,993,000	678,812	123,000	9,779
FROM SWEDEN				
1962	6,720	\$ 1,125	6,720	\$ 1,125
1963	—	—	—	—
1964	304,000	21,413	83,000	9,392
1965	—	—	—	—
1966	276,000	33,814	276,000	33,814
1967	—	—	—	—
1968	60,000	9,572	60,000	9,572

CONTINUED

Table 2—continued

Year	Total hard- wood plywood (square feet surface measure)	Value	Birch plywood (square feet surface measure)	Value
FROM SWITZERLAND				
1962	62,777	\$ 6,373	62,777	\$ 6,373
1963	42,862	3,583	—	—
1964	—	—	—	—
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	—	—	—	—
FROM TAIWAN				
1962	212,504,529	\$10,119,135	—	\$ —
1963	273,028,050	10,908,233	—	—
1964	461,352,000	19,269,196	—	—
1965	468,602,587	18,983,287	—	—
1966	528,336,000	21,747,451	352,000	13,098
1967	485,432,000	19,449,506	84,000	4,320
1968	829,621,000	34,306,368	35,000	4,569
FROM UNITED KINGDOM				
1962	646,556	\$ 56,932	600	\$ 225
1963	226,245	54,814	—	—
1964	219,000	52,394	1,000	204
1965	182,183	47,854	600	196
1966	178,000	52,426	—	—
1967	132,000	41,106	7,000	362
1968	259,000	100,846	1,000	306
FROM U.S.S.R.				
1962	—	\$ —	—	\$ —
1963	5,922	793	5,922	793
1964	—	—	—	—
1965	4,310	420	4,310	420
1966	—	—	—	—
1967	367,000	23,732	367,000	23,732
1968	2,833,000	166,969	2,833,000	166,969

face measure in 1962, valued at \$18,336,516, to 358,600,000 square feet in 1968, valued at \$39,228,452.

U.S. hardwood plywood consumption in 1967 (domestic shipments plus imports less exports) was 4,128,243,000 square feet surface measure. In 1957 apparent U.S. consumption was 1,632,000,000 square feet. Projected growth in construction, furniture, and other markets suggests further substantial increases in future use of hardwood plywood. Per-capita consumption of hardwood plywood has increased from 10 square feet in 1951 to 31 square feet in 1968.

In addition to hardwood plywood, the United States annually imports a fairly large quantity of hardwood veneer (table 3). In 1964 nearly 800 million square feet of hardwood veneer were imported, mostly from Canada. And in 1968 the import of hardwood veneer had risen to over 1 billion square feet. These imports were mostly from Canada, but Singapore captured nearly 20 percent of the trade—whereas in 1964 Singapore exported little or no hardwood veneer to the United States. The total value of hardwood veneer imported in 1968 was estimated at over \$24,000,000.

The U.S. Forest Service stated in their publication *The Demand and Price Situation for Forest Products 1967* that, "In view of continuing declines in the size and quality of domestic timber suitable for the manufacturer of hardwood plywood and veneer, nearly all of the additional demand for hardwood plywood may be supplied by imports."

The Battelle Memorial Institute made a 9-month study of the plywood industry for the Iowa Development Commission in 1967. Battelle estimates hardwood plywood production for 1970 at 3,280,000,000 square feet, and for 1975 at 4,832,000,000 square feet. With 1967 market shipments at 1,663,129,000 square feet, the United States' industry faces a real challenge to meet Battelle's 1970 estimate.

Domestic manufactured birch plywood is cheaper today than it was 19 years ago (table

4). The United States producer has had to lower prices to meet import competition, yet his cost of logs, labor, and machinery continue to go up.

BIRCH MARKETS

Door Manufacturers

Birch flush doors have been a popular product in the United States. There are approximately 125 flush-door manufacturers in the United States. Each flush door uses two doorskins of 1/8-inch plywood. Interior doors are usually 2 feet 8 inches wide x 6 feet 8 inches and have hollow cores. Exterior doors are usually 3 feet 0 inches x 7 feet 0 inches and have solid cores. About 30 hardwood plywood manufacturers in the United States and four in Canada manufacture doorskins. The production of flush doors with hardwood

Table 3.—United States imports of hardwood veneer, by country of origin, 1964-68

Year	Total hard- wood veneer (square feet surface measure)	Value	Birch veneer (square feet surface measure)	Value
FROM CANADA				
1964	781,682,310	\$25,050,957	732,617,286	\$23,636,773
1965	852,171,174	26,308,453	792,154,865	24,611,629
1966	792,846,000	26,093,908	746,177,000	19,260,000
1967	775,157,000	24,585,145	728,897,000	23,048,766
1968	837,476,000	25,586,064	792,995,000	24,072,904
FROM DENMARK				
1964	—	—	—	—
1965	—	—	—	—
1966	467,000	\$ 33,258	4,000	\$ 2,191
1967	—	—	—	—
1968	—	—	—	—
FROM FINLAND				
1964	415,320	\$ 14,084	415,320	\$ 14,084
1965	—	—	—	—
1966	—	—	—	—
1967	806,000	29,743	634,000	23,169
1968	576,000	24,285	576,000	24,285
FROM WEST GERMANY				
1964	16,539,473	\$ 723,916	90,090	\$ 5,288
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	—	—	—	—

CONTINUED

Table 3—continued

Year	Total hard- wood veneer (square feet surface measure)	Value	Birch veneer (square feet surface measure)	Value
FROM INDONESIA				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	—	—	—	—
1967	2,913,000	27,677	2,913,000	\$ 27,677
1968	—	—	—	—
FROM ITALY				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	2,828,000	103,570	8,000	834
1967	—	—	—	—
1968	—	—	—	—
FROM JAPAN				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	3,074,000	117,606	6,000	3,533
1967	3,271,000	179,822	623,000	31,962
1968	—	—	—	—
FROM MEXICO				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	1,484,000	19,848	1,438,000	19,283
FROM THE PHILIPPINES				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	522,727,000	10,606,872	540,000	6,050
1967	—	—	—	—
1968	—	—	—	—
FROM SINGAPORE				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	192,394,000	2,732,003	2,032,000	22,400
FROM SWEDEN				
1964	158,887	\$ 16,240	27,070	\$ 2,357
1965	—	—	—	—
1966	—	—	—	—
1967	—	—	—	—
1968	—	—	—	—
FROM UNITED KINGDOM				
1964	—	\$ —	—	\$ —
1965	—	—	—	—
1966	2,177,000	194,344	294,000	7,354
1967	—	—	—	—
1968	—	—	—	—

faces in the United States for the years 1958 and 1963 was as follows:

<i>Hollow core</i>		
<i>Year</i>	<i>Quantity</i>	<i>Value</i>
1958	14,904,000 ¹	\$ 90,547,000
1963	19,862,000	\$106,560,000

<i>Solid core</i>		
<i>Year</i>	<i>Quantity</i>	<i>Value</i>
1958	1,385,000	\$ 25,984,000
1963	2,350,000	\$ 39,633,000

Source: 1963 Census of Manufacturers—Lumber and Wood Products Major Group 24.

The importation of birch doorskins from Canada has not constituted any threat to the domestic producers of birch doorskins, and presumably will not in the future, any more so than other competing domestic producers.

This is due partially to the fact that Canadian wage rates are near enough to U.S. wage rates that Canadian manufacturers do not have any substantial price advantage over the U.S. manufacturers. The Hardwood Plywood Manufacturers Association (HPMA) has always cooperated with the Canadian Hardwood Plywood Association in its campaigns to promote the sale of birch veneer and plywood in the United States.

Importation of lauan doorskins is a different matter. After the General Agreement on Tariffs and Trade (GATT) negotiations of 1950, imports of hardwood plywood into the United States swelled from 66,761,000 square feet (approximately 8 percent of the domestic market) in 1951 to 3,838,134,000 square feet (more than 50 percent of the domestic market) in 1968. In the early 1950's the predominant doorskin used in the United States

Table 4.—Wholesale price index for plywood.
(1957-58 = 100)

Year	Hardwood plywood	Birch plywood*	Gum plywood**
1947	96.7	86.5	102.8
1948	100.9	90.3	107.5
1949	88.7	89.0	88.3
1950	96.7	96.4	96.7
1951	105.8	103.9	106.6
1952	96.6	102.0	92.9
1953	103.4	107.6	100.5
1954	95.7	101.9	91.5
1955	97.9	103.5	94.1
1956	99.9	103.6	97.4
1957	99.0	99.8	98.4
1958	99.7	100.0	99.6
1959	101.4	100.3	102.1
1960	102.8	101.2	103.8
1961	101.4	98.9	104.4
1962	97.8	94.7	103.8
1963	97.3	93.2	104.0
1964	98.5	94.4	104.9
1965	98.2	94.1	104.9
1966	99.0	95.0	105.8
1967	97.7	92.7	107.8
1968	98.1	93.3	108.5

Source: United States Department of Labor, Bureau of Labor Statistics.

* Birch 1/4-inch standard panel (specifications as below).
 ** Gum 1/4-inch standard panel grade 1-3 or 1-4, type II glue, 3-ply, 48 x 96 inches, car lots, manufacturer to wholesaler or dealer, f.o.b. factory, per M square foot.

was gum. Lauan doorskins shattered domestic production of gum doorskins.

We believe that 40 to 50 percent of the birch plywood imported in 1963-68 was doorskins. Finnish birch doorskins did not go over in the United States, probably because the grain ran the width of the door rather than the length.

The National Woodwork Manufacturers Association (NWMA) made a survey in 1968 of their members who manufacture birch doors. Seventeen manufacturers responded with total annual volume: 1967—1,508,712; 1968—1,707,713 (+ 13.2-percent increase). NWMA asked the 17 manufacturers if they expected to produce more birch doors in 1969. Here is the breakdown of replies:

YES: 10 firms (average 1968 production 82,000, or 48 percent of total 1968 production).

NO: 2 firms (average 1968 production 266,000, or 31 percent of total 1968 production).

NO ANSWER: 5 firms (average 1968 production 70,000, or 21 percent of total production).

Other than this relation between size and optimism, the survey disclosed another bit of insight. In total volume of production, solid-core doors held about the same place in 1968 as in 1967, (less than 1 percent change).

The aggregate +13 percent gain in 1968 was accounted for entirely by hollow-core doors. Hollow-core doors posted a 24-percent increase in volume for 1968 over the preceding year. Also, hollow-core doors gained a 5-percent greater share of total production in 1968.

The firms covered by this survey do not constitute a valid statistical sample. However, the results are an interesting barometer of recent trends.

Although 101,000 more housing starts took place in the United States in 1963 than in 1968, the number of flush doors used in 1968 was probably as great as in 1963 because there is a trend to use more doors in a home or apartment (table 5). The average number of doors in a typical house 5 years ago was 11; today there are about 25.

Five years ago, closets had one door, now many have four (bi-fold) doors.

Our Federal Government has proposed that we build 2 million homes a year for the next ten years. If mortgage funds are made available and we build 500,000 more homes each year than we did in 1968, this will create a tremendous expansion of the market for wall paneling, flush doors, kitchen cabinets, furniture, etc.

Cabinet Manufacturers

The 1968 edition of *Builder's Kitchen Guide* lists 163 manufacturers of wooden cabinets (and vanities). In the early 1950's probably 70 percent of the wooden cabinets were jerry-built on the site. Shoddy construction gave the market to metal cabinets.

Toward the end of 1950, wood recaptured the major share of the cabinet market with factory-built and factory-finished cabinets designed in furniture style concepts. Birch is probably the most popular hardwood plywood species used for kitchen cabinets.

Birch plywood's big competitors today in the cabinet field are wood-grained plastics.

Probably 70 percent of the wooden cabinets sold go into new homes, and the other 30 percent for remodeling.

In 1966, the National Kitchen Cabinet Association indicated that approximately 20 percent of the sales dollar of a cabinet manufacturer went into hardwood plywoods. This same survey estimated that 3 million kitchens would be sold in the United States in 1966 at a conservative average manufacturer's selling price of \$250 per kitchen, or sales of \$750,000,000. Using the figure of 20 percent of the sales dollar as the overall share of hardwood plywood costs, we have a potential

Table 5.—Housing starts in the United States, 1963-68

Year	Single-family construction	Multi-family construction
1963	1,020,700	589,600
1964	971,500	557,800
1965	963,800	509,100
1966	778,500	386,500
1967	843,900	447,500
1968	899,400	609,900

Sources: U.S. Bureau of Census NAHB.

volume of \$150,000,000 to be spent with plywood manufacturers.

Increasing amounts of Finnish birch plywood are being used in the cabinet industry, primarily because of price. Finnish birch has a uniform light color and has more plies than U.S.-manufactured birch. A 3/16-inch Finnish panel is of 4-ply construction; a 1/4-inch panel manufactured in the United States is usually of 3-ply construction. A 1/2-inch Finnish panel is 9-ply; a 1/2-inch U.S. panel is 5-ply. Some risks are involved in using the Finnish birch—in deliveries, dock strikes, and poor communications. The importers have eased the danger of delayed shipments by warehousing sizable inventories of plywood in the States, cut to size, and graded for their customers.

Mobile Home Manufacturers

Birch plywood is used in mobile homes for wall paneling, kitchen cabinets, and flush doors. The new models become more luxurious each year, and hardwood plywood adds to the luxury look. The outlook for continued expansion of the mobile home and travel trailer industry and for increased use of this mode of housing throughout the United States is excellent.

The U.S. Department of Housing and Urban Development (HUD) reports mobile homes sales up from 235,000 in 1967 to 330,000 in 1968. The Mobile Home Manufacturers Association (MHMA) estimates 1972 production around 400,000. Mobile homes are 10 to 12 feet wide and 29 to 59 feet long.

A U.S. Forest Service study in 1966 estimated cost of finished plywood paneling and cabinets at 23 to 25¢ a square foot, totalling \$78,800,000 (translating this mobile home material into dollars). Information gathered from 9 major mobile home manufacturers (31 separate plants) revealed that the use of native hardwood plywood—mostly birch, oak, ash, and elm—averaged 440 square feet for each home. Imported plywood, mostly lauan, averaged 400 square feet. In 1968, MHMA reported that approximately 2,116 square feet of hardwood plywood are used in the average 12- x 60-foot unit.

The three large potential markets for mobile homes are: (1) for vacation, second home, and rural homes; (2) for mobile home development comparable to permanent home development; and (3) for adaptation of

mobile homes to low-rise sectionalized construction (especially in urban rehabilitation).

The U.S. Department of Commerce estimates that the value of mobile home manufacturer's shipments in 1969 will increase 19 percent over 1968. The estimates forecast that mobile homes will provide 80 percent of the new single-family housing made available in 1969 at prices up to \$15,000 per unit. The average cost of a mobile home, furnished, is just at \$8.70 per square foot, compared with \$18.50 for a furnished house built in the conventional manner, land cost excluded.

Home Builders

Birch plywood is used primarily by the home builder for paneling, kitchen cabinets, and flush doors. The greatest use of hardwood plywood in residential construction is in paneling of dens or recreation rooms. Paneling is a popular product for do-it-yourselfers because of the simplicity of installation, and is used in many kitchen-remodeling, add-a-room, and basement-remodeling projects.

The U.S. Census reported that total prefinished, printed, embossed, and vinyl-laminated hardwood plywood in 1967 was 1,481,048,000 square feet surface measure. Lauan is the species most frequently prefinished. Birch is second: over 225,000,000 square feet surface measure were prefinished in 1967.

Furniture and Fixtures

Wholesale sales of household furniture have increased in the past decade from \$2.5 billion in 1958 to an estimated \$4.3 billion at the end of 1968. According to Charles O. Gordon, president of the Southern Furniture Manufacturers Association, furniture sales will double by 1982.

Some of the uses of birch plywood in furniture and fixtures are indicated in table 6.

It is difficult to estimate the amount of birch plywood going into the furniture industry because there is a large captive production of hardwood plywood within the industry. This captive production is not included in the Bureau of Census annual report on hardwood plywood shipments.

CONCLUSIONS

Thomas C. Mason, Director of the Forest Products Division of BDSA, U.S. Department of Commerce, stated at an HPMa meeting

Table 6.—Birch plywood used in selected manufacturing industries, 1965
(In thousand square feet, $\frac{3}{8}$ " basis)

Industry	Native birch plywood	Plywood from imported birch
Total ¹	179,530	25,314*
<i>Lumber and Wood Products, Except Furniture:</i>		
Hardwood dimensions	470**	—
Millwork plants	56,485	3,721**
Veneer and plywood plants	1,837**	726**
Prefabricated wooden buildings and structural members	637*	—
Nailed and lock-corner wooden boxes and shooks	429**	(²)
Other wood products	521*	(²)
<i>Furniture and Fixtures:</i>		
Wood household furniture, except upholstered	62,309	15,577**
Wood household furniture, upholstered	828*	183
Metal household furniture	2,968**	715**
Mattresses and bedsprings; other household furniture	68**	—
Wood office furniture	223**	300
Metal office furniture	1,564*	—
Public building and related furniture	4,217*	126**
Wood partitions, shelving, lockers; office and store fixtures	16,677	1,870**
Metal partitions, shelving, lockers; office and store fixtures	797**	—
Other furniture and fixtures	948*	141**
<i>Leather and Leather Products:</i>		
Luggage	295*	(²)
<i>Transportation Equipment:</i>		
Motor vehicles and motor vehicle equipment	(²)	—
Trailer coaches, housing type	18,794	163**
<i>Machinery, Except Electrical:</i>		
Mechanical power transmission equipment, except ball and roller bearings	—	1,133**
<i>Miscellaneous Manufacturing Industries:</i>		
Musical instruments and parts	495**	—
Games and toys, except dolls and children's vehicles	1,232**	447**
Sporting and athletic goods	(²)	—
Signs and advertising displays	6,741**	143**
<i>All Other Selected Industries</i>	921*	(²)

* Standard error of estimate between 16 and 30 percent. Unmarked figures have a standard error of estimate of 15 percent or less.

** Standard error of estimate of over 30 percent.

¹ Figures may not add exactly to the totals because quantities less than 50,000 square feet have been omitted.

² Less than 50,000 square feet.

Source: Preliminary Summary Tables—Wood Used By Manufacturers Industries, 1965. T. G. Gill, U.S. Forest Service.

in March 1964 that the supply of yellow birch veneer logs grown in the Northeast and the Lake States was virtually exhausted. The supply of large-diameter high-grade birch logs and bolts is extremely limited. The hardwood plywood and veneer manufacturers complain constantly that the quality of logs is going down each year and the price of logs going up so the manufacturer is being forced to haul birch logs greater distances than ever before.

The situation will probably get worse before it gets better. The supply of birch from both old-growth stands and from stands that originated after the heavy cuttings of the turn-of-the-century is rapidly being exhausted, and there are relatively few stands in the less-than-50-year-old age bracket because of the extensive use of partial cuttings and uneven-aged management in 1930-60.

In the face of decreasing supplies, projections for the future indicate that the demand for hardwood veneer logs of all species may increase by as much as 170 percent by the year 2000. Unless this demand can be met, other materials will surely be substituted in

the manufacture of fine furnitures, paneling, and other products.

To meet future demands, every effort must be made to encourage timberland owners — both private and public — to care for their birch timber and to initiate more intensive birch culture on the better sites. New research information will be needed to increase the efficiency of birch timber production, and to reduce the time required to produce a quality crop.

Though reconstituted wood products such as flakeboards, particle boards, and hardboards may eventually replace traditional lumber for many products, it seems certain that the market for high-quality veneers will continue to expand. Thus future markets will continue to place a premium on clear defect-free logs in the large size classes.

The hardwood plywood and veneer industry must adapt technology that will allow it to economically process logs of both small diameter (11 to 14 inches) and low quality, to expand its use of domestic species, and to compete with other wood-processing industries for the available log resource.



BOLT, LOG, AND TREE GRADES FOR BIRCH

by ROSWELL D. CARPENTER, *Forest Products Technologist, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Columbus, Ohio.*

A BIRCH TREE is made up of a variety of round pieces of wood that can be used to manufacture many different products. To convert the tree into its best end use, it is first necessary to classify the usable round pieces into major product classes. These product classes will vary from low-quality wood suitable only for pulpwood or charcoal to high-quality wood for making fancy veneer (fig. 1). After the major product classification is made, a grading system is used to determine the relative value of the log, bolt, or tree for that product.

CLASSIFYING AND GRADING BIRCH LOGS

Birch logs can be segregated into four major product classes: veneer, factory lumber, construction lumber, and local-use lumber.

Veneer logs

Veneer logs are those best suited to conversion into veneer by rotary cutting, slicing, or sawing. Grade specifications are used to segregate the veneer-class logs into high, medium, or low value strata in proportion to their yields of the better quality products. Veneer products represent a great spread in both the value and the timber quality required to yield the various items. Birch veneers include: (1) face veneers for furniture, cabinets, and plywood panels; (2) backs and core stock for plywood panels; and (3) container veneer for containers and picnic utensils.

There are no standard hardwood veneer-log grades now. Work to develop such grades is scheduled for early attack in current project programs. However, we have developed some interim northern hardwood veneer-log specifications; they were evolved by extending some general specifications published earlier by the Northern Hardwood and Pine Manufacturing Association (fig. 2).

Factory-Lumber Logs

Factory-lumber logs are those best suited to sawing into standard factory lumber for remanufacture into other products. Grades for standard hardwood factory lumber logs include three grades, which are related to the yield of various grades of lumber that can be sawed from these logs.

The Forest Service hardwood sawlog grades for standard lumber were developed through research by the Forest Products Laboratory with assistance from the eastern forest experiment stations; they were published by the Forest Products Laboratory in March 1949. My project in Columbus, Ohio, took this work over in late 1959 and is continuing to check the specifications and to develop lumber grade yields for species on which data was either inadequate or lacking. Two publications are planned to make these lumber yield data available within the next year or two. The factory-lumber log grade specifications are shown in figure 3.

Hardwood Construction Logs

Hardwood construction logs are those best suited for sawing into railway cross and switch ties, structural timbers, and other articles of structural lumber such as: studs, railway car material, construction boards, wagon stock, mine lumber and timbers, bridge and crossing plank, and sound square edge lumber. The Forest Service has published standard specifications for this class of logs, but yield data to accompany them in terms of the several alternative products remain to be developed. Present specifications represent the minimum requirements for this class of products, so there is but one grade. The hardwood construction log class specifications are shown in figure 4.

Local-Use Logs

The local-use class of logs includes the droppings from the previous classes. The

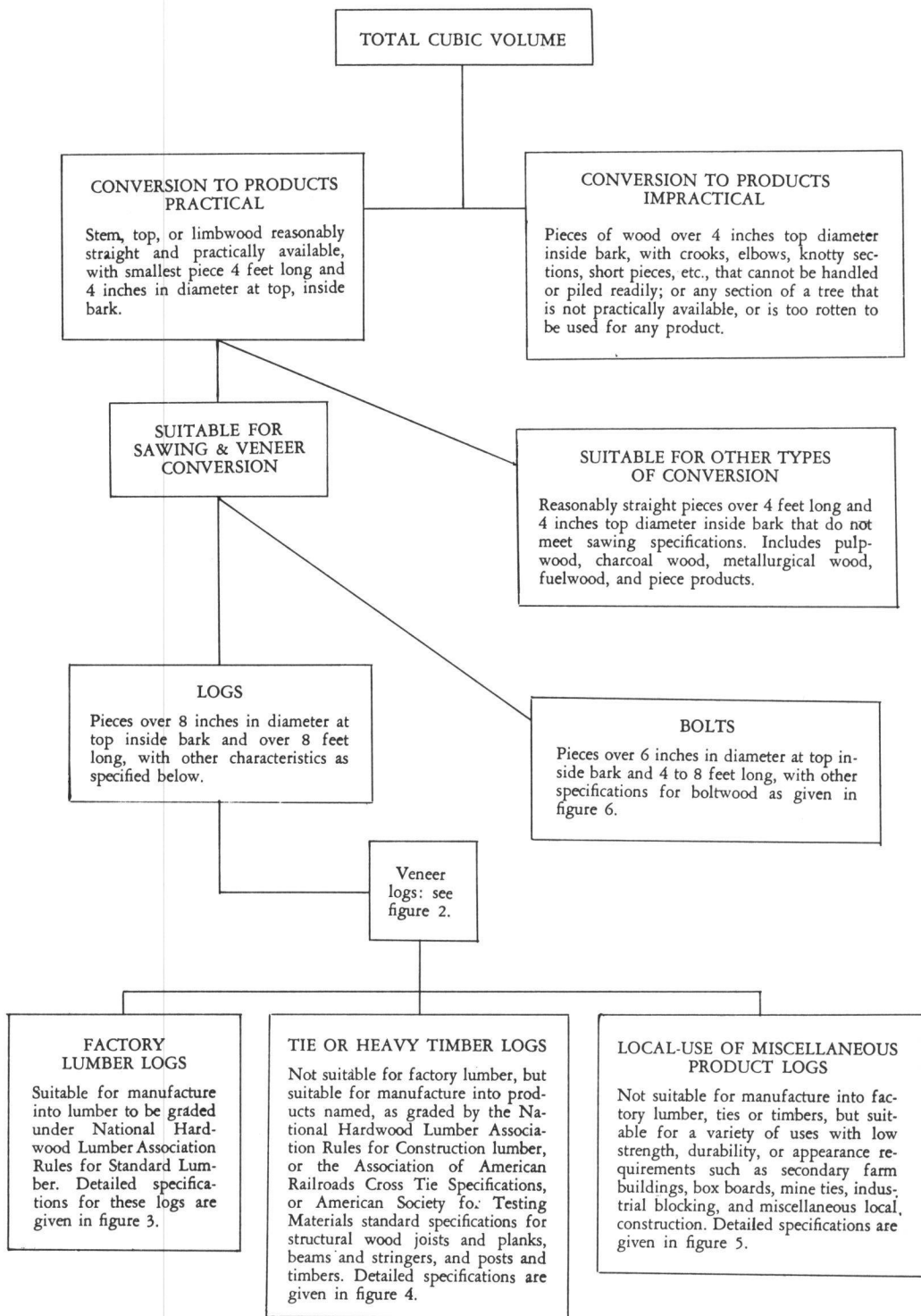


Figure 1.—The products obtainable from the total cubic volume in a birch tree.

NORTHERN HARDWOOD VENEER-LOG AND BOLT SPECIFICATIONS

<i>GRADING FACTORS</i>	<i>SPECIFICATIONS</i>
1. Length	8 feet over (plus 6 inches trim) ¹
2. Diameter, minimum	12 inches d.i.b. (small end) ²
3. Sweep	¼ inch per foot of log length
4. Crook and/or catface	1 admitted if it can be contained in a 2-foot long scaling reduction from either end, or from within the log provided that a cutting at least 52 inches long remains on each side of the scaled-out portion.
5. Spiral grain	Maximum ½ inch per foot of log length.
6. Crotch	Crotch admitted in logs of all diameters provided it can be cut off by deducting 1 foot of length in scaling.
7. Seam	No seams that enter the right cylinder admitted in logs 12-14 inches d.i.b. Logs 15 inches d.i.b. and larger admit 1 seam that enters the right cylinder provided it diverges no more than ½ inch per foot of log length from a straight line between the log ends. Such a seam constitutes 1 standard defect.
8. Standard defect other than seam ³	One standard defect admitted in logs 8-10 feet long, 2 in logs 12 feet, and 3 in logs 14-16 feet.
9. End defects	
A. Black heart and/or mineral stain	Admitted in hard maple logs when not in excess of ½ the scaling diameter.
B. Hole, rot, ring shake, loose or spider heart, and heart checks	Admitted when confined to a central core around the geometric center of the log end and the last 2 feet of log length (subject to scaling reduction.) ⁴ After scaling reduction: logs 12-14 inches d.i.b. can contain central core if long axis is no longer than 3 inches; logs 15 inches d.i.b. can contain central core if long axis is no longer than 4 inches; and logs 16 inches d.i.b. and larger can contain central core if long axis is no longer than 6 inches.
C. Knots, partial ring shake, worm holes, bird pecks, stain spots, incipient rot areas, and bark pockets.	Admitted to all logs outside the central core (9B) when limited to a ¼ segment of one end. When they occur on both log ends they must be limited to same ¼ segment in logs 12-15 inches d.i.b.; they can be in different ¼ segments in logs 16 inches d.i.b. and larger.

¹ 7-foot lengths are accepted by most mills; 6-foot lengths are accepted by most mills for black walnut.

² Select veneer-grade logs (those 14 inches d.i.b. and over) must be free of all defects except for the allowable unsound central core (9B) and sweep (3).

³ Standard defects are knots, worm holes, dead or rotten areas, high bumps (with height over length ratio greater than 1 to 6), heavy bark distortions, and old bird pecks (4 or more per square foot). Treat any number of defects as 1 standard defect when they are located not more than 10 inches from an end or when they are so located within the log that they can be included in a 1-foot reduction in log length when scaling.

⁴ Logs subject to 2-foot scaling reduction in length due to unsound central core (9B) permit unlimited surface defects over the 2 feet that are so treated (8).

Figure 2.—Northern hardwood veneer-log and bolt specifications.

HARDWOOD TIMBER-GRADING SPECIFICATIONS FOR HARDWOOD FACTORY-LUMBER LOGS

GRADING FACTORS		LOG GRADES							
		F1			F2			F3	
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Diameter, scaling, inches		¹ 13-15	16-19	20+	² 11+	12+			8+
Length, without trim, feet		10+			10+	8-9	10-11	12+	8+
Clear cuttings ³ on each 3 best faces ⁴	Length, minimum, feet	7	5	3	3	3	3	3	2
	Number, maximum	2	2	2	2	2	2	3	No limit
	Percent of log length required in clear cutting	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Sweep allowance (maximum) in percent of gross volume	For logs with less than ¼ of end in sound defects	15%			30%				50%
	For logs with more than ¼ of end in sound defects	10%			20%				35%
Total scaling deduction ⁵		40%			* 50%				50%
End defect:		Covered by special instructions							

¹ Ash and basswood butts can be 12 inches if otherwise meeting requirements for small No. 1's.

² 10-inch logs of all species can be No. 2 if otherwise meeting requirements for small No. 1's.

³ A clear cutting is a portion of a face free of defects, extending the width of the face.

⁴ A face is 1/4 of the surface of the log as divided lengthwise.

⁵ Otherwise No. 1 logs with 41-60 percent deductions can be No. 2.

⁶ Otherwise No. 2 logs with 51-60 percent deductions can be No. 3.

Figure 3.—Hardwood timber-grading specifications for hardwood factory-lumber logs (USFS Research Paper FPL-63).

products of this class of log are simply local-use lumber plus a limited yield of pallet boards. The specifications have not been approved by the Forest Service as standard but have been published by the Northeastern Forest Experiment Station on an interim basis (figure 5).

CLASSIFYING AND GRADING BIRCH BOLTS

Birch bolts can be segregated into three major product classes: veneer, saw, and chip and chemical classes.

Veneer bolts

Veneer-bolt grades are subject to the same considerations as veneer-log grades, and the same research program will be followed in developing grades for them.

Saw bolts

Saw bolts are those best suited to sawing into blanks for: (1) furniture dimension — flat and squares, (2) box and crate material, (3) turnery material, (4) handle stock, and (5) specialty products. A single set of bolt grade specifications may apply to several of these product groups, thus making it unnecessary to formulate specifications for each

individual product group. For instance, the same bolt-grade specifications may prove satisfactory for turnery material, handle stock, and specialty products.

Two bolt-grading systems for saw bolts have been used. Both are of arbitrary origin. The first was developed by R. D. Carpenter and C. R. Lockard in 1948 at the Southern Forest Experiment Station; they were used at log-grade training schools in the South. They follow the same basic principle of determining size and number of clear face cuttings that is used in the Forest Service hardwood saw-log grades for standard lumber. There are no product yield tables for them. The grade specifications for this system are included in figure 6.

The second bolt-grading system was published in a report by the Southern Furniture Manufacturers' Association, High Point, N.C., in February 1957.¹ Yield data are included in the report for sweetgum, oak, and yellow-

¹ SHORT LOG BOLTER FOR FURNITURE STOCK, by George P. Redman, Department of Engineering Research, North Carolina State College, Raleigh, North Carolina.
poplar. The grades are as follows:

HARDWOOD TIMBER-GRADING SPECIFICATIONS FOR CONSTRUCTION LOGS

Note: These specifications are minimum for the class. If, from a group of logs, factory logs are selected first, thus leaving only non-factory logs from which to select construction logs, then the quality range of the construction logs so selected is limited, and the class may be considered a grade. If selection for construction logs is given first priority, then it may be necessary to subdivide the class into grades.

Position in tree		Butt and Upper
Diameter, small end		8 inches +
Length, without trim		8 feet
Clear cuttings		No requirements
Sweep allowance, absolute		$\frac{1}{4}$ diameter small end for each 8 feet of length.
Sound surface defects	Single knots	Any number, if no one knot has an average collar diameter in excess of $\frac{1}{3}$ of log diameter at point of occurrence.
	Whorled knots	Any number if sum of collar diameters does not exceed $\frac{1}{3}$ of log diameter at point of occurrence.
	Holes	Any number provided none has a diameter over $\frac{1}{3}$ of log diameter at point of occurrence, and none extends over 3 inches into included timber. ¹
Unsound surface defects		Same requirements as for sound defects if they extend into included timber. ¹ No limit if they do not.
End defects	Sound	No requirements.
	Unsound	None allowed; must be sound internally, will admit 1 shake not more than $\frac{1}{3}$ width of timber and 1 split not more than 5 inches long in contained timber.

¹ Included timber is always square, and dimension is judged from small end.

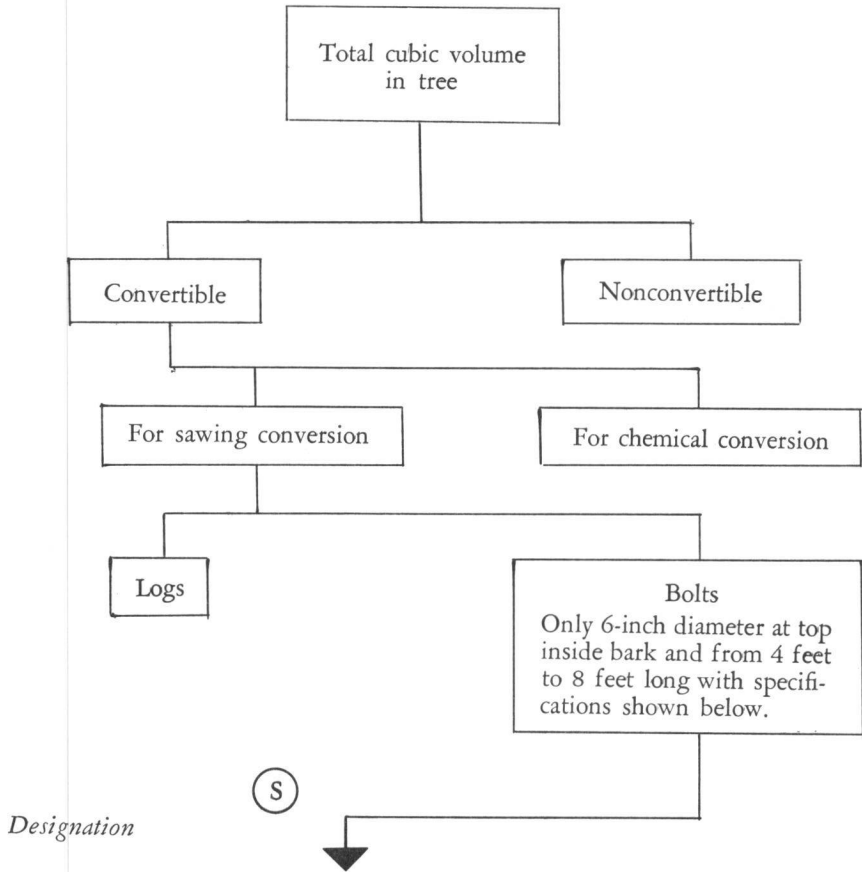
Figure 4.—Hardwood timber-grading specifications for construction logs.

HARDWOOD TIMBER-GRADING SPECIFICATIONS FOR LOCAL-USE LOGS

Position in tree		Butt and upper
Diameter, small end		8 inches +
Length, without trim		8 feet +
Sweep allowance, absolute		$\frac{1}{2}$ diameter of small end
Total scale deduction allowed		50% to 67%
Clear cuttings		No requirements
Surface defects	Sound	Only requirement is that diameter of knots, holes, rot, etc., shall not exceed $\frac{1}{2}$ diameter of log at point of occurrence.
	Unsound	
Sound end defects		No requirements.

Figure 5.—Hardwood timber-grading specifications for local-use logs.

SPECIFICATIONS FOR SAW BOLTS



Specifications \ Grade		S1		S2
Position		Butts	Upper	Butt and upper
Diameter, minimum top		6"	10"	8"
Length		4 feet to 8 feet w/o trim		4 feet to 8 feet w/o trim
Sweep		Max. 1" per 4' length		Max. 15% (in inches) of diam.
Total cull allowed		15% including sweep, if interior confined to heart core or bad face		25%, including sweep
Best 3 faces	% in clear cutting	100% clear		2/3
	Max. no. cuttings			2
	Min. lgth. cuttings			2
Sound end defects		None except that confined to heart core		1/4 area of end outside heart core

Figure 6.—Specifications for saw bolts.

<i>Grade</i>	<i>Description</i>
--------------	--------------------

- | | |
|---|---|
| 0 | No defects visible on bolt. |
| 1 | Visible defects confined to 1 quarter of the bolt. |
| 2 | Visible defects confined to 2 quarters of the bolt. |
| 3 | Visible defects confined to 3 quarters of the bolt. |
| 4 | Visible defects in all 4 quarters of the bolt. |

Anything was considered a defect which would not be permissible in a clear face cutting.

No mention was made of the admission of any sweep, crook, or interior cull; so it must be assumed that all bolts were straight and sound. Bolt lengths were 26, 35, 43, 51, and 72 inches.

Chip and Chemical Bolts

Chip and chemical bolts are those best suited for: (1) pulpwood, (2) charcoal, (3) chemical-distillation wood, (4) roofing felt, and (5) excelsior. Here too it may be possible to develop grade specifications that will apply for more than one product. A set of minimum specifications may be developed rather than a full grading system.

GRADING BIRCH TREES FOR FACTORY LUMBER

There are now no tree grades for birch. However, our plans call for the publication of yellow birch tree grades for factory lumber by 1970. Yellow birch was one of the first species for which we were able to get adequate tree data for this purpose. These data have been used to test different lengths of sections of the butt log as an indicator of tree grade for lumber. So far none of these tests has provided segregation between grade 2 and grade 3 trees. A final set of tests is being run for indicator sections. If these fail, we plan to test defect count on the butt log as an indicator of tree grade. The only way we now have to determine tree quality or grade is to grade each log in the tree, and the grade is expressed only in terms of lumber.

A complete tree-grade system is needed to express the highest potential tree value, when each piece of the stem (log or bolt) is channelled to conversion for the best end product. To accomplish this, we need to complete the development of quality specifications for the whole package of primary round pieces from veneer logs to pulpwood bolts and fence posts.

We also hope to investigate the possibility of developing a hardwood tree-grading system based on yields of random-sized clear cuttings. System analysis will be employed for this investigation. We hope that such a system will permit classification of trees into classes that will reflect their overall value for a wide variety of products.



PRIMARY UTILIZATION OF BIRCH

by HENRY W. SAUNDERS, *Executive Vice President, Saunders Brothers, Westbrook, Maine.*

FROM AN INDUSTRY point-of-view, procurement of raw material and primary manufacture present problems today and challenges for tomorrow.

So that you may become more familiar with the white birch industry and more specifically with Saunders Brothers, I will briefly explain some of the products we manufacture and some of the methods we use to make them. In some ways, we do things quite differently from the long-log users in the industry.

Some of the veneer firms in the birch industry make such items as toothpicks, ice cream spoons, and tongue depressors. Other firms in the industry make thread spools and furniture turnings.

Our company makes dowels for the hardware trade, toy and furniture items, novelty turnings, and pool cues. We are equipped to do almost anything that can be done to a round dowel, including pointing and rounding the ends, drilling, sanding, and painting (fig. 1). For example, one of our customers makes Tinker Toy sets. White birch, because of its light color, moderate strength, and easy workability, is an ideal species for most of our products.

Most of the finished products we sell are less than 12 inches long, and some items such as Beano discs are only 3/16 inch long.

Small Items, Short Bolts

Because our final products are relatively small items, and because hardwoods—particularly white birch—usually grow as crooked trees, the bolter or short-log saw has become the basic head rig in the industry. Four-foot bolts are the most common length that we saw. Various Forest Service studies have indicated a 25 percent greater lumber recovery from a bolter than from a long-log headrig. However, this is not without a sacrifice in production per man. The bolter in many ways is a very old-fashioned tool.

We carefully grade our boltwood according to quality, and sort out the rough knotty sticks to sell as pulpwood. The quality of the timber we use is one of the most important decisions we make because the products we manufacture must be 100 percent clear of defects.

Our company has 350 employees, and nearly 70 of them are involved in sorting and cutting out knots and defects. If we used a slightly poorer quality of birch, our labor costs could easily increase by \$150,000 a year. This does not include anything for the many wasteful steps involved in machining wood that should have gone to a chipper in the first place.

Timber quality is therefore vital to our survival and to operating our mills profitably. And after all, the real reason for being in business is to enjoy profits.

Purchasing Practices

Our philosophy of wood procurement is to buy white and yellow birch from our suppliers in any form. We buy stumpage, bolts, logs, and tree lengths. We accept wood at roadside, loaded on trailers, loaded on the railroad, or delivered to our mills.

Our preference is for 39- and 51-inch bolt lengths, but we also buy 48-inch lengths so that a pulp producer need only sort out his better quality birch bolts. During the summer, we spray bolts and logs with water to prevent spoilage.

We strive to purchase all the boltwood and logs that are offered to us, and then we supplement this open-market wood by logging white birch, yellow birch, rock maple, and beech from our own timberlands.

We do not attempt to log large quantities of species that we do not use ourselves. As an example, it is just not feasible to operate 1,000 cords of pulpwood to produce only 100 cords of birch that we need for our own mills.

I know of no other industry that has more problems and worries with raw material procurement than does ours. In recent years, sales in our industry have definitely been limited by our inability to find a timber supply promptly when the market wanted our products. Some sales have been lost forever to aggressive competitors who sell such products as plastic mouldings and aluminium or steel tubing.

The Problem: Find It

In spite of talk to the contrary, I believe that we have enough white and yellow birch growing to satisfy our present requirements, and that in the not too distant future this resource will be more abundant. These thoughts are based on studies of the forest surveys of Maine and New Hampshire, on many hours hiking in the woods and flying over them, and on discussions with landowners who believe they are not cutting their current growth of birch. In Maine, we are just about cutting our growth of white birch in bolt-wood and sawlog sizes.

I have long believed that we should be prepared for a day when the forest resources are

not as plentiful; and that research in silviculture, tree planting, and genetics should continue. We should strive to produce better quality and faster growing hybrids of birch. I am often reminded of a lot we operated on the National Forest at Twin Mountain, New Hampshire, where many white birch trees grew to be 18 inches in diameter in only 36 years. Reproducing fast-growing trees such as these should certainly be an important challenge to our forest scientists.

The problem of supplying the birch-using industry with raw material is not a lack of adequate timber growth, but a problem of finding and purchasing stumpage, and delivering to the sawmill. Our wood supply must be put on a steady dependable year-round basis and not on the crisis-to-crisis basis that has existed in recent years.

Manpower

This problem is complicated by changing times and a more affluent society. In good times, people tend to gravitate away from woods work: in harder times many will move back into the woods. There is a problem of not having enough people working in the

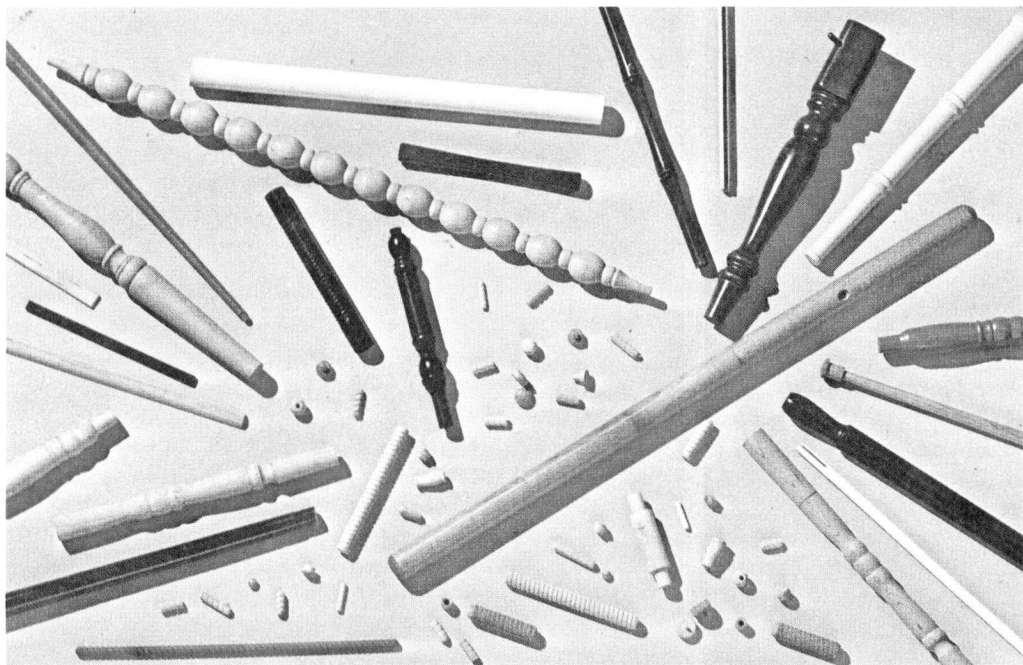


Figure 1.—Some of the dowel products and custom turnings made of birch by Saunders Brothers.

woods to supply the wood requirements in times of prosperity.

In addition, many woods workers are treated as second-class citizens. They frequently do not have steady year-round employment with the same benefits that factory workers enjoy. How many woods workers have group insurance, holiday pay, or vacation pay?

To help solve the manpower problem, I think we will continue to see more company-operated woods crews. These crews will be well-equipped with efficient mechanical equipment and will operate year round. Company crews play an important part in the total supply picture by delivering a steady increment of wood during difficult times such as the heavy snow period of this last winter.

Mechanization

In the past 6 years, mechanization in the woods has been very impressive, but even now we do not have all the equipment we need.

When I was 16 years old, I spent one summer vacation working in the woods as a chopper. My earnings at \$7 per cord were nothing to brag about. The pay for chopping is about the same today because the chain saw is so much faster, but the hard physical work still exists.

Many men can readily learn to operate bulldozers, skidders, loaders, and trucks; but most men never learn to be very productive cutting trees. We desperately need a machine that will cut down a tree, remove the top, and place the remaining stem for easy pickup by a skidder. I have in mind a shear attached to a Prentice-type hydraulic loader to handle trees up to a 20-inch stump diameter. The Beloit people have recently started to make such a unit to handle trees up to 14 inches in diameter.

Another unit of mechanical equipment that we need is an efficient cutup saw to help separate the various grades in each tree and then pile them for trucking. It will become increasingly important for suppliers to separate the various grades in each stem. These saws will become especially important if chip harvesters become more commonplace.

We must strive in the near future to help those who work in the woods become more highly productive. As this trend develops, our sawmills and pulpmills should expect to handle long logs and tree lengths and to separate some of the various grades for other

uses and resale. Long lengths can be cut up easier and faster in the mill yard, and there the grades can be more accurately determined.

Ownership

The next problem that we must solve relates to our changing land ownership. Much of the ownership in the Northeast is in small parcels of approximately 100 acres, and many owners are more interested in recreational use of their land than they are in timber production. The time involved in buying stumpage from such owners is usually considerable because they lack knowledge about timberland. We should encourage our small landowners to join together into efficient long-term management arrangements. They could receive more use of their land for recreation as well as greater earnings from good forest management.

At the same time, they could provide raw materials that would contribute to the general wealth of our area.

The biggest landowner in our region is the U.S. Forest Service. Their present efforts seem to be devoted more to recreation than to helping supply their abundant hardwoods to industry in the Northeast. The economy of the three northern New England States suffers as a result. The largest cut on the White Mountain National Forest was last year when they sold only the equivalent of 1/10th cord per acre from their timber-producing lands. A cut of two or three times this amount would help prevent the panic buying that has existed in the last few years.

We would urge them to consider longer range cutting agreements, easier and quicker methods of selling timber, more efficient methods of scaling, and some way of establishing credit with reliable operators.

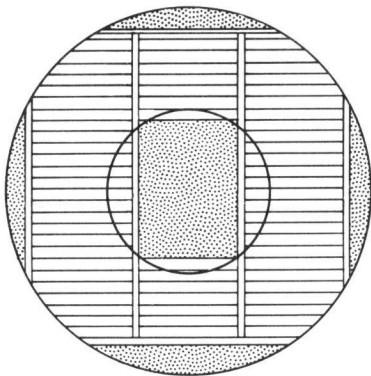
It certainly must be important to our Federal Government to encourage and to help the forest industry that is located in the Northeast and thereby secure the employment they provide. A joint committee of the Forest Service and industry should study these problems.

Our New Sawmill

Now I would like to tell you briefly about the new sawmill that Saunders Brothers are building. We are very enthusiastic about this new mill, which is designed to be far more productive with less manpower than our present mill. We intend to eliminate practically all hard physical work, and we somewhat

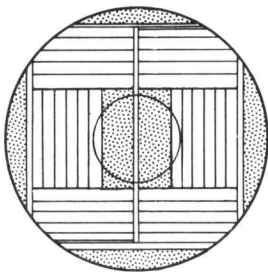
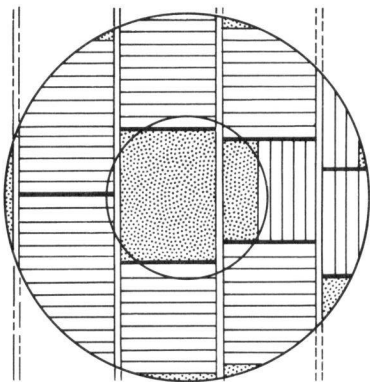
Figure 2.—Sawing patterns for the old-fashioned bolter saw (left) and the new four-saw headrig (right). The new saw rig is expected to increase yield of dowel slats substantially.

BOLTER

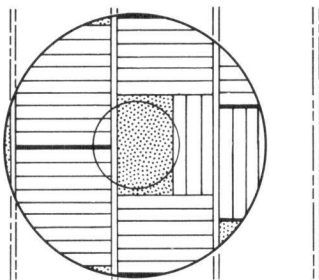


14-INCH BOLT
SAWED INTO 1/2 X 4 BOARDS

FOUR-SAW HEADRIG



10-INCH BOLT
SAWED INTO 1/2 X 4 BOARDS



KEY

TWIN BAND CUTS	——	WASTE	
EDGER CUTS	——	HEARTWOOD	
HEADRIG CUTS	==	PERFECT BOARD	

facetiously say that the mill is designed so women will be able to operate it. I like to joke about hiring a beautiful blonde as a sawyer.

Under our present operation, the bolter removes two or three slabs and then saws the sapwood into 4-inch cants. The redheart is often unsound and is conveyed to the chipper. The cants are then resawed into thin boards on a twin band resaw. This method tends to waste sapwood, which is normally the best part of the bolt (fig. 2).

In addition, the bolter is slow. It requires a strong person as a sawyer, and sometimes a helper to handle the large 4-foot bolts.

Our new method, which is the result of considerable planning, will use a 250-horsepower four-saw headrig with an overhead carriage, to split the bolt into cants. The bolts can be easily rotated to their best sawing

position. The 4-inch cants will be conveyed to an edger, which will remove any edgings and heartwood and saw straight lines for the twin band resaw.

We hope to achieve a substantial increase in production and yield by sawing the bolt in reverse of conventional methods. We should recover nearly 100 percent of a perfect bolt into dowel slats. We can select all the best portion of a lower quality bolt and send all the low-grade wood to the chippers. By this process, we will be able to saw a slightly poorer quality stick and actually end up sending better quality to our dowel mill.

In summary, these are the more serious problems confronting the birch industry, and especially those relating to raw-material supply. I hope that, with the continuing support of groups such as this, we can look forward to successfully meeting the great challenge of the future.



SOME BENEFITS, PROBLEMS, AND CONCERNS OF A SECONDARY USER OF YELLOW BIRCH

by JOHN E. BENT, President, S. Bent & Brothers, Inc., Gardner, Mass.

S. BENT & BROTHERS, Inc. is a small furniture company located in Gardner, Massachusetts, specializing in the manufacture of Early American wooden seat chairs. Because of our size and our specialization, we do not necessarily represent the industry in our ideas about and use of yellow birch as a primary raw material.

Our company during the past 100 years has made furniture from mahogany, chestnut, oak, white pine, hard pine, rock maple, and yellow birch. Various reasons such as availability, price, workability, and consumer demand have dictated which species we have used at different points in our history.

Today we use about 2 million feet of yellow birch lumber and about 2 million feet of yellow birch and rock maple dimension stock. The lumber is used almost exclusively in making seat blanks; the maple dimension stock is used for the arms; and the yellow birch dimension stock is used for the backs and other parts.

Our lumber is purchased in 6/4 and 8/4 thicknesses and is shipped by truck and freight car from mills in Maine, New Hampshire, Vermont, Quebec, and New Brunswick. We stick all this lumber in the air-dry or green condition on bunks on a rail system prior to pre-drying and kiln-drying. Our dimension stock is shipped mainly from New England; and, depending upon the use, is yellow birch, rock maple, or mixed.

We have run maple through our plant in the same manner as yellow birch, but have experienced difficulty in educating our personnel to identify the two species and to understand why they must be kept separate. We feel that we have an easier time drying yellow birch than rock maple, possibly because the mineral in the maple is more likely to cause degrade in the drying cycle. We also feel

that we have fewer problems in checking with the yellow birch while it is being processed prior to finishing.

Because of a more porous grain, yellow birch does not sand to as smooth a finish in the white wood as maple, but this is actually an advantage in the finishing operation. In matching our stain colors to other manufacturers', which is a large part of our business, we find birch is much easier to work with. We actually have to take extra finishing steps when using maple parts to either shade the light parts or artificially open the grain to allow the stain to penetrate better.

It was mentioned earlier that we may not be representative of the industry because there are manufacturers who purchase stock from our same suppliers who specify all birch or all maple. Usually a case-good manufacturer will be able to use maple and realize a good yield regardless of the mineral in the stock, because he needs part of his supply to make hidden parts such as drawer sides or upholstery frames. But in our work—where all parts are exposed, as they are in a Colonial chair—the parts should be 100 percent clear of all defects.

For this reason, we have found a better yield when using both sap and heart wood from yellow birch, because the color differential is usually compatible and there is no mineral to open up in the drying process, as there is in maple.

We are aware that the price of maple is less than that of a comparable grade of yellow birch, but this advantage is mostly washed out in high-grade furniture because we would have to specify No. 1 and No. 2 white (maple), which commands a premium price over regular maple.

The one place where we have found rock maple to be superior to yellow birch is for

parts where there is a critical bending problem. We experience less breakage with maple than with birch; so we use maple exclusively for our arm bows.

However, our backs, which have a less severe bend, are made from yellow birch because we have a better chance of realizing a uniform color to match the birch seat.

As far as technical and structural properties are concerned, beech, yellow birch, and rock maple are so closely comparable that there would be no advantage of one over the other for making furniture.

Machinability is noticeably easier on yellow birch. This shows up in the increased production between knife grindings.

The foregoing remarks should make it evident that we are tremendously interested in any discussion that will promote the growth and harvesting of yellow birch. Even now demand has put a higher price on yellow birch lumber than other high-volume species in the Northeast. We hope to see more evidence of a trend toward multiple-product logging, which seems a necessity to give the land and timber owners the incentive to continually harvest this premium species.



SILVICAL REQUIREMENTS FOR NATURAL BIRCH REGENERATION

by DAVID A. MARQUIS, *Silviculturist, Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Upper Darby, Pa.*

A SCARCITY OF BIRCH REGENERATION

YOUNG STANDS of either paper birch or yellow birch are relatively scarce in the northern hardwood region today, primarily because birch has not regenerated with the silvicultural practices used over the past 30 or 40 years.

Where light cuttings and uneven-aged management have been used, the birches have gradually been eliminated in favor of more tolerant species. By now, I think most of us would agree that some form of even-aged management is required where we want to grow large proportions of the birches. But having reached this conclusion, can we assume that we will automatically get birch regeneration just by clearcutting? Or will special cutting methods or supplemental cultural techniques be required?

There have been *some* heavy cuttings in northern hardwoods over the years, both commercial and experimental. Regeneration obtained on many of these areas has been good. But on others, the birch has not come through as well as we might like. We could probably find examples ranging all the way from smashing successes to dismal failures.

Why have the results varied so widely? What factors have affected the results? What conditions must we provide to insure that prompt and adequate birch regeneration will be obtained? During the next few minutes, I'd like to describe some of our research on the silvical requirements for natural birch regeneration, and then show how we can provide the desired conditions through our choice of silvicultural technique. The three speakers

who follow will comment further on the importance of these factors in their respective regions, and they will describe results obtained from actual use of the various techniques.

FACTORS AFFECTING REGENERATION

To obtain birch regeneration, there are really only two major requirements. First, an adequate supply of seed must be delivered to the desired location at the appropriate time.¹ Second, the moisture, temperature, light, nutrients, and other environmental factors must be conducive to seed germination and seedling survival and growth.

Seed Supply

Both paper and yellow birch are generally considered to be prolific seeders, producing large quantities of seed that may be dispersed fairly long distances by the wind. Many of us have observed birch seedlings that have become established a considerable distance from the nearest known seed source. Yet seed supply is probably a limiting factor more often than we realize.

The quantities of seed produced each year vary tremendously. The 1955 seed crop in a 70-year-old paper birch stand in Massachusetts (*Bjorkbom et al. 1965*) was estimated at about 36 million seeds to the acre. At the other extreme, complete seed failures occasionally occur. Average seedfall from a well-stocked stand is probably between 1 and 2 million seeds per acre.

¹ Although the birches—particularly paper birch—often reproduce by sprouting, such sprouts seldom represent more than a small proportion of the new stems.

A review of annual seed-crop reports from the Lake States and the Northeast reveals that, out of every 10 years, both paper and yellow birch average about 1 heavy seed year, 3½ medium years, 4½ light or very light years, and 1 year of seed failure.² Thus medium or better crops occur a little less than 1 year in 2, but heavy crops occur only about 1 year in 10.

Quality of seed varies from year to year too. Seed viability is usually high during years of a heavy seed crop, but may be low during years of light crops. A study in Maine revealed germination of 77 percent during a heavy seed year versus germination of 13 and 24 percent during two more normal years (Bjorkbom *et al.* 1965). Thus viability is low during years when seed supply is already limited.

Low seed viability during certain years may be related to incomplete fertilization, resulting from either poor flower crops or adverse weather conditions at the time of pollination. The birches are known to be parthenocarpic: pistillate flowers develop into a fruit regardless of whether or not fertilization has occurred (Sarvas 1952, Frovola 1956). This of course results in empty seed coats. The importance of this was illustrated in a study of birch seed crops in Canada. Although the 1951 seed crop was about average size, none of the seeds examined contained embryos (Redmond and Robinson 1954). Thus, there may be a complete failure of viable seeds, even though seedfall is observed.

Insects and diseases also reduce viability of birch seed. Larvae of various insects have been found in birch catkins. They consume many seeds and may provide entrance for fungi. During an outbreak of the weevil *Apion walshii* in 1961 in New Hampshire, it was estimated that about half of the yellow birch seeds were damaged by this insect. Fungi reducing viability or affecting the new seedlings have also been found in catkins that have not been attacked by insects (Shigo and Yelenosky 1963).

Birch seed matures during late summer and is dispersed throughout the late summer, fall, and winter months. Although birch seed is very light in weight, its wings are inefficient

in sustaining flight. Sarvas (1948) found that the rate of fall of European birch seed (0.52 to 0.67 meters/sec) was no slower than that of the much heavier Scotch pine (0.65 meters/sec).

Although individual birch seeds may be dispersed long distances if caught in high winds or blown over crusted snow, quantity dispersal is usually limited to a distance of about two times the height of the seed-producing trees (Sarvas 1948). In a study of paper birch dispersal in Maine, seedfall two tree heights from the bordering seed trees was only about 15 percent of that within the stand.³ Seed weight and germinability also varied with dispersal distance, the heaviest and best seeds falling closest to the seed trees.

Thus the quantity of viable birch seed present actually varies over a wide range. During a bumper seed year tremendous quantities are available, the viability is high, and seedfall should be adequate for regeneration considerable distances from the source. In poor years, however, quantities are limited, viability is low, and seedfall at distances of more than about 150 feet from the seed source is apt to be inadequate for regeneration of stands containing large quantities of birch.

What can we do about seed supply? The first thing we can do is learn to predict the seed crop in advance so that we will know whether or not seed supply is apt to be a limiting factor. This is not as difficult as you might expect. The staminate or male catkins are formed in midsummer. They remain on the tree over the winter and then open after considerable elongation in the spring, at which time their pollen is released and the female flowers are pollinated. The fertilized female ovules then develop into seeds, which are dispersed in the fall. During the winter months, the male catkins average about 1 inch long and are clearly visible from the ground. Their relative abundance at this time is a good guide to the size of the seed crop the following fall—barring unforeseen catastrophies to either male or female catkins. Thus, an estimate of male catkin abundance made in November 1969 would provide a guide to the seed crop in the fall of 1970 and could be

² Marquis, David A. THE SEEDING HABITS OF PAPER AND YELLOW BIRCH. Unpublished report, NE. Forest Exp. Sta., 33 pp., 1963.

³ Bjorkbom, John C. PAPER BIRCH SEED PRODUCTION, DISPERSAL, AND GERMINATION. Manuscript in preparation, NE. Forest Exp. Sta., 1969.

useful in scheduling cutting operations through the spring of 1971.

Armed with knowledge that the seed crop of a particular year is liable to be small, we might take any of several actions. Perhaps the cuttings can be rescheduled so as to avoid the problem. One obvious way is to postpone regeneration cuts to a year of better seed crops; this usually requires just a 1-year postponement. If postponement is not possible, the actual felling operation could be scheduled to take best advantage of the seed that is available. If the cuttings take place between late fall and early spring, seed dispersed from these trees before cutting will be available in the spring to provide for regeneration. However, if cutting is done during the summer months—after the seed from the previous fall is gone and before the new crop is ripened—there will be little seed in the humus to establish a new stand and seed dispersal from the surrounding trees might not be adequate if the opening is large.

Where fall or winter cutting is undesirable or impractical, it may be necessary to retain seed trees, either as individual trees in large clearcuttings or as border trees along small openings. Considering effective dispersal distances during poor seed years, we recommend up to four well-distributed birch seed trees per acre in large clearcuttings, or limiting of openings to a maximum width of 300 feet.

Still another way to take advantage of a limited seed crop is to provide optimum conditions for seed germination. This brings us to the second of our two requirements for birch regeneration.

Environmental Conditions

The small size of the birch seed makes it especially sensitive to environmental conditions at the time of germination. A paper birch seed weighs only about 1/50 as much as a white pine seed, or only about 1/200 as much as a sugar maple seed. The newly germinated seedling is likewise small and extremely sensitive to environmental conditions for the first few months.

Soil moisture and soil temperature are the factors that most directly affect seed germination and early seedling survival. Weather conditions, soil and seedbed type, and exposure to sunlight in turn affect the soil moisture and temperature regime.

The environments that birch seeds find on

cutover lands vary tremendously. Among the more or less stable site factors that have important effects are aspect and soil drainage. Although neither of these factors has been evaluated quantitatively in terms of regeneration, we know something of their effects. For example, southwest aspects are generally drier and hotter than northeast aspects. Excessively drained soils are usually droughty, so they are less favorable for birch regeneration than others. In contrast, poorly drained soils may have more abundant moisture and therefore may be more favorable for seed germination. Both aspect and soil drainage have also been shown to affect productivity of the trees once they are established.⁴

Of course weather conditions affect germination and survival too. We have found germination to be nearly twice as high during a year with a wet spring as it was during a year with more normal precipitation (*Marquis et al.* 1964).

On any particular site during any year, the condition of the seedbed and the amount of exposure to direct sunlight are extremely important in affecting germination and early survival. Seedbed conditions after cutting vary from undisturbed leaf litter and humus to pure mineral soil, depending upon the amount of ground disturbance from skidding. And sunlight exposure may vary from full sunlight—as in a large clearcutting—to fairly dense shade—as in the border of a small opening or under the canopy of residual trees left after a partial or shelterwood cutting.

Best germination and early survival occur where mineral soil has been exposed and where there is shade. In some of our studies at Bartlett, we found that the number of paper birch seedlings present on mineral soil after 1 year was about 15 times greater than the number on leaf litter and about 3 times greater than the number on unloosened humus. Likewise, the number present was about 2½ times greater in the shade than in the sun (Fig. 1). On many of the leaf litter seedbeds exposed to full sunlight, no seedlings survived after one growing season (*Marquis et al.* 1964). Similar results have been re-

⁴ Post, Boyd W., and Robert Curtis. SITE CHARACTERISTICS AND SITE INDICES OF NORTHERN HARDWOODS IN THE GREEN MOUNTAINS OF VERMONT. Manuscript in preparation, Vt. Agr. Exp. Sta.

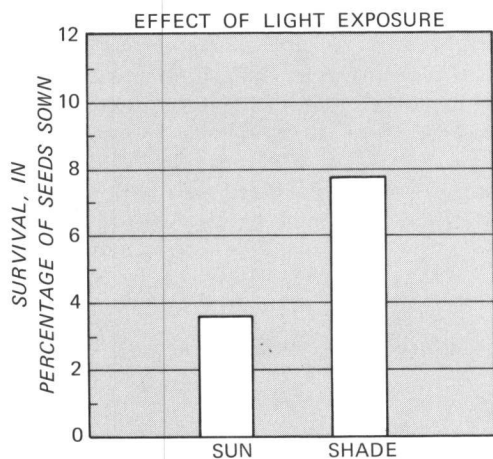
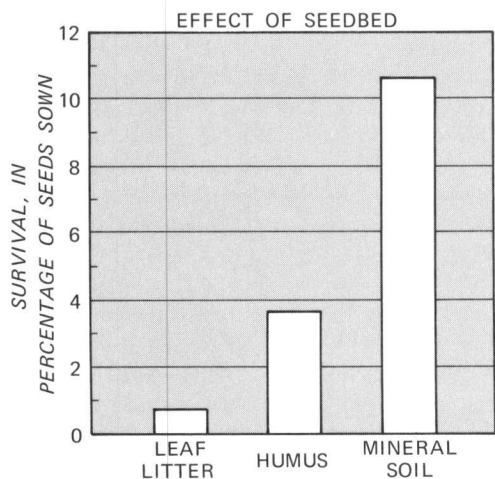


Figure 1.—Number of paper birch seedlings surviving after one growing season, as affected by seedbed and light exposure.

ported by numerous others for both paper and yellow birch.

One of the key factors in these seedbed and light exposure effects is soil moisture. Good germination and survival occur almost any place where moisture is high. In the previously mentioned study, surface moisture remained substantially higher throughout the growing season on the mineral soil seedbeds than it did on the humus and leaf litter seedbeds, particularly where the seedbeds were exposed to direct sunlight. Available moisture also remained higher in shady loca-

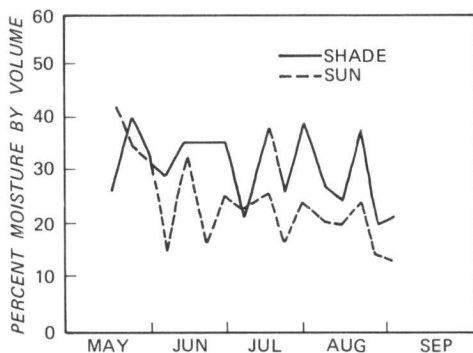
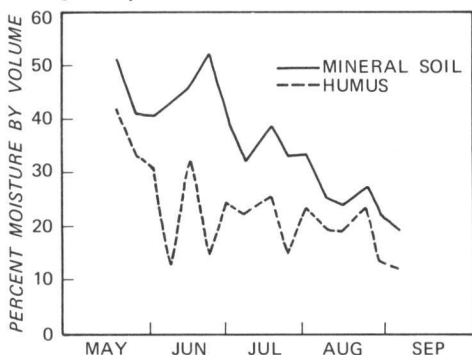
tions than it did in sunny locations (fig. 2).

That these differences are due mainly to moisture can be demonstrated by artificial watering. When this is done, germination and early survival are about the same in direct sun as they are under shade (*Marquis 1966*). Likewise, germination is uniformly good over a wide variety of seedbed types if moisture is artificially maintained at a high level⁵ (*Winget and Kozlowski 1965*).

Soil temperature also affects the responses to seedbeds and light exposures. Very high surface temperatures may be a direct cause of seedling mortality in some cases; we have recorded surface temperatures of over 150°F. on humus seedbeds exposed to full sunlight.

⁵ Tubbs, Carl H. THE INFLUENCE OF LIGHT, MOISTURE, AND SEEDBED ON YELLOW BIRCH REGENERATION. Manuscript in preparation, North Cent. Forest Exp. Sta.

Figure 2.—Soil moisture near the soil surface in a patch cutting, as affected by seedbed and light exposure.



But generally soil moisture and soil temperature are so closely interrelated that the effects of the two cannot be separated. As long as the soil moisture is high, soil temperatures remain moderate. Extremely high soil temperatures occur only when soil moisture has dropped to a very low level (fig. 3) (*Marquis 1967*). Thus it is not surprising that surface temperatures go extremely high on dry humus seedbeds exposed to direct sunlight, or that they remain relatively moderate (generally below 100°F.) in shaded areas, or on moist mineral seedbeds.

Growth is also affected by seedbed and light exposure. Growth is generally not as good on mineral soil as it is on the organic seedbeds. This difference is apparently due to low nutrient levels, or nutrient imbalances, in the mineral soil. The humus layers are relatively rich in nutrients and support good birch growth. *Tubbs (1965)*, *Hoyle (1965)* and *Winget and Kozlowski (1965)* have all demonstrated the differences in yellow birch growth that occur between the organic and mineral horizons in soils on which birch commonly grows.

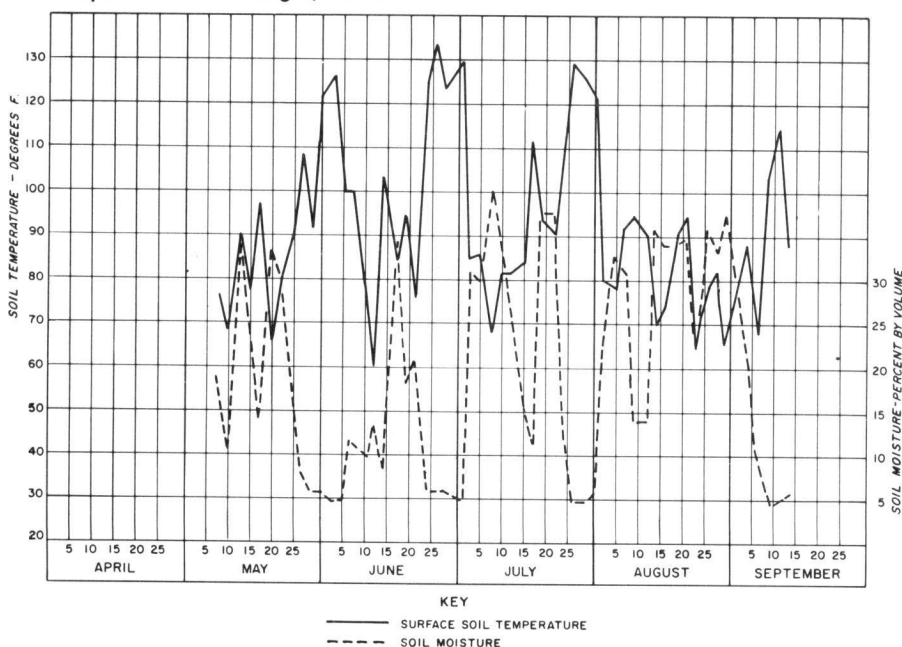
Growth of birch seedlings generally increases with increased light exposure, at least

up to a point. This effect is especially apparent with root growth. Root growth of both paper and yellow birch is greatest in full sunlight, but less in shade. *Logan (1965)* found significant reduction in root growth of both species at light levels below 45 percent full sunlight. And I have found that root-shoot ratio of paper birch is reduced nearly 3 times and of yellow birch nearly 2 times by shade levels of 43 to 66 percent of full sunlight (*Marquis 1966*) (fig. 4).

Reductions in root growth under shade may be especially important where the birches are competing with other species. Roots of some of the more tolerant species—such as sugar maple—are not significantly reduced by shade, so that these tolerant species are better able to compete for the limited growing space under shaded conditions (*Logan 1965*). The birches often fall behind the other vegetation under these conditions.

However, moderate shade during the first few years may not significantly reduce height or dry weight growth. In fact, moderate shade may be beneficial during this period, particularly for yellow birch. Results of numerous studies on this effect have given varied results, but light levels of between 50 and

Figure 3.—Soil moisture and soil temperature on a sandy loam soil exposed to full sunlight, 1963.



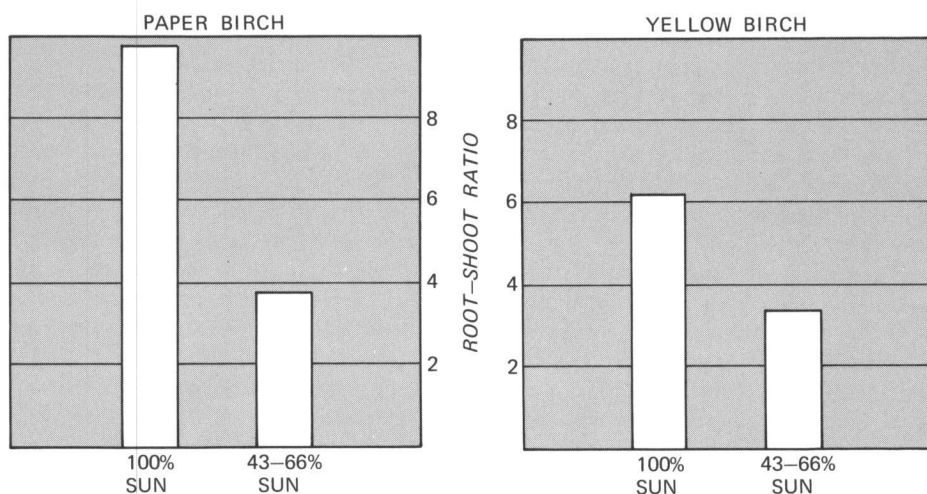


Figure 4.—Root-shoot ratio of birch seedlings after one growing season under varying degrees of shade.

100 percent of full sunlight generally seem best. Paper birch seems to do better nearer the 100-percent level, while yellow birch grows better at intensities closer to the 50-percent level⁵ (Logan 1965, Godman and Krefting 1960, Marquis 1966). It must be remembered that most of these results were obtained under controlled study conditions, with no competition among species. Under more natural conditions competition would be a factor, and the reduced root growth under shade would probably have an effect.

It seems to me that best growth and development of birch regeneration would be obtained by providing moderate shade for the first few years, and then increasing the amount of light as the seedlings enter into active competition with other species.

In attempting to provide the optimum conditions for birch regeneration, we are faced with several conflicts. Whereas germination and survival are best on mineral-soil seedbeds in deep shade, growth and development are better on humus seedbeds and in moderate shade or full sunlight.

The ideal seedbed would be one in which the mineral soil is exposed but in which the humus has been retained. The humus would be mixed with the mineral soil rather than scraped away. Such a seedbed preserves the nutrients of the humus for good growth and still provides the desirable moisture and temperature characteristics of mineral soil. De-

liberate soil scarification to obtain such seedbeds would materially increase the amount of birch in the regeneration.

Some scarification is obtained as a byproduct of logging, but the amount scarified in this way is generally inadequate. In our experimental patch cuttings, we found exposed mineral soil on only about 10 percent of the cutover area, and this was not well distributed but was concentrated in the skid trails (Marquis and Bjorkbom 1960). Even smaller amounts of scarification have been reported from Lake States selection cuttings (Church 1961).

Logging during the summer, and the use of narrow strips to channel skidding, both increase the proportion of the area scarified. I understand that the White Mountain National Forest has been at least partly successful in obtaining good scarification on some of their summer-logged sales by encouraging their operators to scarify as much as possible during their normal activities. Nevertheless, additional scarification would often be desirable.

Since light exposure can be controlled to a degree by the type of cutting used, we also have the opportunity to provide the best possible light environment. This can be done in several ways. One way is to use a partial cutting or shelterwood cutting to retain a certain amount of shade for germination. After a period of establishment, the residual stand could be reduced further or eliminated entirely depending upon the amount of light

desired for best growth. Such a technique provides somewhat irregular overhead shade.

Another technique is to use very small or narrow clearcuttings. The open shade (usually about 15 to 20 percent of full sunlight) found around the borders of these openings provides excellent conditions for germination and early survival. Additional light can be provided after the seedlings are established by cutting new openings adjacent to the original ones.

In a north-south oriented strip, the ground is shaded in the morning and afternoon, with a period of exposure to sunlight during the middle of the day, which varies with strip width. In New Hampshire, on level ground, a 70-foot-wide strip with 70-foot tall border trees receives about $3\frac{1}{2}$ hours of direct sunlight in June, while a strip 35 feet wide receives about 2 hours of direct sunlight (Marquis 1965). Light exposure in these strips averages 40 to 75 percent of full sunlight (Berry 1964).

An east-west strip receives shade during the middle of the day. To be completely shaded during the middle 4 hours of the day, east-west strips should be no more than about 25 feet wide. Areas beyond 30 feet from the south edge in east-west strips receive very nearly full sunlight. Light exposure in the southern 25-foot area of east-west strips averages 25 to 50 percent of full sunlight.

Northwest-southeast strips are exposed to full sunlight about 10:30 in the morning, when the sun shines directly down the long axis; but these strips are shaded during the hot afternoon hours. A 40-foot wide northwest-southeast strip receives about $2\frac{1}{2}$ hours of sunlight in the morning.

When strips are used, the heavy shade from the border trees is desired only for a few years while the new seedlings are becoming established. After that, a new strip should be cut adjacent to the original strip to provide the established seedlings with additional light.

PUTTING IT ALL TOGETHER

To review briefly, seed supply and environmental characteristics of the seedbed determine the amount of birch regeneration obtained. Proper scheduling of the cutting and retention of seed trees in or bordering the cutting area will reduce failures due to lack of seed. The use of cuttings that provide shade and the scarification of seedbeds will

increase germination and survival. Good luck with weather will also help.

Although it is relatively easy to say that certain measures will increase birch regeneration, it is much more difficult to determine when their use is required. Expensive or time-consuming special measures are certainly not justified in situations where regeneration would be adequate without them. Unfortunately, there are such wide variations in so many different factors that it is difficult to predict when scarification, strip cutting, seed trees, or other measures will be required.

We might calculate the number of birch seedlings that will be obtained under different circumstances by starting with various assumed numbers of seeds and reducing these numbers by various percentages corresponding to estimates of the viability of the seed crop, estimates of germination and survival, and similar factors. In the following example (table 1), I have assumed four classes of seed crops, 2 amounts of insect-disease damage to this seed, and 4 amounts of reduction in seed quantity due to dispersal distance. Likewise, I have recognized 2 groups of sites, 3 groups of weather conditions, and 4 groups of seedbed-light exposures that could affect germination and survival during the first year. Two classes of competition are also recognized as affecting survival during years 1 through 5.

The values used for each of these classes represent my own judgment as based on research results and published information. Where differences occur between paper birch and yellow birch, I have used values appropriate for paper birch. Although you can argue with any or all of these values, they are probably all in the right ball park.

With these assumptions and figures, I simply calculated the number of birch seedlings that might be present at 5 years of age for each of the various combinations of conditions. There are 1,536 possible combinations of conditions represented here. The number of seedlings calculated varied from 608,000 per acre in the best possible combination (which would probably never occur) to 8 per acre in the worst possible combination. I believe this illustrates rather dramatically the extreme variation that can be encountered in attempts to obtain birch regeneration.

If we assume some minimum number of birch seedlings required at 5 years of age to be considered successful, we can determine

Table 1.—Assumptions used in calculation of regeneration success.

SEED SUPPLY	
1. Seed crop, in number of <i>viable</i> seed per acre:	
a. Bumper (15,000,000)	
b. Average (1,000,000)	
c. Poor (500,000)	
d. Very poor (250,000)	
2. Proportion of seed not damaged by insects-fungi:	
a. 90%	
b. 50%	
3. Proportion of seed obtained at various dispersal distances:	
a. within 25 feet (100%)	
b. 25 to 40 feet (50%)	
c. 40 to 100 feet (35%)	
d. 100 to 200 feet (15%)	
ENVIRONMENT	
Proportion of seed germinating and surviving ¹ under various conditions of:	
4. Site:	
a. Average (100%)	
b. Unfavorable (50%)	
(South or southwest aspect or somewhat excessively drained soil.)	
5. Weather:	
a. Wet (150%)	
b. Average (100%)	
c. Dry (50%)	
6. Micro-environment:	
a. Shaded-scarified (12%)	
b. Shaded-unscarified (5%)	
c. Unshaded-scarified (7%)	
d. Unshaded-unscarified (3%)	
7. Competition during years 1 to 5:	
a. Average (50%)	
b. Severe (25%)	

¹ Germination and survival figures for micro-environment (item 6) are based on averages from field studies on the Bartlett Experimental Forest under conditions of average site and average weather. Figures for other weather or site conditions (4) and (5) are adjustments to the average figures given in item (6).

which combinations of conditions produce success. I have used a figure of 2,500 birch seedlings per acre as the minimum number required. This figure was calculated from estimates of tree drop-out rate (Leak 1969)

for paper birch stems in stands <0.6 inches average diameter (Marquis *et al.* 1969) We might also recognize another level where the number of birch stems is below the successful level but above some minimum level at which failure is virtually assured. Investments in special regeneration measures such as soil scarification, use of narrow strip cuttings, or retention of seed trees would be absolutely necessary to reproduce birch under these circumstances. I have subjectively set this level at 500 birch seedlings per acre at 5 years of age.

Selected results of these calculations are shown in table 2. It can be seen that clear-cuttings will fail to provide adequate regeneration if there is a poor seed crop. Failure may also occur during average seed years on sites where soil type or aspect are unfavorable, especially if the weather is unusually dry or there is extensive insect damage to the seed crop, or if severe competition develops from other tree species. Retention of seed trees on the clearcut area, or logging in winter or spring after natural seedfall improves the chances of success, as does use of supplemental scarification, or strip cutting. Strip cutting with seedbed scarification virtually assures successful birch regeneration under all but the most unusual conditions.

Although not shown in the table, bumper seed crops resulted in successful regeneration under all circumstances. Seed supply proved to be the single most important factor affecting results. This is due to the extreme variation that occurs in seed production.

Silvicultural recommendations based in part on these calculations have been incorporated into a published guide for paper birch. A similar guide for northern hardwoods—including yellow birch—has also been prepared.

The calculations just presented are extremely crude, but they illustrate the sort of approach now being used to develop much more accurate estimates of regeneration. Computer simulation studies, using much more sophisticated models of the birch regeneration process (Leak 1968), are now being undertaken by William B. Leak of our silviculture research unit at Durham; they will enable us to refine our silvicultural recommendations and provide more useful guides to the regeneration of these two valuable species.

Table 2.—Success of birch regeneration under various combinations of seed supply and environment.

Silviculture practice	Seed crop			
	Average site		Unfavorable site	
	Average	Poor	Average	Poor
1. Clearcutting				
a. Seed from bordering stand (summer logging), no scarification.	?	F	??	F
b. Seed from bordering stand (summer logging), with seedbed scarification.	S	??	?	F
c. Seed source on area (winter logging or seed trees), no scarification.	S	?	S	??
d. Seed source on area (winter logging or seed trees), with scarification.	S	S	S	?
2. Strip cutting (50 feet wide, east-west), logging either summer or winter.				
a. No scarification, seed from both borders.	S	S	S	?
b. Seedbed scarification, seed from both borders.	S	S	S	S

F = Expect regeneration failure (<500 paper birch seedlings per acre).

S = Expect regeneration success (>2,500 paper birch seedlings per acre).

?, ?? = Questionable regeneration success (500 to 2,500 paper birch seedlings per acre). Two question marks indicate that dry weather, heavy seed losses to insects or fungi, or more serious than average competition will reduce regeneration below 500 birch seedlings per acre. One question mark indicates that two of these three events combined would reduce regeneration below 500 birch seedlings per acre.

LITERATURE CITED

- Berry, A. B.
1964. EFFECT OF STRIP WIDTH ON PROPORTION OF DAILY LIGHT REACHING THE GROUND. *Forestry Chron.* 40(1): 130-131.
- Bjorkbom, John C., David A. Marquis, and Frank E. Cunningham.
1965. THE VARIABILITY OF PAPER BIRCH SEED PRODUCTION, DISPERSAL AND GERMINATION. USDA Forest Serv. Res. Paper NE-41, 8 pp., illus. NE Forest Exp. Sta., Upper Darby, Pa.
- Church, Thomas W., Jr.
1961. SEASON OF LOGGING UNIMPORTANT IN CREATING DISTURBED SEEDBEDS FOR YELLOW BIRCH. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 605, 2 pp. St. Paul, Minn.
- Frolova, G. D.
1956. THE BIOLOGY OF FLOWERING IN SOME BIRCHES. *Forestry Abstracts* 1386, vol 18. From *Botanicheskii Zhurnal*. (Russian.)
- Godman, Richard M., and Laurits W. Krefling.
1960. FACTORS IMPORTANT TO YELLOW BIRCH ESTABLISHMENT IN UPPER MICHIGAN. *Ecol.* 41: 18-28, illus.
- Hoyle, Merrill C.
1965. GROWTH OF YELLOW BIRCH IN A PODZOL SOIL. USDA Forest Serv. Res. Paper NE-38, 14 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Leak, William B.
1968. BIRCH REGENERATION: A STOCHASTIC MODEL. USDA Forest Serv. Res. Note NE-85, 7 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Leak, William B.
1969. STOCKING OF NORTHERN HARDWOOD REGENERATION BASED ON EXPONENTIAL DROP-OUT RATE. *Forestry Chron.* (accepted for publication).
- Logan, K. T.
1965. GROWTH OF TREE SEEDLINGS AS AFFECTED BY LIGHT INTENSITY. I. WHITE BIRCH, YELLOW BIRCH, SUGAR MAPLE, AND SILVER MAPLE. Canada Dep. Forestry Pub. 1121. 16 pp., illus.
- Marquis, David A. and John C. Bjorkbom.
1960. HOW MUCH SCARIFICATION FROM SUMMER LOGGING? USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 110. 3 pp., illus., Upper Darby, Pa.
- Marquis, David A., John C. Bjorkbom, and George Yelenosky.
1964. EFFECT OF SEEDBED CONDITION AND LIGHT EXPOSURE ON PAPER BIRCH REGENERATION. *J. Forestry* 62: 876-881, illus.

- Marquis, David A.
1965. CONTROLLING LIGHT IN SMALL CLEAR-CUTTINGS. USDA Forest Serv. Res. Paper NE-39, 16 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1966. GERMINATION AND GROWTH OF PAPER BIRCH AND YELLOW BIRCH ON SIMULATED STRIP CUTTINGS. USDA Forest Serv. Res. Paper NE-54, 19 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1967. SOIL MOISTURE - SOIL TEMPERATURE INTER-RELATIONSHIPS ON A SANDY-LOAM SOIL EXPOSED TO FULL SUNLIGHT. USDA Forest Serv. Res. Note NE164, 5 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-130, 47 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Redmond, D. R., and Robena C. Robinson.
1954. VIABILITY AND GERMINATION IN YELLOW BIRCH. Forestry Chron. 30: 79-87.
- Sarvas, Risto.
1948. A RESEARCH ON THE REGENERATION OF BIRCH IN SOUTH FINLAND. Comm. Inst. For. Fern. 35(4). English summary 82-91.
- Sarvas, Risto.
1952. ON THE FLOWERING OF BIRCH AND THE QUALITY OF THE SEED CROP. Comm. Inst. For. Fern. 40(7): 35 pp.
- Shigo, Alex L., and George Yelenosky.
1963. FUNGUS AND INSECT INJURY TO YELLOW BIRCH SEEDS AND SEEDLINGS. USDA Forest Serv. Res. Paper NE-11, 11 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Tubbs, Carl H.
1963. ROOT DEVELOPMENT OF YELLOW BIRCH IN HUMUS AND A SANDY LOAM. USDA Forest Serv. Res. Note LS-33, 2 pp., illus. Lake States Forest Exp. Sta., St. Paul, Minn.
- Winget, C. H., and T. T. Kozlowski.
1965. YELLOW BIRCH GERMINATION AND SEEDLING GROWTH. Forest Sci. 11: 386-392.
-

NATURAL REGENERATION OF BIRCH IN NEW ENGLAND

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ALMOST ANY method of cutting will provide some natural regeneration of birch in the northern hardwood forests of New England. However, where high proportions of yellow and paper birch are to be naturally regenerated, cutting and cultural measures must be given special consideration. Generally some form of clearcutting—patches, strips, or blocks—and seedbed preparation are the prime requisites for successful stand establishment. These appear to be simple prescriptions to follow; but in many timber-management programs the clearcutting is not complete enough, and seedbed preparation is often overlooked.

Why clearcutting? Why seedbed preparation? Silvicultural studies on our Bartlett Experimental Forest at Bartlett, New Hampshire, and elsewhere in the region, demonstrate that cutting method and seedbed condition greatly influence the establishment and development of birch regeneration. These influences must be taken into account to achieve good natural regeneration of birch in New England.

EFFECT OF CUTTING METHOD

Regeneration that follows any cutting method comes from one or both of two sources: (1) advance reproduction that was already on the ground at time of cutting, and (2) seedlings and sprouts that originate after the cutting (*Leak and Wilson 1958*).

Often in New England stands, the advance reproduction at time of cutting is mostly beech and sugar maple. Very little advance reproduction of yellow birch is present (about 2 percent), and practically no paper birch (*Jensen 1943*). Therefore, for all practical purposes, to regenerate birch we must depend on seedlings that originate after cutting. If so, what cutting methods provide conditions that are favorable for birch seedling establishment—and later development?

Results of a comprehensive study of three cutting methods (*Leak and Wilson 1958*)—moderate selection, clearcut patches of 0.1 to 0.6 acre, and a clearcut block of 22 acres—show how cutting alone can affect species composition of regeneration (table 1).

Although the selection cutting was especially favorable for regenerating beech and sugar maple, a small proportion of yellow birch became established. However, the proportion of paper birch regeneration was negligible.

Patch cutting resulted in fairly good yellow birch regeneration. The larger clearcutting was highly favorable for paper birch. Of course, in both of these cuttings, as in selection cutting, the proportion of beech and sugar maple was very high, often exceeding that of birch.

In the clearcuttings, all trees over 2 inches d.b.h. that were left after logging were felled or girdled.

Other studies have also shown the favorable effects of patches, strips, and other stand openings on birch regeneration (*Barrett et al. 1962, Blum and Filip 1962, Marquis 1966*). Often both yellow and paper birch establish

Table 1.—Species composition of regeneration in stocked milacres¹

Tolerance group ²	Selection cutting	Patch cutting	Clear- cutting
	Percent	Percent	Percent
Tolerant	92	62	43
Intermediate	7	34	19
Intolerant	1	4	38

¹ 10 to 15 years after logging.

² Commercial species included in each tolerance group: Tolerant: mostly beech and sugar maple; some hemlock and spruce. Intermediate: mostly yellow birch; some white ash and red maple. Intolerant: mostly paper birch; some aspen.

and develop in nearly equal proportions (Blum 1966).

EFFECT OF SEEDBED CONDITION

Seedbed condition is probably one of the most important factors affecting birch establishment (Marquis 1965a). Birch regenerates best on disturbed seedbeds where mineral soil is exposed or mixed with humus. In patch cuttings at Bartlett, seedlings were more numerous where mineral soil had been exposed in skidroads and other disturbed areas than in areas not disturbed by logging (table 2). In the Adirondack Mountains of New York, the number of yellow birch seedlings was five times greater on areas scarified to mineral soil as compared with areas not scarified (Barrett et al. 1962). In the Berkshire Mountains of Massachusetts, there were twice as many paper birch seedlings on scarified seedbeds as there were on unscarified ones: 8,000 versus 4,000 seedlings per acre (Cunningham, F. C., unpublished data. U.S. Forest Service, Durham, N.H.).

APPLYING WHAT WE KNOW

Cutting

Under favorable environmental conditions, and with good luck, heavy cutting of a mature stand may be all that is necessary to obtain satisfactory birch regeneration. Unfortunately this approach fails as often as it succeeds. It is better to rely on appropriate cutting methods and follow-up cultural measures to insure the desired results.

Although patch cuttings have been successful in regenerating a fairly high proportion

of both birches, they are impractical to handle when the entire area of a stand is to be systematically covered over a period of years in an even-aged program of management. However, patches are appropriate when used in combination with selection cutting under uneven-aged management. Groups of mature, overmature, or defective trees are used as nuclei for the patches (Marquis 1965b). Patches should be no larger than about 2/3 acre (Gilbert and Jensen 1958).

Clearcuttings up to 100 acres can be used to regenerate paper birch (Marquis et al. 1969). However, in cuttings larger than about 5 acres, four to five well-distributed seed trees should be retained on each acre to insure an adequate seed supply. If cutting is done between late fall and early spring to take advantage of the current seed crop, seed trees may not be needed.

Strips are just as good as patches for regenerating birch (Marquis 1966). When strips are cut in progressive order, they are readily adaptable for use in even-aged management.

In strip cutting, the heavy shade from border trees is required for only a few years to help the new seedlings become established. After that, a new strip is cut next to the original strip. For best birch regeneration, we recommend strips about 50 feet wide, oriented in an east-west direction.

With east-west strips, the new cuttings are made on the south edge of the previous strip. This provides sunlight for the established seedlings while at the same time it creates a new strip that is heavily shaded where new seedlings can become established. Thus succes-

Table 2.—Stocking of birch and other species in patch cuttings by seedbed condition¹

Species	Skidroad		Disturbed		Undisturbed		Slashpile	
	M stems per acre	%	M stems per acre	%	M stems per acre	%	M stems per acre	%
Paper birch	57	(20)	25	(14)	6	(6)	1	(4)
Yellow birch	88	(32)	24	(13)	4	(4)	—	—
Sugar maple	28	(10)	23	(13)	36	(37)	7	(28)
Beech	11	(4)	9	(5)	13	(13)	6	(24)
Others	95	(34)	97	(55)	39	(40)	11	(44)
Total	279	(100)	178	(100)	98	(100)	25	(100)

¹ 3 years after logging.

sive clearcuttings, each on the south of the previous opening, create an environment that is successively favorable for best establishment and then for rapid growth.

In practice, the strips are cut in groups, in progressive order, so that every third or fourth strip is cut simultaneously (fig. 1). This allows the entire area to be cut over in three or four cycles of cutting, spanning 4 or 6 years if 2 years are allowed for establishment between cuts (*Marquis 1965b*).

Seedbed Preparation

Seedbed preparation not only provides the desired mineral soil-humus mixture, but also removes much unwanted advance reproduction that often suppresses newly established birch seedlings.

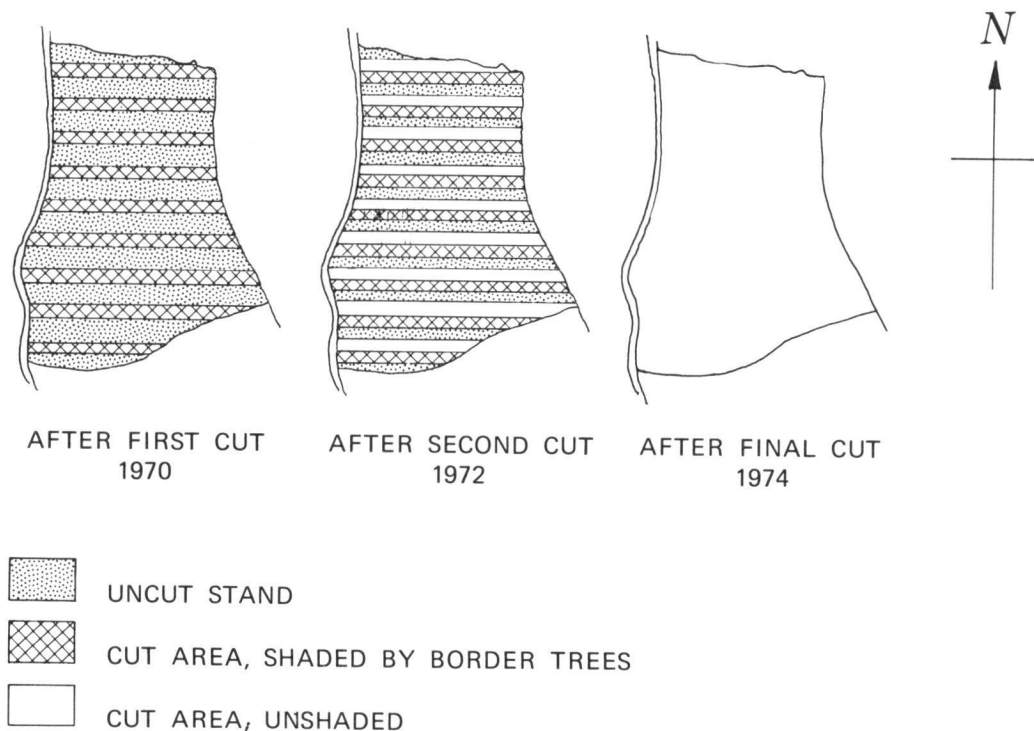
You might think that summer logging with tractors or skidders would prepare enough of the required seedbed. It doesn't. Less than 10 percent of a cutting area gets scarified in

the usual logging operation (*Bjorkbom 1967, Marquis and Bjorkbom 1960*). I consider this too low for successful birch establishment. I think the proportion should be at least 25 percent, and it should be well distributed. For maximum benefit, the goal should be about 50 percent (*Marquis et al. 1969*).

In most cases, seedbed scarification should be done after logging. Nevertheless, in special situations it can be done before logging. An experienced operator can achieve a fairly good scarification job with a regular large-size bulldozer. But too often an operator finds blade control very difficult, and deep scalping results. A rock rake or root rake is better adapted for scarification than a solid blade. Rakes are readily available in New England, and are preferred for getting a better job done (*Filip and Shirley 1968*).

Seedbed scarification costs will vary, depending on the obstacles encountered—slash, rockiness, steepness, etc.—and the additional area

Figure 1.—Stages in progressive strip cutting of east-west strips. The cut area shaded provides ideal conditions for seedling establishment. The cut area unshaded provides ideal conditions for seedling growth.



needed to supplement the soil disturbed by logging. Based on our experience, costs can be expected to range from about \$9 per acre for 25-percent coverage to \$34 per acre for nearly complete area scarification (table 3).

**Controlling Residual
Trees and Stump Sprouts**

All stems larger than about 2 inches d.b.h. (or 10 to 15 feet tall) should be removed after any clearcutting if the production of quality material is the objective (*Leak et al. 1969, Marquis et al. 1969*). This can be done economically by applying an herbicide. Several herbicides and methods of application can be used effectively. One of these is 2,4,5-T in basal incisions. A mixture of 2,4,5-T ester in fuel oil is applied with a tree injector in overlapping cuts made near the base of the tree. If a majority of the trees are less than 10 inches d.b.h., a 40-pound aehg (acid equivalent per hundred gallons) dilution can be used. Each injector cut should receive about 2 milliliters of solution. For larger trees, more herbicide, or a stronger solution, would be required.

The time required to inject trees larger than 2 inches d.b.h. after clearcutting and scarification operations will range from 1 to 5 man-hours per acre. The following equation gives a fairly accurate estimate of injector time:

$$Y = 0.88 + 0.0041X$$

Where Y = Man-hours per acre.

X = Average d.b.h. (in inches) of trees treated, multiplied by number of trees treated per acre.

After clearcutting northern hardwoods, stumps of most species commonly develop sprouts. Stumps smaller than about 12 to 14 inches in diameter generally produce more sprouts than larger stumps (*Solomon and Blum 1967*). Red maple is the most prolific sprouter. The number of sprouts increases as the stump diameter approaches 9 inches, and decreases at greater diameters. Beech has a tendency to produce many root suckers. Where vigorous sprouts or root suckers compete with birch, control is often necessary. This can be done by basal-spraying the troublesome sprouts with a 2,4,5-T solution.

Table 3.—Scarification costs with a rock rake¹

Area scarified (percent)	Time required	Cost ²
	Hours/acre	\$ per acre
80	2.00	34.00
50	1.30	22.10
25	.54	9.18

¹ Mounted on a D-7 crawler tractor.

² Includes equipment and operator but not supervision and transportation.

LITERATURE CITED

- Barrett, John W., C. Eugene Farnsworth, and William Rutherford, Jr.
1962. LOGGING EFFECTS ON REGENERATION AND CERTAIN ASPECTS OF MICROCLIMATE IN NORTHERN HARDWOODS. *J. Forestry* 60: 630-639.
- Bjorkbom, John C.
1967. SEEDBED-PREPARATION METHODS FOR PAPER BIRCH. USDA Forest Serv. Res. Paper NE-79, 15 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Blum, Barton M.
1966. SNOW DAMAGE IN YOUNG NORTHERN HARDWOODS AND RAPID RECOVERY. *J. Forestry* 64: 16-18.
- Blum, Barton M., and Stanley M. Filip.
1962. A WEEDING IN TEN YEAR-OLD NORTHERN HARDWOODS—METHODS AND TIME REQUIREMENTS. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 135. 7 pp., illus., Upper Darby, Pa.
- Filip, Stanley M., and N. D. Shirley.
1968. COST OF SITE PREPARATION WITH A TRACTOR RAKE IN NORTHERN HARDWOOD CLEARCUTTING. *N. Logger* 17: 18-19.
- Gilbert, Adrian M., and Victor S. Jensen.
1958. A MANAGEMENT GUIDE FOR NORTHERN HARDWOODS IN NEW ENGLAND. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 112. 22 pp., illus., Upper Darby, Pa.
- Jensen, Victor S.
1943. SUGGESTIONS FOR THE MANAGEMENT OF NORTHERN HARDWOOD STANDS IN THE NORTHEAST. *J. Forestry* 41: 180-185.
- Leak, William B., and Robert W. Wilson, Jr.
1958. REGENERATION AFTER CUTTING OF OLD-GROWTH NORTHERN HARDWOODS IN NEW HAMPSHIRE. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 103. 8 pp., Upper Darby, Pa.

- Leak, William B., Dale S. Solomon, and Stanley M. Filip.
1969. SILVICULTURAL GUIDE FOR NORTHERN HARDWOODS IN THE NORTHEAST. USDA Forest Serv. Res. Paper (in press). NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1965a. REGENERATION OF BIRCH AND ASSOCIATED HARDWOODS AFTER PATCH CUTTING. USDA Forest Serv. Res. Paper NE-32, 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1965b. CONTROLLING LIGHT IN SMALL CLEAR-CUTTINGS. USDA Forest Serv. Res. Paper NE-39, 16 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1966. GERMINATION AND GROWTH OF PAPER AND YELLOW BIRCH IN SIMULATED STRIP CUTTINGS. USDA Forest Serv. Res. Paper NE-54, 19 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A., and John C. Bjorkbom.
1960. HOW MUCH SCARIFICATION FROM SUMMER LOGGING? USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 110. 3 pp., illus., Upper Darby, Pa.
- Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-130, 47 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Solomon, Dale S., and Barton M. Blum.
1967. STUMP SPROUTING OF FOUR NORTHERN HARDWOODS. USDA Forest Serv. Res. Paper NE-59. 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

NATURAL REGENERATION OF YELLOW BIRCH IN CANADA

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The Yellow Birch Resource

IN CANADA yellow birch populates a geographic range that extends from the Manitoba-Ontario border through southern Ontario and Quebec and eastwards throughout the Maritime Provinces and Newfoundland (fig. 1). The northern limit of its range corresponds closely with the 64°F. isotherm of the mean daily July temperature.

The important commercial stands of yellow birch forests are restricted to the southern portion of the Canadian Shield, extending up the St. Lawrence Valley to the Maritimes. In Ontario, the major concentrations occur in the vicinity of the Algoma, the Algonquin and

Haliburton Highlands. The southern boundary of commercial distribution is closely associated with the 1000-foot contour of elevation. Peculiar to this highland condition is a cooler temperature but increased precipitation, giving rise to a somewhat Maritime climate, which appears to favor yellow birch. In the same province, according to published statistics, yellow birch comprises about 7 percent of the total hardwood growing stock, and of this, 42 percent occurs in the Sault Ste. Marie Forest District (Algoma area) and 40 percent in the North Bay, Pembroke, and Parry Sound Forest Districts (Algonquin area) together (Dixon 1963).

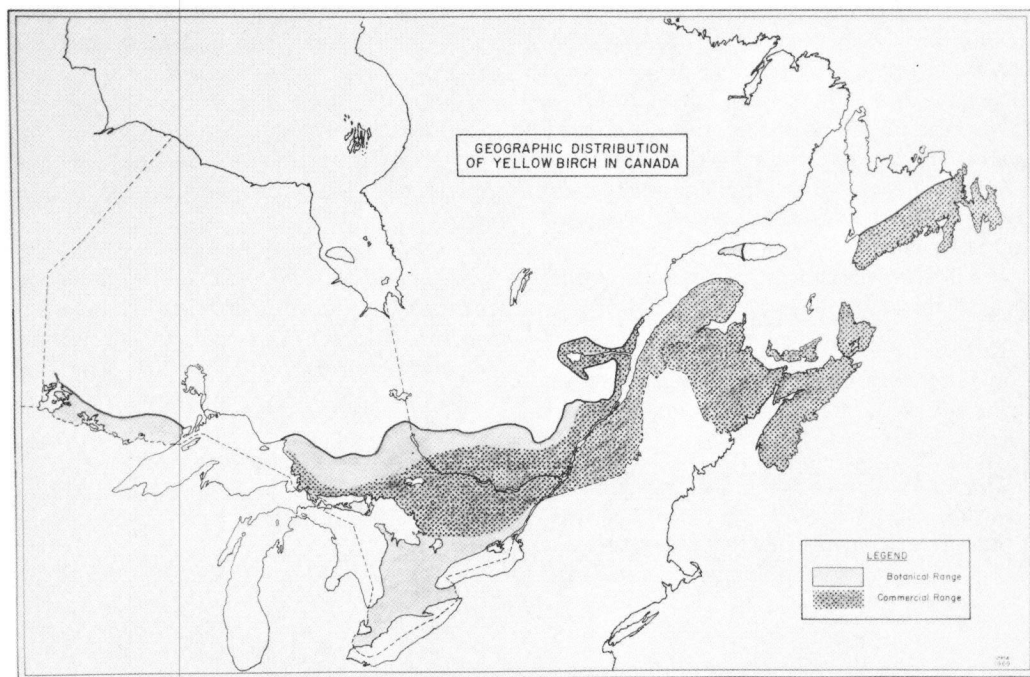


Figure 1.—Geographic distribution of yellow birch in Canada.

The species is utilized extensively in Ontario, where in 1965 yellow birch comprised 19 percent of the total hardwood cut from crown lands, some 20,000 M board feet coming from Sault Ste. Marie alone (*Brunelle 1967*). In terms of financial return, yellow birch provides 50 percent of the stumpage value received from all hardwoods cut, and this species accounted for 38 percent of the sawtimber and veneer depletion.

The heavy cutting pressure has continued more or less unabated over the last few decades, rising from 6 million cubic feet in 1957 to 9 million cubic feet in 1965 (*Anonymous 1967*). The increasing mill demands are now being filled with greater amounts of sugar maple, a species generally of poorer quality. In the last decade the use of sugar maple has doubled and now approaches yellow birch in gross volume cut. Similar pressures are apparent in Quebec, where the hardwood growing-stock volume appears to be higher than in Ontario.

The serious lack of young growing stock of yellow birch in the uncut and selectively cutover hardwood stands has been documented in regeneration surveys in Ontario (*Leslie 1931, Jarvis 1956, Hosie 1953*), Quebec (*Cunningham 1952, Winget 1968*) and the Maritimes (*Drinkwater 1957*). In addition to the lack of birch regeneration (1 to 4 inches d.b.h.), only 12 percent of the almost 4 billion cubic feet of yellow birch growing stock in Ontario is 4 to 9 inches d.b.h. As much as 97 percent of the cubic-foot volume in some areas is in trees over 100 years old.¹ Studies in mature stands of yellow birch indicate that the majority of veneer-quality trees are well over 200 years old.²

In Ontario two approaches have been taken to offset this important problem:

1. Large-scale regeneration procedures based upon research to secure birch growing stock for the market minimally some 60 years hence.
2. The application of techniques for growing quality hard maple to bear the brunt of the current pressure, pending the maturation of the birch regeneration that we are just beginning to obtain.

Ecological Framework

The center of dominance (ecologically speaking) of yellow birch spreads through

central Ontario and into southern Quebec (*Hills 1959, Rowe 1959*). The acid soils of the Precambrian Shield, combined with areas of higher precipitation, favor the birch association over the hard maple-beech type, which encroaches from the south, in the vicinity of Lakes Ontario and Huron (fig. 2). In the northern part of the birch range of dominance, a strong boreal influence is seen, where the birch type is relatively restricted to the somewhat drier uplands, especially the northerly aspects (fig. 2). Growth form is affected as a result of ecological pressure, in that birch growing in the Algoma highlands have shorter clear boles and smaller volumes per tree than trees in the Algonquin highlands, which is closer to the central portions of the birch zone (*Morawski and others 1958*). Conversely yellow birch, as it approaches its southern limit, tends to be restricted to areas having a higher water table.

Effects of glaciation have left much of the Canadian Shield area with a thin discontinuous mantle of till on the uplands, and deep water-laid deposits in the valleys and lower flats. In such areas excellent production of birch is found on the lower slopes, influenced by a telluric water table, and on the broad deep-soil drumlinoid ridges. Performance on the shallow-soil uplands is more variable and is related to many factors such as aspect, eco-climate, soil texture, humus development, etc. Extreme site variations occurring over short distances—the so-called fractured site complex—necessitate site-typing as a prerequisite for any serious attempt to obtain regeneration, establishment, and development of yellow birch.

Though regional differences in soils and climate occur east of Ontario, yellow birch appears to prefer a rather exacting ecological niche in Quebec (*Lemieux 1963*) and the Maritimes (*Drinkwater 1957*) in a somewhat similar order of magnitude.

Background Research

It has been shown by Redmond and Robinson (1954) that yellow birch seed contains

¹Cardwell, B. Personal communication, unpublished timber-inventory data, Ontario Dep. Lands and Forests, 1969.

²Duncan, J. M. THE ORIGIN OF YELLOW BIRCH IN TOLERANT HARDWOOD STANDS. Undergraduate thesis, Univ. New Brunswick, 1962.

a water-soluble germination inhibitor in the seed-coat, which is inactivated by exposure to light. This "chemical rain gage" prevents premature germination during cold weather when sugar maple seed is breaking dormancy. Light inactivation of the system occurs later in the spring when the very delicate birch germinant would be less prone to low-temperature hazards. These authors also note the lack of viability in certain years, which they attribute to weather effects on pollination: however, our observation at Swan Lake, Ontario, suggests that birch adheres very closely to a 3-year cycle (1950, 1953, 1956, 1960), with practically no seed produced intermediately, except

distress crops from low-vigor specimens. The bulk of the yellow birch seed falls after the cold weather of October sets in; it may be blown over the crusted snow for some distance, having been recorded on the snow-covered lakes as far as 1/4 mile from shore.

Linteau (1948) showed in a study of two seedbed conditions (mineral or litter) and three light conditions (open, partial, and closed) with artificially-seeded plots, that there is a negative effect of litter and low light level on the establishment of yellow birch reproduction. Summer logging by group selection in a good seed year was suggested as an alternative to the normal light selective logging.

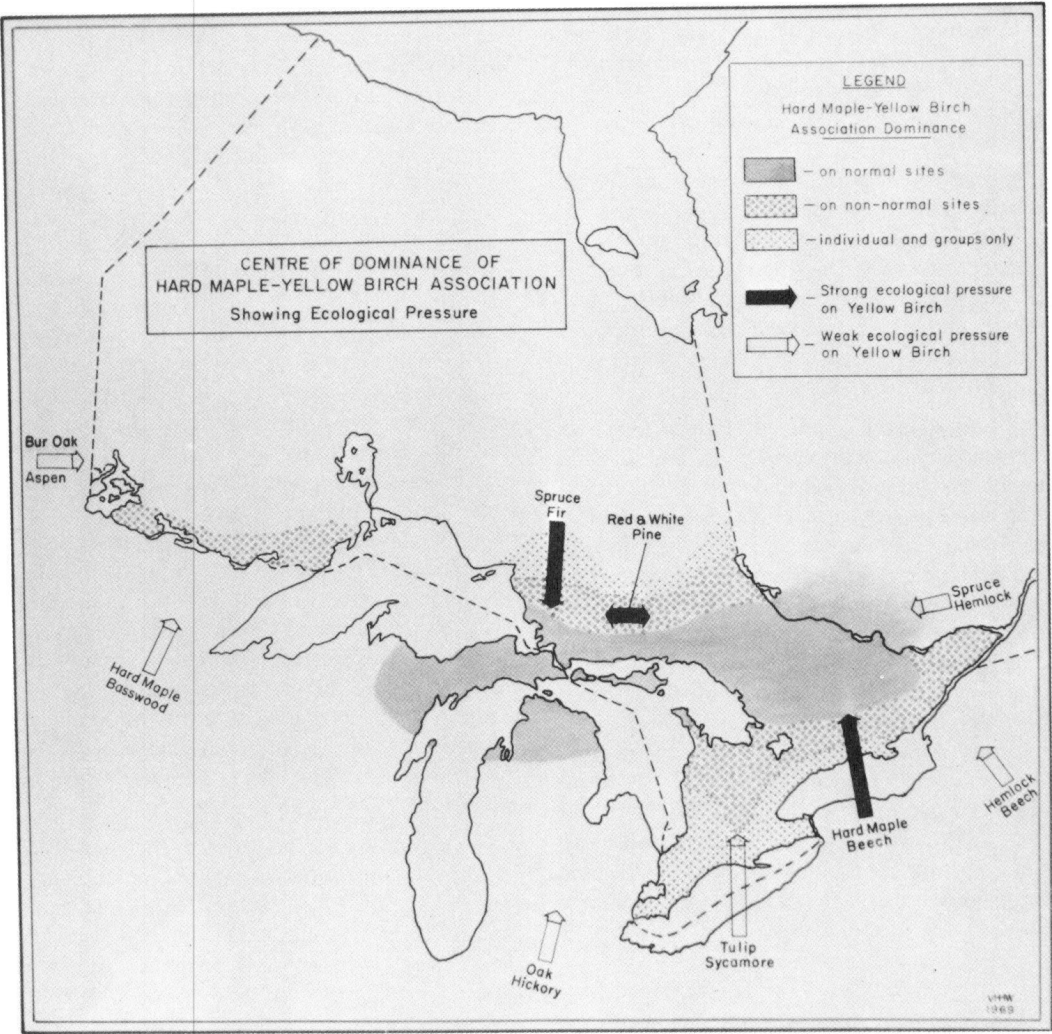


Figure 2.—Center of dominance of hard maple-yellow birch association, showing ecological pressure.

In 1950, a modified commercial cutting operation was initiated at Thurso, Quebec.³ Heavier than normal cutting (13-inch diameter limit) increased the birch stocking by 10 percent compared to light selective cutting, apparently because of the greater degree of ground disturbance and canopy opening. Stocking to sugar maple, a severe competitor under restricted light conditions, also increased, leaving the birch in a less than desirable condition for good development. Nevertheless, early results supported Linteau's previous conclusions.

Moist mineral soil enriched with considerable humus contributes to better survival and growth of yellow birch than either mineral soil or duff alone (*Jarvis 1957*). Redmond (1954) demonstrated much better root development in loam (ignition loss 7.64 percent oven-dry weight) than in sand (ignition loss 0.39 percent oven-dry weight). In 1957, Redmond noted that in mature hardwood stands heavy to birch, 80 percent of the feeding rootlets occurred in the humus layers, usually comprising the top 5 cm. of the soil profile. Larger roots occurring in the B horizon normally had their feeding roots in the upper organic layers. Deeper rootlet penetration commonly followed decomposing old root channels. Two-year-old leaf litter was also invaded by rootlets.

Wang (1965) compared seedbed moisture, texture, and canopy density in the Algoma region of Ontario with respect to the performance of 2-year-old natural birch regeneration. The mixed-texture seedbed consistently gave the best height growth regardless of canopy density or moisture regime. Duff tended to yield better growth at heavier canopy densities than mineral soil seedbeds, the reverse being true for open stands. In all of these cases, however, development was best on the freshest moisture regimes. There was also the suggestion that better growth occurred at lower canopy densities on moist areas than on drier sites. In the early stages of life, seedbed moisture may be more limiting to growth than light availability, at least at the northern limit of the species' range.

The Ontario government established, in 1950, a forest research reserve at Swan Lake in Algonquin Park. The land was to be used to study the factors that limit the establishment and development of yellow birch in central Ontario. Early work at the Algonquin Reserve was concentrated in undisturbed mature and overmature hardwood and mixed-wood stands of the area. From 1950 to 1957, a number of factors were studied, including seed supply, viability and dissemination, continuous determination of moisture, temperature and physical condition of various seedbed types, precipitation and vegetation phenology, and dynamics, all relative to yellow birch and hard maple survival and development.

A good birch seed year in 1950 at Algonquin provided material for a study of reproduction in undisturbed forest conditions. Viability of the seed was better than 40 percent, providing an opportunity for more than adequate stocking. A series of permanent sample plots was established, and a fixed representative population of new yellow birch germinants were staked, numbered, and mapped in the fall of 1951, so that specific seedling histories could be followed over time. Stocking and density estimates were sacrificed in favor of specific biological information relating to mortality. Three hundred yellow birch seedlings were tagged in September 1951. After one growing season, the marked seedlings were stratified according to their current leaf development. It was apparent that seedlings entering the winter in an advanced stage of development suffered far less first-winter kill (fig. 3). In fact, it was possible to separate survival rate in the sequential order of original leaf development; however, all seedlings were dead by 1961. From this early work, the major factors contributing to seedling death in a natural uncut forest were determined by continuous examinations throughout the snow-free periods (*Burton and Leslie 1952*).

High germination occurred in the spring of 1951 in uncut Algonquin stands, on the surface of the litter mat. These germinants died rapidly in great numbers primarily because their radicals could not penetrate the so-called "crust barrier" of snow-flattened maple leaves some 10 layers thick. Seed positioned between the layers of the litter mat also germinated. These died somewhat earlier than

³ Daubney, P. E. REPORT ON REGENERATION SURVEY ON TWO-YEAR-OLD CUTOVER AREAS. Unpublished report, Singer Manufacturing Co., Papineau, Quebec, 1952.

those on the surface because the delicate hypocotyls were unable to pierce the litter overburden.

The felt-like matting of hard maple litter is a major seedbed problem in south-central Ontario, where the associated species is predominantly hard maple and current litter breakdown is comparatively slow. This may not be a problem in other areas, including parts of southern Ontario, where there is rapid incorporation.

Maple leaves have a strong tendency to mat. This is because of their size and weak palmate venation as compared with beech, elm, and birch, which are pinnately veined and tend to curl upon drying.

Finally it was determined that the first-year height growth of the seedlings (1 to 2 inches) was not sufficient in the low light level of the uncut forest to withstand the overwinter flattening and smothering effects of the subsequent autumn leaf fall (Koroleff 1954).

In the spring of 1954, the sample plots used in the 1951 study were used to study regeneration occurring as a result of the heavy 1953 seed crops; and new germinants were staked over a variety of micro-environments. In this study, only cotyledonous seedlings were available, and thus no differential in leaf developments had yet occurred. However, it had been noticed that hypocotyls show a response in their color to the amount of light they received, so the seedling population was stratified and staked according to the degree of redness of the hypocotyl, ranging from red through pink and pink-white to green-white.

The survival rate could be segregated, sequentially in order of the four stem colors, redness indicating a better survival rate (fig. 4). The rapid fall of the red curve was due to a very small sample; the occurrence of *reds* was limited by the low light level. As before, extensive mortality occurred within a very few years.

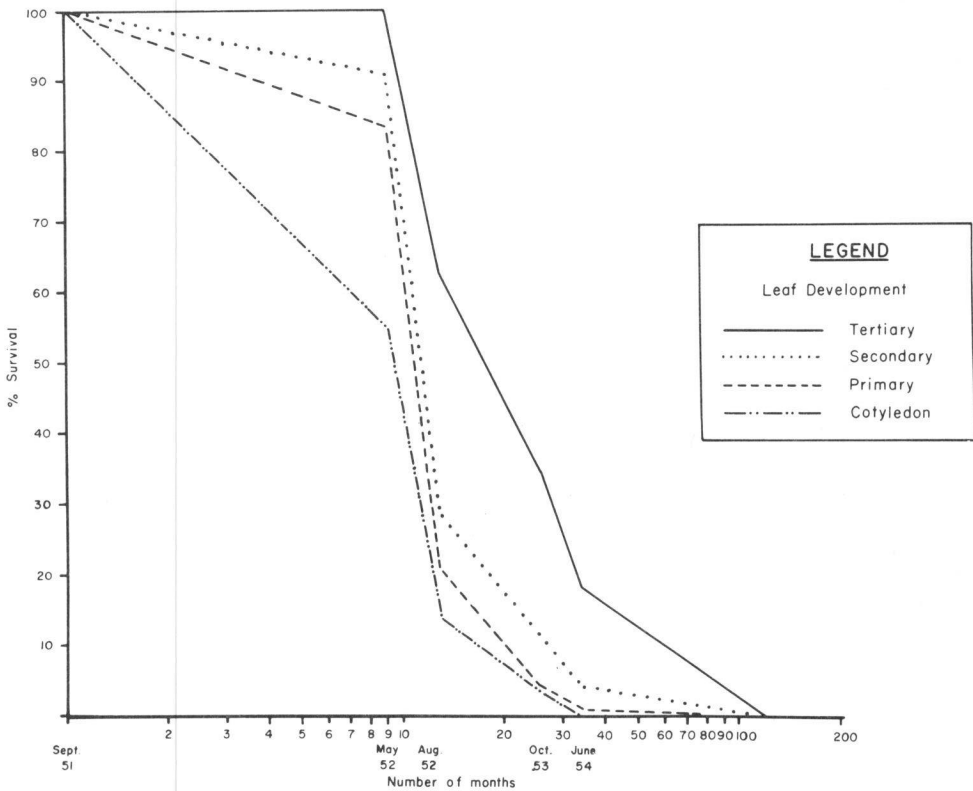


Figure 3.—Survival rate according to degree of leaf development of yellow birch germinants in an uncut forest. (Seed-year 1950.)

Hypocotyl colorations have been noted previously in new germinants of other tree species, especially conifers (*Bates 1925, Krugman 1956*), and the phenomenon has been associated with light (especially ultraviolet) in alpine plants (*Weaver and Clements 1938, Caldwell 1968*). Harvey (*1923*) suggested that they may have a protective action with the respect to insolation injury, since the red color would tend to reflect the destructive heat rays.

The red hypocotyl coloration may be a photomorphogenically produced vacuolar flavonoid pigment, dependent upon two basic radiant-energy systems for its formation. In such a mechanism, bright-level exposure to high-energy blue light at 470 nanometers establishes the prerequisites which, if followed

by low-energy radiation at 660 nanometers, will give rise to flavonoid compounds that are red in acid environments (anthocyanins). The low quantum red effect is mediated by the well-known phytochrome system (*Hendricks 1968*), and perhaps exerts its action by affecting the acetyl coA reactions of fat metabolism (*Butler and Downs 1960*) known to be precursors of part of the flavonoid system. The blue effect presumably affects hormone or enzyme activation through a cis-trans isomerism, such as with cinnamic acid and several other metaloblic regulators (*Zimmerman and Hitchcock 1939, Kauffman et al. 1968*). The coloration develops in situ within the cell and is an inherent characteristic of the species, although in some plants, such as wheat, coleoptile color is related to chromosome number (*Anonymous 1952*).

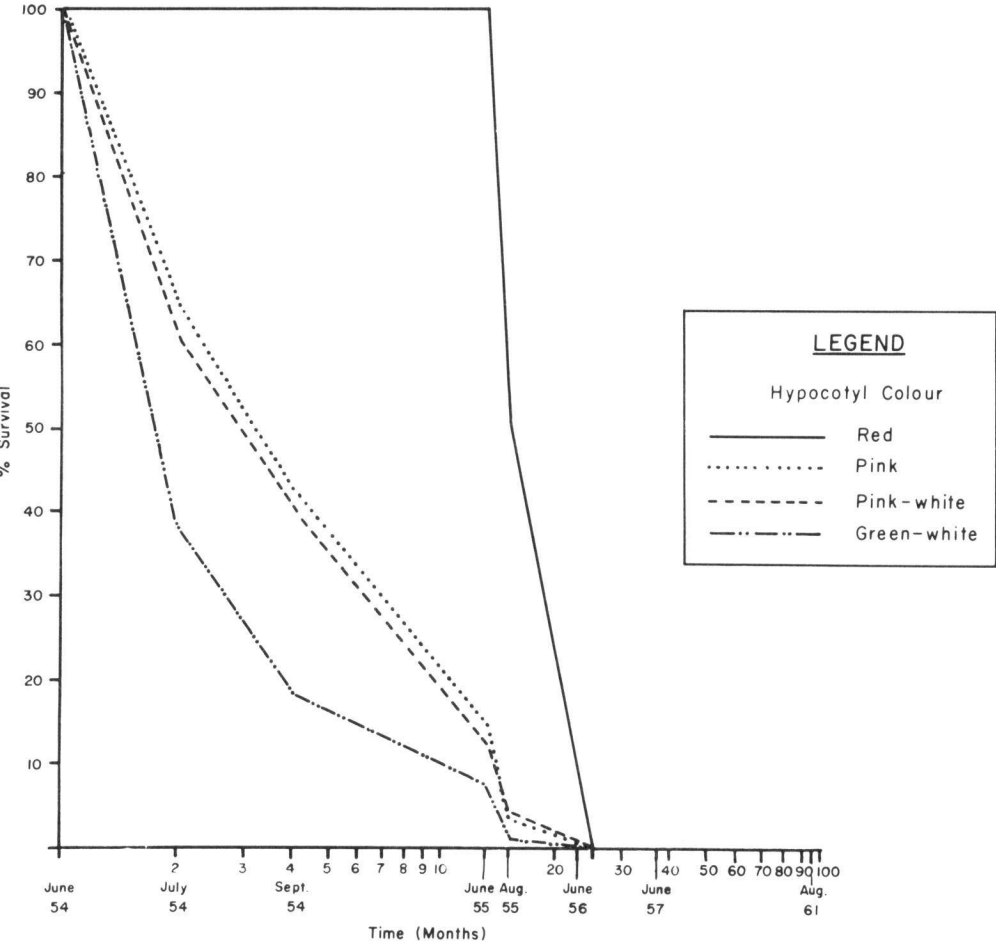


Figure 4.—Survival rate according to hypocotyl color of yellow birch germinants in an uncut forest. (Seed-year 1953.)

The variation in coloration, duplicating that found in the forest, has been produced by germinating birch seed under low light, then providing replicates with light exposures (cool white fluorescents plus incandescents, 16-hour photoperiod) of from 2,000 to 35 foot-candles on a logarithmic scale in a growth chamber. Coloration is well developed in 3 days. After 10 days, primary leaf development and root length and form are related to light treatment and thus to hypocotyl color. The color pattern that can be easily recognized in new germinants is indicative of the light budget of the seedbed location and reflects the potential degree of fibrous root development and height growth of the seedling in its critical early life. The similarity of figures 3 and 4 would support this finding in terms of first-year survival. The 35 and 60-foot candle light levels used in the growth chamber approximate, in terms of intensity, the light levels of uncut hardwood forest.

In terms of relative occurrence according to stand density, it can be shown that only about 10 percent of the seedlings are red under fully stocked uncut stands, but that 59 percent of the seedlings are red under selectively cut stands, 78 percent are red in small patch cuttings (less than 0.05 acres) and 95 percent are red in large patch cuttings (0.05 to 0.19 acres).

Experimental Regeneration Systems

The findings of the early studies allowed the prescription of cultural stand treatments designed to overcome the limiting factors; and the bumper seed crop of 1953 was made to coincide with two separate comprehensive cutting experiments (*Burton 1956, Jarvis 1957*).

The Canada Department of Forestry established a study in the Haliburton Highlands in forest where a somewhat heavier-than-normal cut was taken out (about 3,000 board feet/acre) due to the general high quality of maple. Concurrent purposeful ground scarification, using tractors with straight blades, and girdling of culls to reduce crown canopy to about 40 percent, were further treatments. Control areas were not scarified, and crown canopies had normal cutover closure. On the basis of subsequent regeneration cruises, using permanent transects, excellent results were achieved on the treatment areas with yellow birch stocking of 66 percent

and densities of 4,800 seedlings per acre existing after 10 years. Control areas had less than half the stocking and density values, although some ingrowth from subsequent seed years has probably been included in these figures.

In the same year (1953) at the Algonquin Reserve a different approach was taken, with differing results. A light "normal" selective cut (2,000 board feet/acre) was made, and incidental scarification was accomplished by skidding tractor treads (no blade). Somewhat heavier-than-normal ground disturbance was obtained in the vicinity of cut trees by having separate skid trails located for each log from a given tree. Around the cut stumps, with their areas of disturbed litter, additional trees were felled to produce patch cuttings of different sizes. The purpose was to disturb the litter mat, to reduce subsequent leaf fall, and to supply more light to the seedbed than would normally be available in a cutover. Normal cutover conditions prevailed between the patches.

An excellent catch of germinants was obtained. A selected population of these was staked according to stem color on each patch and normal cutover area for survival and growth studies. In both the Haliburton and Algonquin experiments, a considerable number of seedlings reached a minimum height of 5 inches the first year. In contrast to the Haliburton study, however, there was total mortality of the thousands of staked birch seedlings at Algonquin in both patch cuttings and normal cutover by 1961.

This mortality was attributed to the unusually high resident deer population in Algonquin Park, where deer are protected by law. Surveys showed that 10 to 15 deer per square mile inhabit the area in summer; this exceeds the carrying capacity of the land, if overbrowsing is to be avoided.⁴ In addition, incidences of clipping by hares were observed in 1955-57 during a population peak of these animals. Continuous summer deer browsing in July and late August over a 6-year period effectively eliminated yellow birch regeneration. In retrospect, it is probable that the patch cutting, complete with concentrated tree-tops, attracted the deer to the openings and subsequently led to browsing of seedlings for food.

From a sample of 1,000 staked seedlings over a 3-year period (1955-57), slightly more

than 95 percent of the yellow birch in the patches that attained a minimum height of 6 inches were browsed at least once, and most of them two or three times.

As with the companion study in uncut stands, hypocotyl color proved a good indication of survival in both patch cutting and normal cutting (fig. 5). Green-white seedlings have a low survival rate; and after two growing seasons 74 percent of the seedlings growing in patch cutting that had attained at least 6 inches of height were pink-or red-stemmed. These favored seedlings were the first to be browsed by deer. Deer browsing killed some seedlings directly, but more frequently height was reduced to about 4 inches or less, which places a seedling in a position to be smothered by leaf fall or killed by suppression from less palatable vegetative competitors.

The Haliburton area, in contrast, was subjected to fairly heavy deer hunting pressure.

Though 79 percent of the quadrats showed some incidence of browsing, large numbers of seedlings escaped injury and developed uninhibited. Deer exclosures established at Swan Lake in 1956, after 21½ years of browsing⁴ allow comparison of the two studies. The reduced browsing and slightly better sites are reflected in the better Haliburton height growth, where 20 feet is an average dominant height after 10 years (*Wang 1968*). The heavier browsing conditions are clearly evident in the average height of the browse line on the two areas (fig. 6).

The extreme importance of animal populations was emphasized in an after-cutting scarification comparison trial established in

⁴ Stephenson, A. B., and R. L. Hepburn. DEER AND FOREST REGENERATION, ALGONQUIN PARK. Unpublished report, Ontario Dep. Lands and Forests, 1958.

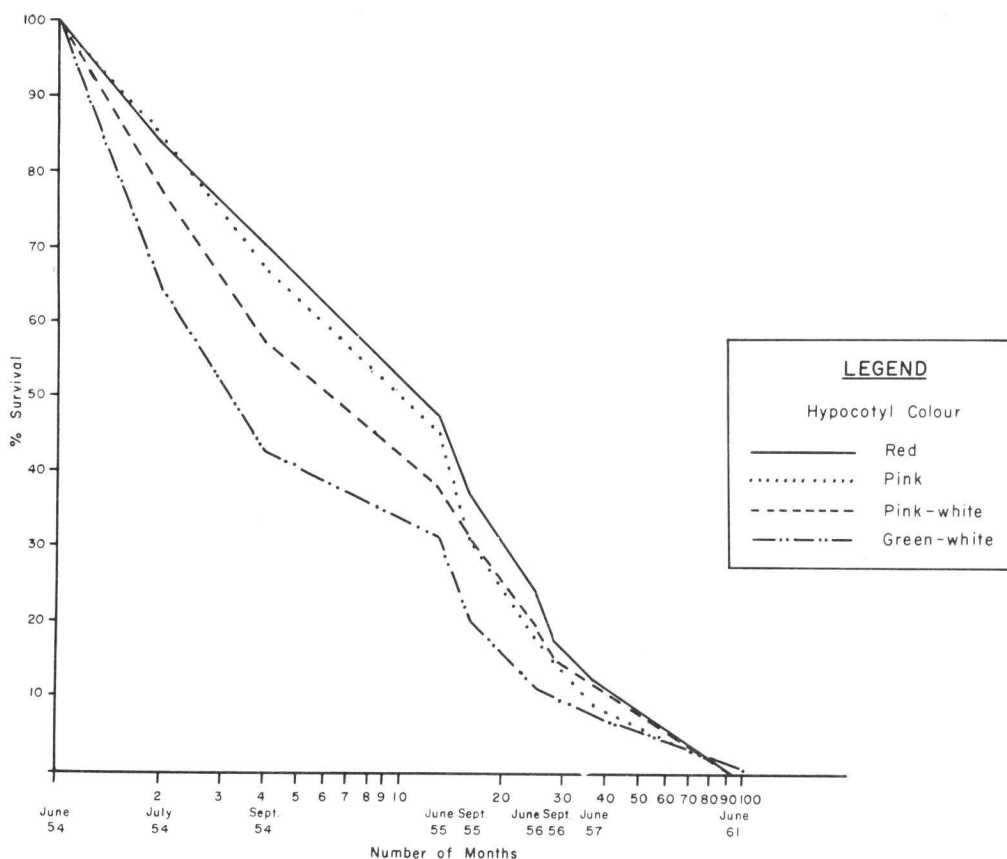


Figure 5.—Survival rate according to hypocotyl color of yellow birch germinants in a patch-cut area (cut in seed-year 1953.)

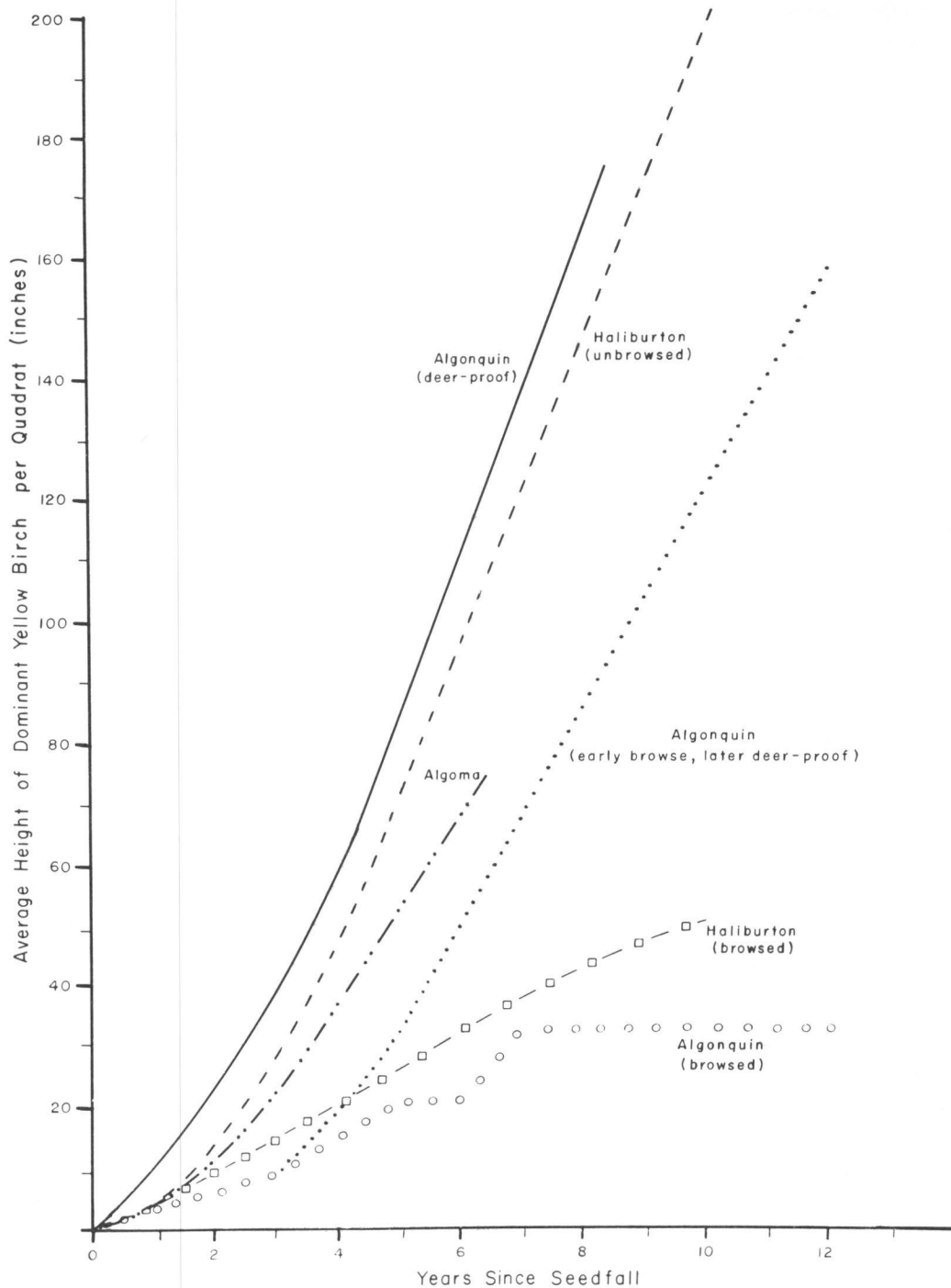


Figure 6.—Height growth of yellow birch obtained in several regeneration trials.

Haliburton in 1955, just before the peak of the hare population cycle (Fayle 1961). Clipping by hares destroyed the birch regeneration after an excellent catch of germinants. This problem is without comparable solution unless the culinary habits of Canadians can be changed to a preference for lagomorph stew instead of venison.

The total exclusion of deer in the Algonquin study by fencing resulted in an interesting shift in successional trend. Whereas normal light selective logging combined with an unrestricted deer herd invariably results in a predominantly maple ingrowth, heavier cutting combined with complete exclusion of deer allowed invading intolerant species, such as white birch, willow, aspen, and pin cherry, as well as yellow birch, to become established. This was perhaps more noticeable on the moister and richer sites, especially in combination with large crown openings. These encroaching species usually outgrew both yellow birch and hard maple, especially the latter.

Disease killed a number of seedlings on regeneration study plots. In 1954 and 1955, dieback and cankering affected many 2-year-old yellow birch seedlings growing in the experimental patches, often in the more exposed locations. Culture isolations yielded *Phomopsis* spp. in most cases, organisms similar to those that had been found infecting yellow birch showing birch dieback symptoms (Hansbrough 1952, Redmond 1952).

This fungus was shown to be moderately pathogenic upon inoculation and could cause mortality in yellow birch germinants and young seedlings. Infection in vigorous older stems was accomplished only through injuries, while trees under physiological stress were infected by topical application without wounding (Horner 1952). In 1960, sapling wilting, dieback, and cankering associated with *Phomopsis* spp. were noticeable on yellow birch, often on trees injured by browsing or early fall frost (Raymond 1960). The disease probably accounted for a considerable part of the mortality in the experimental patch cutting, the condition being aggravated by the infection courts established by the browsing and by the severe summer drought of 1955. There is some indication that high densities of seedlings, in conjunction with rapidly developing root systems and concomitant root competition, may promote development of the disease.

Early stem differentiation into positions of dominance would seem to reduce the severity of the disease due to its effect in reducing density and thus avoiding the prevalence of low-vigor stock.

Operational Regeneration Systems

At the completion in 1956 of the first phase of the Algonquin and Haliburton studies and as a direct result of them, the Ontario Department of Lands and Forests initiated large-scale scarification procedures throughout the commercial range of yellow birch in Ontario (some 5,000 acres in 1967).

A variety of machines and scuffer devices was employed, partly on pilot-scale trials to determine their effectiveness. In addition to seedbed treatment, stands are being opened up to a considerably greater extent than in the past. Precutting and concurrent scarification has been carried out, but a great amount of effort has been put forth on after-cutting scarification, to rehabilitate degraded stands. Scarification techniques are designed to destroy the litter barrier, root out advanced growth to some degree, and prepare a receptive environment for germination, establishment, and growth of the more valuable commercial species.

In the operational trials, consideration was given to obtaining a suitable mix of seedbed components, the importance of which has already been mentioned.

Scarification was tested in the Haliburton Region on more than 1,000 acres, using various sizes of bulldozers equipped with blades. TD-14 and D-6 machines were powerful enough to root out advance growth and wind-falls as well as scarify the ground. Additional cutting was done to make patches 1/10 to 1/3 acre in size. In some places, the blades dug too deep, exposing the A₂ horizon. Though this ground condition afforded a good catch of birch, subsequent survival and growth were very poor.

By a stocking standard of 10 birch per milacre as satisfactorily stocked, three growing seasons after treatment there was 88 percent stocking on scarified samples in patches, 26 percent stocked in normal heavy cutovers, but 0 percent in closed forest.⁵ At this time, 50

⁵ Sinclair, G. A. EVALUATION OF CULTURAL TREATMENTS. Unpublished report, Ontario Dep. Lands and Forests, 1959.

percent of the seedlings were taller than 24 inches in the patches, but only 26 percent achieved this height in the normal cutting. On unscarified ground, 30-percent stocking occurred in the patches, with no stocking in uncut forest.

Similar operations carried out in northern Algonquin Park, near Kiosk, had limited success due to the deer population, although excellent catches were initially recorded. This trial was one of the first attempts at scarifying ground in early winter. The litter mat was frozen and the bulldozer blade easily peeled it back, exposing the humus and duff layers. This was one of the most economical blade-scarification jobs ever carried out, mainly due to the litter condition. The area overwintered a deer population of approximately 60 deer per square mile; however, the very extensive cutting operation was partitioned with purposely manufactured "top-jackpots" which acted as natural deer exclosures to some degree, and which tended to interrupt the natural browse continuum. The deer population dropped to about 15 per square mile the following winter, and there was almost negligible browse damage on the birch seedling stock.⁴

Some of the most extensive rehabilitation and testing work in the Province has been carried out in the Algoma Region by the Sault Ste. Marie District staff. In studies similar to the Haliburton trial, blade scarification was found to give a higher initial density of birch compared with that obtained by using a mounted rake in place of a blade, but average dominant height was substantially better on the rake-prepared sites.⁶ The blade removed more of the competing vegetation. Shelterwood systems (some residual stems peripheral to patches $\frac{1}{3}$ acre or less) and clearcut strips were tested. Optimum strip width was 1 chain, and length (up to 440 feet) had little effect on performance. Birch stems grew somewhat better near the strip center (edge effect), but overall growth rate was similar in strip and patch systems. Mortality on patches was only half that in strips. Aspect had an influence in the strip method, the NW-SE orientation showing about 30 percent better density and average height after 5 years than strips oriented in a NE-SW direction. Birch consistently outperformed maple, perhaps in part because of the

negligible deer browsing. Some new germination occurred 2 and 3 years after seedfall; however, the seedbed had completely deteriorated within 5 years.

One study showed that 2 years after scarification (where there was about 40 percent ground coverage) and strip canopy reduction, 86 to 99 percent of the quadrats were stocked (10+ seedlings) to yellow birch, and that 35 to 48 percent of the quadrats had seedlings in a free-to-grow condition.⁷ After eight growing seasons, average dominant height was 6.39 feet, with 32 percent of the plots stocked to dominant yellow birch (fig. 6).

Rear-mounted, hydraulically-operated scarifiers such as disc- and fire-plows are suitable for site preparation only on level terrain. Better success on steep slopes or very rocky ground was obtained with anchor chain tractor-pad drag units. The fluid motion of a chain allows it to override rocks, stumps and slash and facilitates excellent mixing of mineral soil and humus. The degree of disturbance can be modified by choice of three weights (15-, 22-, or 32-pound links). Gross cost per chain-treated acre is around \$12, and net coverage varies from 20 to 40 percent. Winch-equipped tractors are recommended and ripper-cleat attachments facilitate the concurrent reduction of advance growth on the scarification corridor.

Auld and Graham⁸ point-sampled scarified strips made by rock rake, straight blade, and blade with Young's teeth to compare organic contents of the upper 2 inches of seedbed as a result of treatment. Ignition loss, expressed as a percentage of oven-dry weight, was used as a measure of organic content. Considerable variation was found both within and between treatments, ranging from about 2 percent to 50 percent. The degree of humus incorporation was influenced in part by the land physiography, very low values being associated with areas of ponded sand with a high water table. Upland areas generally

⁶ Graham, H. D. FIVE YEARS OF TESTS ON SEEDBED PREPARATION. Unpublished report, Ontario Dep. Lands and Forests, 1962.

⁷ Graham, H. D. YELLOW BIRCH REGENERATION SURVEY. Unpublished report, Ontario Dep. Lands and Forests, 1958.

⁸ Auld, J. M., and H. D. Graham. SOIL SURVEY OF AREAS MECHANICALLY SCARIFIED FOR YELLOW BIRCH. Unpublished report, Ontario Dep. Lands and Forests, 1967.

showed values averaging around 15 to 20 percent organic matter. No significant differences could be demonstrated between methods of treatment (95 percent confidence limit). No edge effect was found in sampling across the width of strips. These latter figures compare favorably with those given by Redmond (1954) for loam soil, which promoted good fibrous root development of yellow birch seedlings.

Riley⁹, in a study of incidental ingrowth of birch after site preparation for planting in Algoma, noted that rear-mounted drums produced 30-percent scarification of the mixed type, and a V-blade produced 20 percent, while an angle blade developed only 1 percent mixed. This latter figure, however, emphasizes that dependence for satisfactory site preparation lies entirely with the skill of the operator when front-end scarifiers are used.

A cost analysis, comparing two degrees of scarification, one in which only the best yellow birch sites were scarified and another in which all possible sites were prepared (dozer blade), showed average cost per net acre treated as \$8.74 and \$20.13 respectively.⁹ Relative birch stocking after 7 years was 64 percent (3,300 stems per acre) compared with 81 percent (5,100 stems per acre). By normalizing the degree of scarification to 60 percent, the estimated site-preparation cost per thousand trees established is about the same (\$3.32 vs. \$3.43).

Though after-cutting scarification for rehabilitation of degenerated cutover is important, it would seem desirable to accomplish restocking procedures coincidentally with the cutting operation. Recently the use of prescribed fire has shown much promise in terms of application, cost, and effectiveness (Sloane 1960; Burton and Sloane 1958). Autumn application of fire reduced seedling density (mainly maple) from 160,000 to a level of 18,000 per acre in an old-growth hardwood stand. It is estimated that almost all of the current maple seed crop had fallen before the burn, and was therefore consumed by it (Sinclair 1962). Single fall burns do not drastically reduce the number of sapling maple, although basal scarring and sprouting are apparent (Holowacz 1960). No significant changes in microbial numbers, soil pH, or the levels of available phosphorus, potassium, calcium, or magnesium were found.¹⁰

Spring burning, though somewhat more difficult to effect, usually has a higher killing power with respect to small saplings (Sykes 1964). In fact, three consecutive spring fires may kill up to 55 percent of all trees in the diameter range of 0.6 to 4.5 inches. A single fall fire primarily removes only the current leaf-fall unless a dry autumn has allowed the previous litter barrier to dry out. However, that layer is in the initial stages of decomposition at this time, and by the spring after the burn it will not offer the extreme obstacle to newly germinating seed as it did the previous spring. From experience gained in several different trials, it is believed that the treatment can be done at an approximate cost of \$1 per acre.

An interesting point regarding seedbed texture after burning is that light fall fires seem to stimulate the growth of *Erythronium* (dog's-tooth violet) in the early spring, which have the faculty of "plowing" the litter or duff as they emerge from the soil, a sort of natural disturbance.

Current Research

Two regeneration experiments are now under way. At Valcartier, Quebec, an experimental patch cutting with scarification and hand-seeding was initiated in 1960. Four-year results indicate that patch size should be limited to 1/10 acre on south slopes to reduce temperature extremes and desiccation (Hatcher 1966). Also, it was shown that current leaf-fall is minimal on the larger patches, and thus summer treatment might be possible on such areas. Patches less than 1/10 acre in size close their canopy rapidly. The most efficient size, therefore, would perhaps be in the neighborhood of 1/5 acre on normal sites. Loosened humus seedbeds appeared to give good results.

In 1960, a good birch seed year, a regeneration demonstration was established at Swan Lake Reserve. A 10-acre block of old-growth timber growing on a drumlinoid ridge was fenced to exclude deer. It was logged in early fall, using a partial cutting technique

⁹ Riley, L. F. A STUDY OF YELLOW BIRCH REGENERATION UNDER VARIOUS SEEDBED CONDITIONS AND TREATMENTS. Unpublished report, Can. Dep. Fisheries and Forestry, Ontario, 1968.

¹⁰ Raymond, F. L. SOIL SAMPLING AFTER PRESCRIBED FIRES. Unpublished report, Can. Dep. Agr. Forest Pathol. Lab., Ontario, 1960.

and taking the poorer trees. Skidding was done with a crawler-type vehicle, which provided some scarification, and skid trails were laid out to provide maximum ground coverage without being inefficient. Additional scarification was carried out with a drag-type scuffer and one-half the block was burned later in the fall. The logging operation amounted to a heavy improvement cutting, and resulted in a variety of residual densities from essentially uncut forest through to large open patches.

Quadrats were laid out in burned and unburned conditions and populations of yellow birch and/or hard maple germinants were permanently staked in 1961. An excellent catch of both species was obtained.

Survival, 33 percent after 8 years, was facilitated by the complete exclusion of deer. Quadrats had from 0 percent to 63 percent actual survival (fig. 7). Average height of the six tallest birch per plot after 8 years decreased as the residual point density (prism count) about the plot increased (fig. 8).

Good correlation exists between residual stocking and vigor, with some increase in variance occurring at the open end due to important azimuth effects of horizontal structure variation. Anderson (1964) also found that, for 2-year-old yellow birch, best height growth was related to lowest canopy densities.

Hard maple on the burned plots is developing more slowly than on unburned sites, for a given stand density (fig. 9). Both conditions, however, produce considerably less growth for maple than for birch. Little birch stocking was found on unburned soil, but those seedlings that survived in that condition performed as well as those on burned soil. The favorable maple development on the unburned seedbed may reflect a preference of the species for the natural maple environment. On the other hand, the fact that the poorer maple were always in mixture with yellow birch might suggest that some biological antagonism exists between the two species.

After the establishment period of 3 years or so, yellow birch should maintain about 3

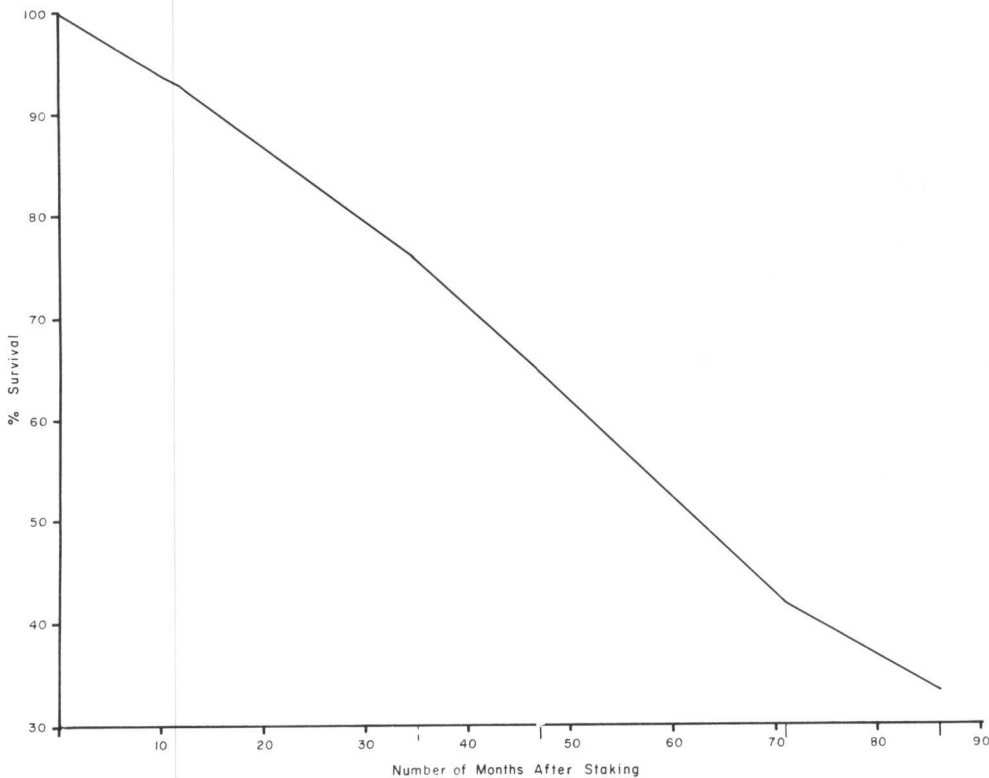


Figure 7.—Survival rate of yellow birch germinated in 1961, averaged over a range of stand densities. (Swan Lake drumlin.)

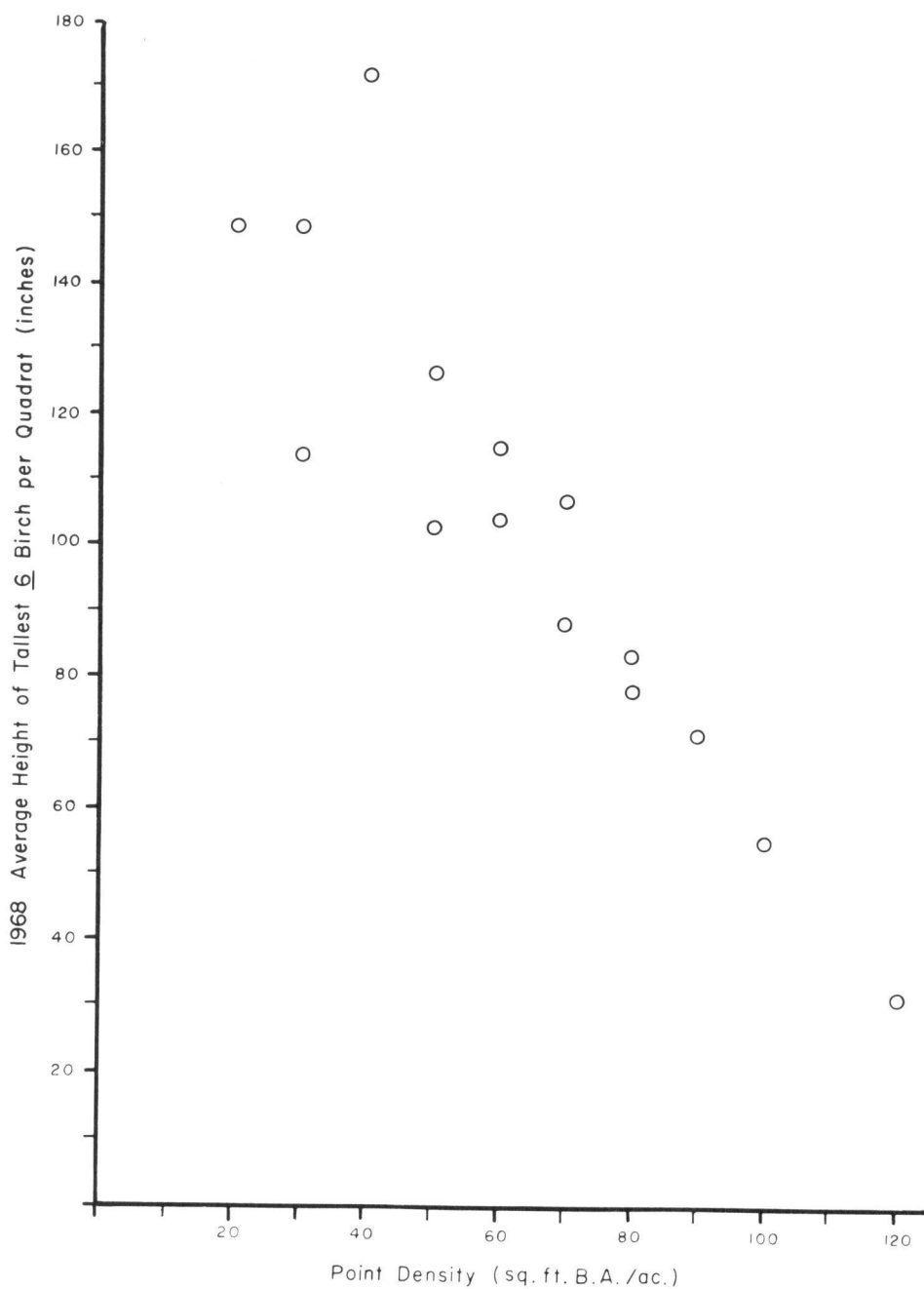


Figure 8.—Relationship of height of dominant yellow birch seedlings to stand density eight growing seasons after germination. (Swan Lake drumlin.)

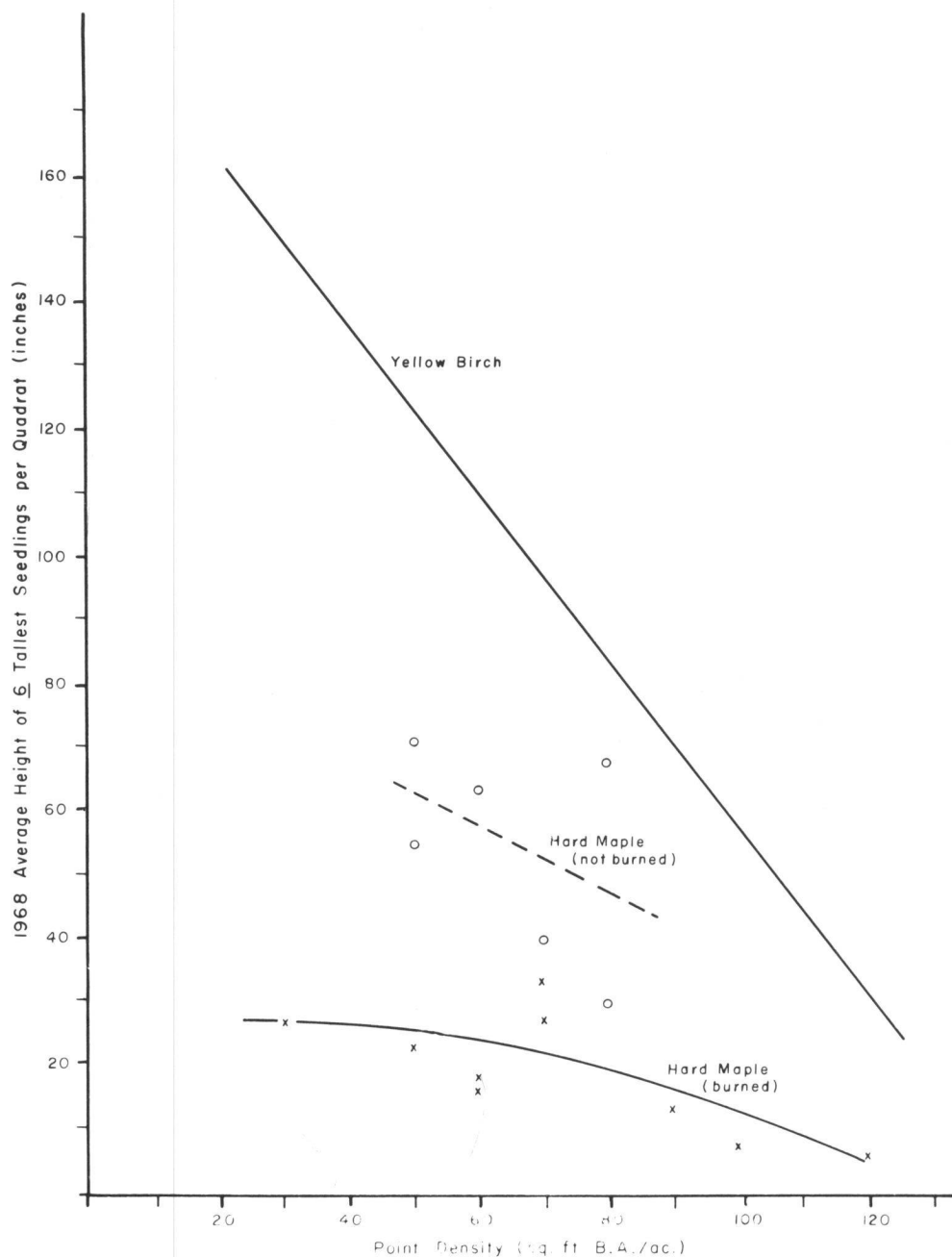


Figure 9.—Relationship of height of dominant hard maple seedlings to stand density eight growing seasons after germination, according to seedbed treatment. (Swan Lake drumlin.)

feet of terminal growth per year. Height ranking of individuals varies considerably from year to year in a given plot: the tallest seedling this year was not necessarily the tallest last year, nor may it be next year. Some minor tip-killing by *Phomopsis* (or the like) is fairly prevalent each year, and this may explain the fluctuation. Generally persistent dominant trees cannot be accurately chosen for the first 4 years after germination, and indeed there is doubt in some plots after even 8 years. However, most plots showing good vigor have at least a consistent group of three seedlings that dominate the plot.

Plots showing the best birch growth also show the highest birch mortality. Apparently the emergence of dominance is associated with trees that develop the best root system and that, as the root pattern of these trees develop as a result of better competitive position, root competition causes the smaller trees to succumb. This mortality, however, helps the dominants to more efficiently utilize the surrounding soil. A consistently rapid height growth in vigorous birch at low canopy densities would seem to be made at the expense of survival. At higher canopy densities, mortality is less extreme but height growth is not consistent, tending to slow down after 4 years. Lack of height or root differential in the quadrat population seems to cause overall lowering of vigor, rather than an abrupt polarizing effect on survival.

Such is the paradox with yellow birch. Initially we are hoping for a good seedling catch, yet later we would prefer crown differentiation at the expense of survival. Hand-seeding studies have demonstrated also the adverse effects of overstocking in yellow birch, in terms of development and disease occurrence.

Yellow birch possesses well developed, extensive lateral rooting and less intensive central rooting than maple (Fayle 1965), although birch roots may also penetrate deeply under favorable soil conditions (for example, old root channels).

The improved light conditions affect root development more than height development after 3½ years (fig. 10). Lateral roots extend radially as far as the tree is tall, and it is reasonable to assume that intense root competition exists in such plots. This extensive root development probably gives birch an ad-

vantage over maple in terms of initial establishment under low canopy densities.

Logan (1965) considered the effect of light intensity on root and top development of yellow birch and hard maple. Yellow birch showed best height growth in 25 to 45 percent light while shoot and foliage dry weights were maximized at 45 to 100 percent light. Sugar maple tended to perform less selectively over a wider and lower range of light conditions. In terms of root development (dry weight) yellow birch produced best on 45 to 100 percent light, whereas hard maple showed absolutely no preference in this respect. Our observations support Logan's findings with respect to both top and root development, although full sunlight was not tested in our work (fig. 10).

In at least two studies,^{5,9} average height growth of yellow birch seedlings for a given canopy density (open to partially closed) has been better on the few seedlings that become established through cracks, holes, or vegetation plowing on unscarified ground than on prepared seedbeds (including mixed conditions). This suggests that for yellow birch as well as for maple, as discussed previously, a natural rhizosphere is best for growth, provided initial establishment is possible. However, this observation is based on limited data, and further study is required on the fundamental requirements of root environment for young seedlings. Light-intensity measurements made in 1964 (fourth growing season), using a Weston illuminometer, showed maximal values of about 40 percent full sunlight, corresponding to the lowest residual stand densities. Poor correlation was noted at that time between height and light; however, after eight growing seasons, 8-year-growth shows a fair degree of correlation with fourth-year light intensity.

Eighth-year mortality also showed some degree of correlation, as one would expect. Maple, on the other hand, showed an overall lack of correlation of height or mortality on light intensity. This improved fit of values after 8 years with the birch is further evidence of the initial juggling that occurs for the first 4 years or so.

Height growth of yellow birch depends to a large degree on current photosynthate, and increases in light intensities up to 40 percent of full sunlight. At the molecular level, the

saturation point in terms of energy utilization at the metabolic sink usually occurs at about 20 percent full light. Other factors limit saturation, which are also illustrated by the well-known Blackman effect. However, the extra light energy beyond 20 percent presumably aids the shaded lower leaves to approach saturation, which would not occur under optimal light levels for the top leaves only.

The limit imposed upon the size of opening desired may be affected more by the chance of invasion by pioneer species than by growth considerations. Riley⁹ demonstrated also that

yellow birch tends to dominate all quadrats at canopy densities of 40 percent but that the chance of dominance decreases as canopy density increases. To obtain optimum light condition for growth, it is necessary to consider patch size, stocking density, light intensity, or canopy density; and perhaps studies should be undertaken to relate these factors to one another, all in relation to performance of yellow birch. There seems to be little problem in getting yellow birch to regenerate now; the current need is for information to help this regeneration to grow into veneer-quality trees.

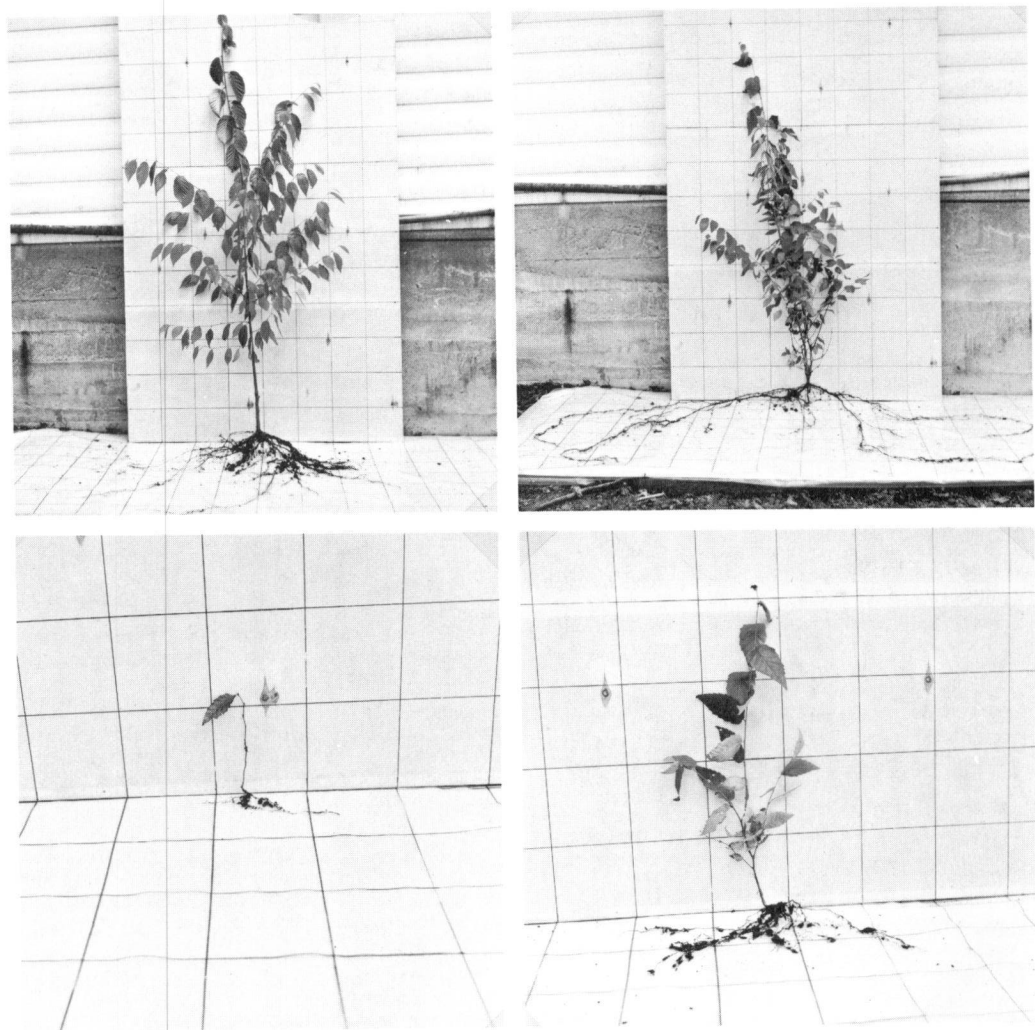


Figure 10.—Yellow birch seedlings excavated during their fourth growing season, representing overwood densities (reading clockwise from upper left) of 30, 60, 90, and 120 square feet of basal area per acre. Grid squares are 6 inches. Note especially root development.

Literature Cited

- Anonymous.
1952. MUNSELL COLOR CHARTS FOR PLANT TISSUES. Munsell Color Co., Inc., Baltimore, Md.
- Anonymous.
1967. A STATISTICAL REFERENCE OF LANDS AND FORESTS ADMINISTRATION 1967. Ontario Dep. Lands and Forests, Operations Br. 215 pp. Toronto, Ont.
- Anderson, M. L.
1964. HEIGHT GROWTH OF YELLOW BIRCH SEEDLINGS UNDER VARIOUS CANOPY DENSITIES. Can. Dep. Forestry mimeo. report 64-0-2. 9 pp.
- Bates, C. G.
1925. A KEY TO THE IDENTIFICATION OF SOME CONIFEROUS SEEDLINGS. J. Forestry. 23: 278-281.
- Brunelle, R.
1967. ANNUAL REPORT OF THE MINISTER OF LANDS AND FORESTS, PROVINCE OF ONTARIO FOR THE FISCAL YEAR ENDING MARCH 31, 1967. 124 pp. Ontario Dep. Lands and Forests, Toronto, Ont.
- Burton, D. H.
1956. YELLOW BIRCH REGENERATION. Sylva 12: 17-21.
- Burton, D. H., and A. P. Leslie.
1952. SOME SILVICAL CHARACTERISTICS OF YELLOW BIRCH. Symp. Birch Dieback Proc.: 57-58, Ottawa, Ont.
- Burton, D. H. and N. H. Sloane.
1958. PROGRESS REPORT ON PRESCRIBED BURNING IN THE HARD MAPLE - YELLOW BIRCH COVER TYPE IN ONTARIO. Ontario Dep. Lands and Forests Res. Br. Sect. Rep. 25. 10 pp.
- Butler, W. L., and R. J. Downs.
1960. LIGHT AND PLANT DEVELOPMENT. Sci. Amer. 203(6): 56-63.
- Caldwell, M. M.
1968. SOLAR ULTRAVIOLET RADIATION AS AN ECOLOGICAL FACTOR FOR ALPINE PLANTS. Ecol. Monogr. 38(3): 243-268.
- Cunningham, G. C.
1952. RESEARCH IN TOLERANT HARDWOODS. Birch Dieback Symp. Proc.: 52-56. Ottawa, Ont.
- Dixon, R. M.
1963. THE FOREST RESOURCES OF ONTARIO. Ontario Dep. Lands and Forests, Timber Br., 108 pp. Toronto, Ont.
- Drinkwater, N. H.
1957. THE TOLERANT HARDWOOD FORESTS OF NORTHERN NOVA SCOTIA. Can. Dep. N. Affairs and Natl. Resources, Forestry Br. Tech. Note 57. 25 pp.
- Fayle, D. C. F.
1961. HARE BROWSING MAY SPOIL YELLOW BIRCH REGENERATION. Can. Dep. Forestry. Forestry Res. Br., mimeo. 61-14. 10 pp.
- Fayle, D. C. F.
1965. ROOTING HABIT OF SUGAR MAPLE AND YELLOW BIRCH. Can. Dep. Forestry Pub. 1120. 31 pp.
- Hansbrough, J. R.
1952. THE SIGNIFICANCE OF THE FUNGI AND VIRUSES ASSOCIATED WITH BIRCH DIEBACK. Birch Dieback Symp. Proc.: 128-135. Ottawa, Ont.
- Harvey, R. B.
1923. RED AS A PROTECTIVE COLOR IN PLANTS. Ann. Rep. Minn. State Hort. Soc. 279 pp.
- Hatcher, R. J.
1966. YELLOW BIRCH REGENERATION ON SCARIFIED SEEDBEDS UNDER SMALL CANOPY OPENINGS. Forestry Chron. 42: 350-358.
- Hendricks, S. B.
1968. HOW LIGHT INTERACTS WITH LIVING MATTER. Sci. Amer. 219(3): 175-186.
- Hills, G. A.
1959. A READY REFERENCE TO THE DESCRIPTION OF THE LAND OF ONTARIO AND ITS PRODUCTIVITY. Ontario Dep. Lands and Forests Res. Div. 142 pp. Maple, Ont.
- Holowacz, J.
1960. PROGRESS REPORT ON PRESCRIBED BURNING IN THE HARD MAPLE-YELLOW BIRCH COVER TYPE IN ONTARIO. Ontario Dep. Lands and Forests Res. Br. Sect. Rep. (Forestry) 37, 16 pp.
- Horner, R.
1952. MYCOLOGICAL INVESTIGATIONS OF BIRCH IN ONTARIO. Birch Dieback Symp. Proc.: 144-146. Ottawa, Ont.
- Hosie, R. C.
1953. FOREST REGENERATION IN ONTARIO. Univ. Toronto Forestry Bull. 2. 134 pp.
- Jarvis, J. M.
1956. AN ECOLOGICAL APPROACH TO TOLERANT HARDWOOD SILVICULTURE. Can. Dep. N. Affairs and Natl. Resources Forestry Res. Div. Tech. Note 43. 43 pp.
- Jarvis, J. M.
1957. CUTTING AND SEEDBED PREPARATION TO REGENERATE YELLOW BIRCH, HALIBURTON COUNTY, ONTARIO. Can. Dep. N. Affairs and Natl. Resources Forestry Res. Div. Tech. Note 53. 17 pp.
- Kaufman, H., S. M. Vratsanos and B. F. Erlanger.
1968. PHOTO REGULATION OF AN ENZYMIC PROCESS BY MEANS OF LIGHT SENSITIVE LIGAND. Sci. 162(3861): 1487-1488.
- Koroleff, D.
1954. LEAF LITTER AS A KILLER. J. Forestry 52: 178-182.
- Krugman, S.
1956. THE ANTHOCYANIN AND LEUCO-ANTHOCYANINS OF SUGAR PINE SEEDLINGS. Forest Sci. 2(1): 273-280.
- Lemieux, G. J.
1963. SOIL-VEGETATION RELATIONSHIPS IN THE NORTHERN HARDWOODS OF QUEBEC. Proc. Second North Amer. Forest Soils Conf.: 163-176 pp. Corvallis, Ore.
- Leslie, A. P.
1931. REPORT ON THE FOREST REGENERATION SURVEY OF CUTOVER PINE LANDS UNBURNED SINCE LOGGING, ALGONQUIN PARK. 69 pp. Ontario Forestry Br., Toronto.
- Linteau, A.
1948. FACTORS AFFECTING GERMINATION AND EARLY SURVIVAL OF YELLOW BIRCH (*Betula lutea* MICHX.) IN QUEBEC. Forestry Chron. 24: 27-86.
- Logan, K. T.
1965. GROWTH OF TREE SEEDLINGS AS AFFECTED BY LIGHT INTENSITY: I WHITE BIRCH, YELLOW BIRCH, SUGAR MAPLE, SILVER MAPLE. Can. Dep. Forestry Pub. 1121. 16 pp.

- Morawski, Z. J. R., K. B. Turner, and J. T. Basham.
1958. A SURVEY OF THE PATHOLOGICAL CONDITION OF THE FORESTS OF ONTARIO - CULL STUDIES. Ontario Dep. Lands and Forests Timber Div. Rep. 25. 95 pp.
- Raymond, F. L.
1960. AN UNUSUAL WILTING AND DIEBACK OF YELLOW BIRCH SAPLINGS. Can. Dep. Agr. Bi-monthly Prog. Rep. 16(6): 2.
- Redmond, D. R.
1952. TWIG INHABITING FUNGI OF YELLOW BIRCH; TWIG INOCULATIONS OF LIVING BIRCH WITH FUNGI. Birch Dieback Symp. Proc.: 136-137. Ottawa, Ont.
- Redmond, D. R.
1954. VARIATIONS IN DEVELOPMENT OF YELLOW BIRCH ROOTS IN TWO SOIL TYPES. Forestry Chron. 30: 401-406.
- Redmond, D. R.
1957. OBSERVATIONS ON ROOTLET DEVELOPMENT IN YELLOW BIRCH. Forestry Chron. 33: 208-212.
- Redmond, D. R., and R. C. Robinson.
1954. VIABILITY AND GERMINATION IN YELLOW BIRCH. Forestry Chron. 30: 79-87.
- Rowe, J. S.
1959. FOREST REGIONS OF CANADA. Can. Dep. N. Affairs and Natl. Resources Forestry Br. Bul. 123. 71 pp.
- Sinclair, G. A.
1962. PROGRESS REPORT OF PRESCRIBED BURNING IN HARDWOOD STANDS IN ONTARIO. Ontario Dep. Lands and Forests Res. Br. Sect. Rep. 45. 18 pp.
- Sloane, N. H.
1960. AN APPRECIATION OF PRESCRIBED BURNING AS A SILVICULTURAL TOOL IN ONTARIO. Ontario Dep. Lands and Forests, Res. Inform. Paper 1. 12 pp.
- Sykes, J. M.
1964. REPORT ON THE INTERIM RESULTS OF PRESCRIBED SPRING BURNING IN A POOR QUALITY HARDWOOD STAND. Ontario Dep. Lands and Forests Res. Br. Sect. Rep. 49. 13 pp.
- Wang, B. S. P.
1965. SEEDBED CANOPY AND MOISTURE EFFECTS ON GROWTH OF YELLOW BIRCH SEEDLINGS. Forestry Chron. 41: 106-107.
- Wang, B. S. P.
1968. THE DEVELOPMENT OF YELLOW BIRCH REGENERATION ON SCARIFIED SITES. Can. Dep. Forestry. Forestry Br. Pub. 1210. 14 pp.
- Weaver, J. E., and F. E. Clements.
1938. PLANT ECOLOGY. 601 pp. McGraw Hill Book Co., Inc., N.Y.
- Winget, C. H.
1968. SPECIES COMPOSITION AND DEVELOPMENT OF SECOND-GROWTH HARDWOOD STANDS IN QUÉBEC. Forestry Chron. 44: 31-35.
- Zimmerman, P. W., and A. E. Hitchcock.
1939. ACTIVATION OF CINNAMIC ACID BY ULTRA-VIOLET LIGHT AND THE PHYSIOLOGICAL ACTIVITY OF ITS EMANATIONS. Contr. Boyce Thompson Inst. 10: 107-200.

NATURAL REGENERATION OF YELLOW BIRCH IN THE LAKE STATES

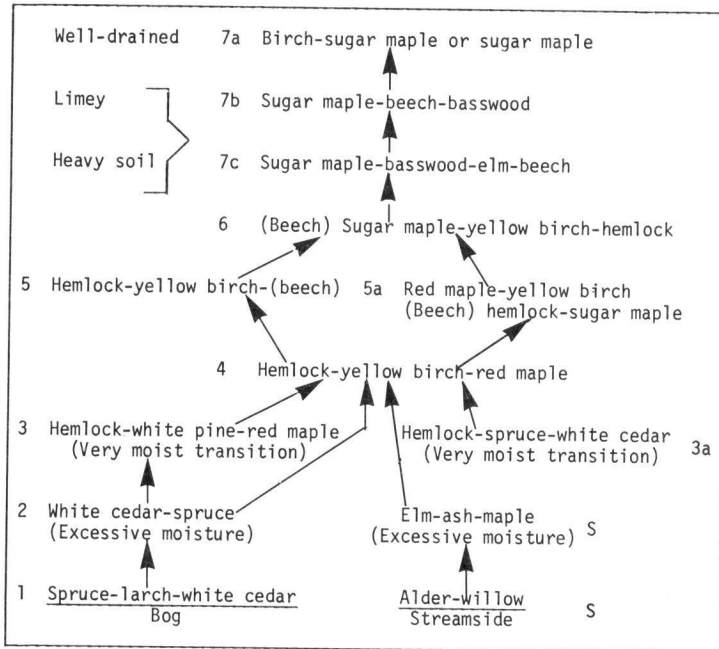
by CARL H. TUBBS, Plant Physiologist, North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Marquette, Mich.

YELLOW BIRCH has been a difficult species to regenerate in the Lake States. This is partly because, although yellow birch is a member of the climax, it displays few of the attributes of a climax species (such as ability to grow in shade, and ability to seed on undisturbed forest floor). Though yellow birch functions as a pioneer species after stand disturbance, techniques ordinarily used to regenerate pioneer species are not usually successful. Results with group selection have been the most consistent, but this system is difficult to apply.

An understanding of basic ecological trends is helpful in evaluating the results of the many silvicultural trials and in identifying the sites where yellow birch regeneration should be most successful. Undisturbed stands in the most important types are temporary (fig. 1) but long-lived, and over long time periods tend toward the sugar maple or sugar maple-beech type in which yellow birch occurs consistently but in low numbers.

The most important place of yellow birch in old-growth stands is on moist sites. Yellow birch is prominent in moist-site associations

Figure 1.—Illustration of northern hardwoods successional series.
(From L. Braun, *Deciduous Forests of Eastern North America*.)



but declines and nearly disappears in the more mesic types.

It should be pointed out that other developmental series exist, depending on climate, soil, and topography (*Whitford 1901*). However, most soils have a generally similar pattern of succession: white birch, the poplars, and various conifers preceding the more mesic hardwoods. This process has been noted on such soils as sands, clays, and loams and on shallow to bedrock sites.

The principal difference is in the rate of succession, and this seems true of secondary successions, too. For example, on sand soils, the various pines continue for long periods of time before giving way to more mesic trees such as hemlock, yellow birch, and the maples. Once these latter species are established, extreme disturbance can start succession anew with grass and shrubs; and long periods are required to restore mesic vegetation, which includes yellow birch. Moderate disturbance (such as selection cutting) may speed the process toward mesic communities. The same is true of wetter sites and shallow sites, where the grass-brush stage is prolonged for many years after extreme disturbance (such as clear-cutting). On the other hand, moderately moist sites appear to rebound more rapidly to the mesic or climax vegetation even after rather severe disturbance.

Yellow birch invades a wide range of soils and topography after heavy cutting and fires. Although the occurrence of yellow birch is directly related to seedbed and overstory disturbance, all disturbances will not result in stands of yellow birch. Controlled-environment studies in the Lake States have helped, along with the ecological relations discussed, to show how yellow birch becomes established on such a wide variety of sites, and to indicate what environments should prove to be the most successful for regeneration.

In general, any combination of factors that provides a relatively cool, moist environment will result in successful initial establishment and growth.

On well-drained sites, shade favors germination by keeping surfaces cool and moist. Survival and growth are relatively good in either light shade or full sunlight on such sites, if the sites are scarified (*Tubbs 1969*). Undisturbed litter, because of high temperature, low moisture, and physical impediments,

prevents appreciable germination except under relatively dense shade where growth and survival are poor.

On moist sites, full sunlight is detrimental to birch regeneration regardless of the seedbed prepared. Light shade is necessary for good germination, survival, and growth (*Godman and Krefting 1960, Tubbs 1969*). Scarification ensures adequate germination; but germination may occur on undisturbed seedbeds, too, on these sites (*Tubbs 1969, Godman (1959)*). Scarification that mixes the mineral soil and humus is best because growth is usually poor on mineral soil. Root shoot ratios are better in mixtures than in humus alone (*Tubbs and Oberg 1966*). Mixing mineral soil and humus is particularly important on well podzolized soils whose A₂ and B horizons are relatively infertile. Growth is better under partial shade on moist sites and in full sunlight on well-drained sites (*Tubbs 1969*).

Competition with other tree species influences the regeneration of yellow birch in the Lake States. Red maple is a shade-tolerant competitor in wet-mesic and dry-mesic situations, chiefly because it is a prolific sprouter. Sugar maple competes on all sites, but seems most important on mesic sites. It owes its success to several factors: good seed years are frequent (USDA Forest Service 1965); it has a low temperature requirement for germination, which allows it to germinate early while moisture supplies are adequate (*Tubbs 1965*); it persists under dense shade (*Ashby 1961, Logan 1965*); and it can respond to release at advanced ages (*Tubbs 1969*). In addition to this, we have demonstrated an antagonism between yellow birch and sugar maple, which appears not to be normal physical competition.¹

Competition with grasses and shrubs may also hinder birch regeneration. It is uncertain, however, whether these groups of plants are directly responsible for failures of yellow birch regeneration or whether the environment that favors them is simply unfavorable to yellow birch.

Biotic influences may sometimes work against yellow birch. Plantation failures in the Lake States have been attributed to deer, hare,

¹ Unpublished data, North Central Forest Experiment Station, Marquette, Michigan.

and mouse damage, for example; and some authors have attributed forest regeneration failures to deer damage (*Stoeckeler and Limstrom 1950, Graham 1954*).

On the other hand, Winget et al. (1965) argued that competition and poor environment have more impact than animals. Jacobs' observations (*J. Forestry, in press*) support Winget's argument.

Influence of Cutting Methods on Regeneration

Silvicultural trial results are for the most part predictable on the basis of our ecological and silvical information. Although moist sites are generally best for yellow birch production, each site responds best to a specific method of regeneration.

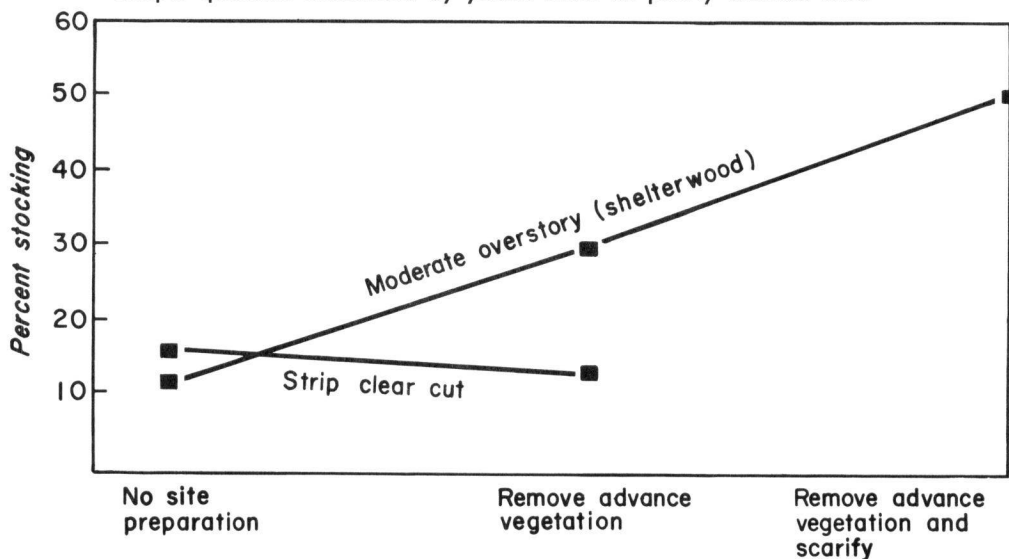
Regardless of the cutting method or silvicultural system used, little yellow birch regeneration follows unless advance regeneration is removed or the site is scarified (figs. 2 and 3). On well-drained sites, controlling advance regeneration results in a greater increase in birch stocking on clearcut areas than under a shelterwood stand, but the shelterwood cutting provides better stocking on poorly drained sites. Scarification is more effective and probably more necessary on the drier upland sites than on the cooler, more moist sites.

Results of clearcutting are usually inconsistent on moist sites or sandy sites even with site preparation. For example, removing advance regeneration on a poorly drained site after strip clearcutting produced few birch seedlings and resulted in brush and grass invasion (fig. 2). A scarification trial on a well-developed sandy soil did not increase birch regeneration, apparently because the resulting sandy seedbed was a poor substrate for seedling growth.

Adequate birch regeneration may occur even without special site treatment, but it seldom persists. Ten years after a commercial clearcutting of old-growth hardwoods on a poorly drained site, half the sample plots contained yellow birch. Some of these trees reached sapling size in the next 16 years, but stocking dropped to 5 percent.

Group selection seemed to offer ideal conditions for yellow birch regeneration—particularly if coupled with scarification. Trials indicated that 1/10-acre groups resulted in the most birch regeneration (*Eyre and Zillgitt 1953*). Although group selection seems effective for regenerating yellow birch in mature stands, it is difficult to practice. Groups are hard to identify, and management is complex. For this reason group selection is recommended only when combined with individual tree selection (*Arbogast 1957*). Creating groups is left to the marker's judgment, and

Figure 2.—Influence of cutting method and site treatment on percent of sample quadrats dominated by yellow birch on poorly drained sites.



no specific attempt is made to return to the groups to apply timber-stand-improvement practices. Marking for release can be done during regular marking when practical. This system has proved reasonably successful in stimulating increases in the number of yellow birch.

There has been some question whether or not individual tree selection would eventually result in pure stands of maple, with yellow birch excluded entirely. After 40 years of periodic cutting, small amounts of yellow birch are still being produced from selection stands. Continual disturbance over moist seedbeds on swamp edges, drainageways, and rotten logs apparently results in suitable conditions for a few birch.

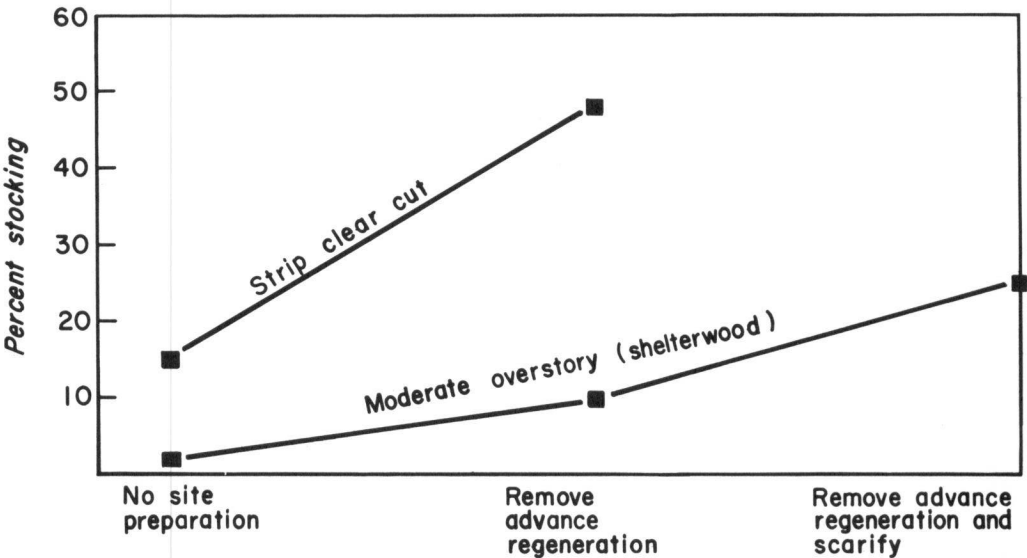
In the Lake States, methods of controlling competition and providing seedbeds have been studied less frequently than other factors. Summer logging has not proved advantageous (Church 1961). Poisoning with shelterwood cutting (Tubbs and Metzger, unpublished manuscript), disk scarification (Godman and Krefting 1960), mounding (Tubbs 1963), and bulldozer-blade scarification (Tubbs and Metzger) have all been tried and have proved successful in increasing initial yellow birch establishment.

Since removing advance regeneration alone seemed a promising way to increase yellow birch on sites difficult to scarify, we made one trial of spring burning under shelterwood on a rocky, shallow-soil site. Numbers of yellow birch 2 years after burning varied from 111,000 per acre to nearly 3 million, depending on burn conditions, and sugar maple decreased drastically. Limited trials indicate that partial shade is necessary for establishing yellow birch after controlled burning in the Lake States climate (Tubbs 1969), regardless of the soil moisture.

I should point out that yellow birch is seldom found in association with aspen or white birch in the northern Lake States, so regeneration techniques used to produce yellow birch do not produce white birch as they might in other regions.

The evidence so far indicates that an overstory should be left, temporarily at least, on moist sites (those that exhibit impeded drainage) or on areas to be prepared by burning. Removal of advance regeneration is necessary to increase yellow birch numbers, and preparation of a mixed mineral soil-humus seedbed results in optimum conditions on any site tested thus far. Strip clearcutting has proved successful when coupled with site preparation only on well-drained medium-texture soils.

Figure 3.—Influence of cutting method and site treatment on percent of sample quadrats dominated by yellow birch on moderate to well-drained sites.



Literature Cited

- Arbogast, Carl, Jr.
1957. MARKING GUIDES FOR NORTHERN HARDWOODS UNDER THE SELECTION SYSTEM. USDA Forest Serv. Lake States Forest Exp. Sta. Sta. Paper 56, 20 pp. St. Paul, Minn.
- Ashby, William Clark.
1961. RESPONSES OF AMERICAN BASSWOOD TO SEVERAL LIGHT INTENSITIES. *Forest Sci.* 7: 273-280.
- Church, Thomas W., Jr.
1961. SEASON OF LOGGING UNIMPORTANT IN CREATING DISTURBED SEEDBEDS FOR YELLOW BIRCH. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 605, 2 pp. St. Paul, Minn.
- Eyre, F. H., and W. M. Zillgitt.
1953. PARTIAL CUTTINGS IN NORTHERN HARDWOODS OF THE LAKE STATES. U.S. Dep. Agr. Tech. Bull. 1076, 124 pp.
- Godman, Richard M.
1959. ARE WATER TABLE LEVELS AN IMPORTANT FACTOR IN THE ESTABLISHMENT AND GROWTH OF YELLOW BIRCH? *Papers Mich. Acad. Sci., Arts, and Letters (1958 Meeting)*: 183-190.
- Godman, Richard M., and Laurits W. Krefting.
1960. FACTORS IMPORTANT TO YELLOW BIRCH ESTABLISHMENT IN UPPER MICHIGAN. *Ecol.* 41: 18-28.
- Graham, S. A.
1954. CHANGES IN NORTHERN MICHIGAN FORESTS FROM BROWSING BY DEER. *Trans. N. Amer. Wildlife Conf.* 19: 526-533.
- Jacobs, Rodney D.
1969. GROWTH AND DEVELOPMENT OF DEER-BROWSED SUGAR MAPLE SEEDLINGS. *J. Forestry*, in press.
- Logan, K. T.
1965. GROWTH OF TREE SEEDLINGS AS AFFECTED BY LIGHT INTENSITY. I. WHITE BIRCH, YELLOW BIRCH, SUGAR MAPLE AND SILVER MAPLE. *Can. Dep. Forest. Pub.* 1121, 16 pp.
- Stoeckeler, J. H., and G. A. Limstrom.
1950. REFORESTATION RESEARCH FINDINGS IN NORTHERN WISCONSIN AND UPPER MICHIGAN. USDA Forest Serv. Lake States Forest Exp. Sta. Paper 23, 34 pp. St. Paul, Minn.
- Tubbs, Carl H.
1963. ARTIFICIALLY CONSTRUCTED MOUNDS SHOW PROMISE IN YELLOW BIRCH REGENERATION. USDA Forest Serv. Res. Note LS-32, 2 pp. Lake States Forest Exp. Sta., St. Paul, Minn.
- Tubbs, Carl H.
1965. INFLUENCE OF TEMPERATURE AND EARLY SPRING CONDITIONS ON SUGAR MAPLE AND YELLOW BIRCH GERMINATION IN UPPER MICHIGAN. USDA Forest Serv. Res. Note LS-72, 2 pp. Lake States Forest Exp. Sta., St. Paul, Minn.
- Tubbs, Carl H.
1969. THE INFLUENCE OF LIGHT, MOISTURE, AND SEEDBED ON YELLOW BIRCH REGENERATION. USDA Forest Serv. Res. Paper NC-27, 12 pp. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Tubbs, Carl H., and Robert R. Oberg.
1966. GROWTH RESPONSE OF SEEDLING YELLOW BIRCH TO HUMUS-MINERAL SOIL MIXTURES. USDA Forest Serv. Res. Note NC-6, 2 pp. North Cent. Forest Exp. Sta., St. Paul, Minn.
- United States Forest Service.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U.S. Dep. Agr. Agr. Handb. 271, 762 pp.
- Whitford, H. H.
1901. THE GENETIC DEVELOPMENT OF THE FORESTS OF NORTHERN MICHIGAN; A STUDY IN PHYSIOGRAPHIC ECOLOGY. *Bot. Gaz.* 31: 289-325.
- Winget, C. H., G. Cottam, and T. T. Kozlowski
1965. SPECIES ASSOCIATION AND STAND STRUCTURE OF YELLOW BIRCH IN WISCONSIN. *Forest Sci.* 11: 369-383.



SEEDING AND PLANTING BIRCH

by JOHN C. BJORKBOM, *Silviculturist, Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Orono, Maine.*

ARTIFICIAL REGENERATION of hardwoods does not have a very good reputation. Many of the early attempts to establish these species by seeding or planting resulted in failure. Then too, natural regeneration is usually adequate on cut over areas, so that there is little need for artificial regeneration on such areas.

Nevertheless there are situations where artificial regeneration will be needed. It may be desirable to fill in blanks in existing natural reproduction, or to increase the proportion of valuable species such as birch. Any stand with an inadequate seed supply would be a candidate for artificial regeneration, and we are beginning to realize that seed supply may limit natural birch regeneration more often than was previously believed.

Artificial regeneration will certainly be required to introduce genetically improved birches—once they become available. And seeding or planting is required to establish birch on land that has been abandoned for agriculture or other nonforest land uses.

The reasons for past failures have been well documented. Much of the problem can be traced to the fact that hardwoods were planted on sites and with techniques that were more appropriate for conifers. Also, most of the plantings were made in old fields that were particularly poor because the soils had been depleted of nutrients and organic matter, the areas often had a heavy sod cover, and these fields generally had high rodent populations.

We know now that only the best sites should be used for seeding or planting hardwoods, and that site preparation is absolutely essential; competition must be controlled until the seedlings are established. And the seedlings must be protected from animals.

We still have much to learn about planting and seeding of hardwoods. But we have learned how to avoid some of the problems on old fields, and we have achieved a pretty

fair level of success in artificial regeneration of recently cut over forest lands. This paper summarizes the current state of our knowledge.

To Seed or To Plant

The decision to seed or to plant will depend on the individual circumstances involved. For a given area, seeding can be done more rapidly than planting (*Shirley 1937*). This is important because more acres can be treated in the relatively short period in the spring when moisture conditions are best. Sowing may also result in seedlings with better root systems (*Chapman 1940*); since the seedlings do not have to be lifted or planted, there is little danger of mechanical injury, as there is in planting (*Hirt 1959, Little et al. 1958*). Root systems distorted by planting may be an important factor in poor survival and growth (*Hirt 1959, Rudolf 1939*) although the evidence is not conclusive (*Gruschow 1959, Wakely 1954*).

Despite these advantages there are situations in which planting may be better. Well-developed seedlings with their greater size and vigor can more easily overcome the hazards encountered on certain sites. Thus planting might be the wiser choice on sites where the soils are subject to surface drying, on sites likely to erode, or on sites where herbaceous vegetation can be a serious competitor.

Let's look at the results of some birch seeding and planting trials and research conducted in northern New England and adjoining New York.

Seeding Birch

Trials of direct seeding birch on old fields have been limited in both extent and in degree of success. Nash et al. (1951) have reported on a series of direct seeding trials with paper and yellow birch in Maine. They found that removing the sod by bulldozing

and furrowing resulted in good germination on some plots. Fall sowing generally gave better results than spring sowing; germination of spring-sown seed sometimes was delayed until late in the growing season. Most of their trials resulted in high mortality due to severe drought conditions, mouse feeding, and grass competition.

Much better results have been obtained in direct-seeding birch in recently cutover areas. Horsley (1968)¹ found large numbers of paper birch seedlings after direct seeding in 50-foot wide east-west strip cuttings in New York.

He found that tractor scarification resulted in better survival and growth after 2 years than did spot scarification with hand tools. The spots frequently filled with leaves that apparently smothered some seedlings, acted as a barrier to root extension, and reduced the amount of light and moisture that reached the seedling. Reduced height growth in the spots was thought to be a result of nutrient deficiencies brought about by complete removal of the humus. Although tractor scarification stimulated the growth of herbaceous vegetation and increased competition losses, the overall result was better than with spot scarification.

Horsley also found that germination is reduced if the scarified seedbeds are allowed to dry before seed is sown in the spring. To insure best results, seeding should be done right after snowmelt, or immediately after scarification. The importance of moisture was also evident in the larger numbers of seedlings found in the shaded—as opposed to the sunny—portions of the strips.

An important point to be made is that it will generally be a waste of effort to attempt direct-seeding without first insuring that the basic requirements for light, moisture, temperature, and nutrients have been satisfied. Horsley did this by using narrow strip cuttings and seedbed preparation in all his study treatments.

There are many other examples of successful direct-seeding of birch in cutover areas. Numerous studies aimed at natural regenera-

tion have employed the sowing of seed and have resulted in successful regeneration. The White Mountain National Forest and the Northeastern Station now have a large-scale study of strip cutting, scarification, and direct-seeding under way, and initial observations indicate that very good results are being obtained.

Although many improvements in technique, especially to reduce costs, are still needed, it appears that direct-seeding of birch on cutover forest land is possible today for those areas where natural regeneration is not expected to be adequate. However, direct seeding of birch in old fields is not recommended at this time.

Planting

Early planting trials with birch seedlings in old fields revealed that furrowing gave better results than other techniques to control the sod. Bulldozing, plowing, harrowing, burning, and herbicides all were less satisfactory (Nutting 1953, 1957).

More recent experiments by the Northeastern Forest Experiment Station (Bjorkbom 1968) have substantiated the fact that survival and growth are better when the sod is removed than when it is left intact. Of the various site-preparation treatments used, planting on the second slice of a double furrow provided best 10-year survival (58 percent), as opposed to planting in furrow bottoms (44 percent), on scalps (37 percent), and in the sod (27 percent).

Best growth in our studies was also obtained from seedlings planted on the furrow slice—many of these were in the larger diameter and height classes (table 1). Trees in the other treatments did not do nearly as well, especially those in the sod. The largest trees now have diameters of about 3 inches and heights up to 24 feet.

Animals have caused much damage to seedlings planted in old fields. Almost all surviving trees have been damaged in one way or another by deer or mice. We tried repellents, but they proved ineffective in our studies because of the long intervals between applications and the high animal populations. The use of poisoned baits seemed to offer some promise against mice, at least in our small study plantings.

In addition to animal damage, seedling mortality in our studies could be attributed to frost heaving, poor site or soil conditions, poor

¹ Horsley, Stephen B. DIRECT SEEDING PAPER BIRCH (*BETULA PAPYRIFERA*) IN STRIP CLEAR-CUTTINGS. Univ. Mass. master's thesis. 116 pp., illus., 1968.

planting technique, and poor planting stock. Some of the seedlings were extremely small when planted, and probably should have been discarded. In general, larger seedlings have been found most likely to survive.

Apparently few attempts have been made to plant birch in recently cutover areas. One attempt that I know about involved a small number of paper birch seedlings planted in recently clearcut patches on the Bartlett Experimental Forest in New Hampshire. Although deer damage was severe during the first few years, some seedlings survived and grew very well. After 10 growing seasons, there are a fair number in the 2-inch diameter class, and a few in the 3-inch class. Heights range from 25 to 30 feet.

To date, we have not demonstrated that birch plantings can be made with any assurance of success, either on old fields or in recently cutover forests. This is not to say that all plantings have been failures. The isolated instances of high survival and good growth are indicative of what can be expected. And we have learned how to avoid some of the failures.

When old fields are to be planted, site conditions must be considered carefully. It is not safe to plant birches on these sites just because they may be growing in the adjoining forest. Cultivation has probably depleted the nutrients, has resulted in some topsoil and humus erosion, has compacted the surface, and has changed soil porosity, among other things (*Bedwell 1937, DenUyl 1951*). Plantings should therefore be attempted only on those soils that appear to be better than average in terms of nutrients, moisture conditions, and physical properties.

Where soils seem to be suitable, planting of birch in old fields might be attempted on a

limited basis. Site preparation is an absolute necessity. Until better techniques are developed, planting seedlings on the second slice of a double furrow will give the best results. Control of competing vegetation near the seedling is another requisite. Mulching around the seedlings might be one way to accomplish this for the critical first few years. The largest and best planting stock should be used; usually 2-0 stock is required. And animal populations should be determined and appropriate control measures should be employed. It will generally be useless to invest in planting unless all of the factors above are considered.

What of the Future?

As forest land management becomes more and more intensive, it seems almost certain that the need for artificial regeneration of birches and other hardwoods will increase. In anticipation of this need, we will have to learn a great deal more about both seeding and planting. More effective methods of site preparation will be needed — methods that expose the favorable mineral soil without exposing infertile soil horizons, methods that do not provide a runway for rodents as a furrow does, methods that provide effective and long-lasting control of sod and other competitive growth. Effective treatments for control of animal damage are a must. And techniques for evaluation of site suitability will also be required, to permit intelligent selection of sites to be planted and to guide us in the use of fertilizers or mulches needed to improve soil conditions.

There is also much room for improvement in seeding and planting techniques. For example, the possibilities of container planting need to be explored. And more information

Table 1.—Percentage distribution of seedlings by diameter class, height class, and treatment after 10 growing seasons

Treatment	Diameter class			Height		
	Less than 1-inch	1-inch	2-inch and larger	9.5 feet and less	9.6-14.5 feet	14.6 feet and larger
Furrow slice ..	26	47	27	37	43	20
Scalp	51	36	13	62	27	11
Furrow bottom.	53	39	8	60	40	0
Sod	68	32	0	78	22	0

is needed about seeding methods and rates, planting-stock grades, and spacing of planted seedlings. Economic evaluations are also needed.

All in all, many diverse problems remain

to be solved. But with a well-reasoned approach to the development of new ideas and the refinement of old ones, practical methods for the successful artificial regeneration of birch stands can be found.

Literature Cited

- Bedwell, J. L.
1937. FACTORS AFFECTING ASIATIC CHESTNUTS IN FOREST PLANTATIONS. *J. Forestry* 35: 258-262.
- Bjorkbom, John C.
1968. PLANTING PAPER BIRCH IN OLD FIELDS IN MAINE. USDA Forest Serv. Res. Paper NE-103, 12 pp., illus. NE Forest Exp. Sta., Upper Darby, Pa.
- Chapman, A. G.
1940. PROBLEMS IN FORESTATION RESEARCH, *J. Forestry* 38: 176-180.
- DenUyl, Daniel.
1951. FROM FIELD TO FOREST—A 50-YEAR RECORD. *J. Forestry* 49: 698-704.
- Grushchow, George F.
1959. OBSERVATIONS ON ROOT SYSTEMS OF PLANTED LOBLOLLY PINE. *J. Forestry* 57: 894-896, illus.
- Hirt, Ray R.
1959. PINUS STROBUS L. A LITERATURE REVIEW AND DISCUSSION OF ITS FUNGUS DISEASES IN NORTH AMERICA. N. Y. State Univ. Coll. Forestry Tech. Pub. 82, 99 pp.
- Little, S., C. B. Cranmer, and H. A. Somes.
1958. DIRECT SEEDING OF PITCH PINE IN SOUTHERN NEW JERSEY. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 111, 14 pp. Upper Darby, Pa.
- Nash, Robley W., Edward J. Duda, and Norman H. Gray.
1951. STUDIES ON EXTENSIVE DYING, REGENERATION, AND MANAGEMENT OF BIRCH. Maine Forest Serv. Bull. 15, 82 pp., illus.
- Nutting, A. D.
1957. THIRTY-FIRST BIENNIAL REPORT OF THE FOREST COMMISSIONER. 160 pp., illus. Maine Forest Serv.
- Nutting, A. D.
1953. TWENTY-NINTH BIENNIAL REPORT OF THE FOREST COMMISSIONER. 194 pp., illus. Maine Forest Serv.
- Rudolf, Paul O.
1939. WHY PLANTATIONS FAIL. *J. Forestry* 37: 377-383.
- Shirley, H. L.
1937. DIRECT SEEDING IN THE LAKE STATES. *J. Forestry* 35: 379-387.
- Wakely, Philip C.
1954. PLANTING THE SOUTHERN PINES. U. S. Dep. Agr. Agr. Monogr. 18, 233 pp., illus.

BIRCH NURSERY PRACTICE

by SIDNEY H. HANKS, Nursery Specialist, Northeastern Area, State and Private Forestry, Forest Serv., U.S. Department of Agriculture, Upper Darby, Pa.

OF THE forty or so species of trees that comprise this genera, seven are native to North America. Three are of silvicultural importance in North America: yellow birch, paper birch, and sweet birch (*USDA Forest Service 1965*). When ornamental, landscaping, and reclamation uses are considered, three additional species—gray birch, European white birch, and river birch—and numerous varieties would be included.

Birch is not widely produced in this country for reforestation. Fewer than 100,000 yellow birch seedlings were produced in 1968 for reforestation purposes. About 125,000 river birch and 116,000 European white birch were produced for reclamation planting. Sales of these species and numerous varieties for ornamental use were estimated at 1 million in 1968.

Flowering

The birches are monocious, producing both male and female flowers on the same tree. The male flowers are formed in midsummer in clusters of two or three, or solitary. They remain on the tree over winter, maturing in the spring; soon after pollen dispersal, they drop off the tree (*Harlow and Harrar 1950*). The female flowers mature with the leaves in the spring. Pollination, by wind, usually occurs before the leaves are fully expanded. The catkins ripen in late summer and early autumn—except river birch, which ripens in the late spring—becoming brown and woody when ripe. Catkins of paper birch are pendant, while those of most other birch species are erect. Catkins are 1 to 1½ inches long in most birch species. Seeds are borne on trident bracts in the cone; the seed is oval and laterally winged with two persistent stigmas at the base (*Harlow and Harrar 1950*).

Seed Collection

Speed ripening is a local thing, so it should be investigated before collection is begun.

Birch is judged to be ripe when the exterior of the seed has lost its green color and becomes brown. The interior of the seed should have lost its milky or watery condition, and the kernel should have attained a firm condition. This condition should develop in late August or early September over much of the birch range; however, confirm ripeness before collection is begun.

Seeds are collected by hand from standing trees or from felled trees. The shattering habit of the birch catkins make it advisable that collectors place the catkins into picking bags as picked instead of allowing them to fall on to tarps.

A bushel of collected fruit may weigh from .9 to 13½ pounds depending upon the species and year of collection (*Stoeckeler and Jones 1957*).

Extraction, Cleaning, and Storage

Collected seed should be spread on tarps or screen trays to dry, because fresh seed usually has high moisture content and injury to the seed may result from heat in confined storage such as burlap sacks or closed containers. The conelets disintegrate during the drying process, and some mixing with a rake by hand will complete the extraction.

Cleaning is desirable to improve the purity and avoid storing stalks, cone scales, and debris. One successful cleaning practice is to scalp the larger material off on a screen that allows the seed to pass through. Round-hole screens of 8/64-inch screens are suitable for yellow birch and paper birch; 10/64-inch screens are suitable for a river birch (*USDA Forest Service 1948*).

Most nurserymen do not bother to dewing the birch seed since the rudimentary wing is not a serious obstacle to seed handling, storage, and sowing. Average numbers in thousands of cleaned seed per pound for several birch

species are shown in the following tabulation (USDA Forest Service 1948):

	Low	Average	High
<i>Yellow birch</i>	278	447	907
<i>River birch</i>	287	375	548
<i>Paper birch</i>	610	1,380	4,120
<i>European</i>			
<i>white birch</i>	1,510	2,400	5,040

The variability in viability among seed lots make it imperative that the nurseryman determine the characteristics of each lot of seed so that accurate sowing rates can be computed. Bed density has a striking effect on the quality of seedlings produced. Overdense beds cannot be managed successfully except by expensive thinning. It is far more economical to determine number of seeds per pound and purity and germination percent for a seed lot, and then compute the desired sowing rate than to be faced with overdense beds or extremely thin beds. Bed densities of 15 to 25 seedlings per square foot are optimum. This range seems to yield the most high-quality plantable seedlings.

Germination of birch seed is generally prompt, beginning in 10 days and completed within 30 days. Germination tests of seed lots can be made quickly by placing the seeds in shallow dishes filled with water and exposing the dishes where they will receive light (Yelenosky 1961). For uniform results, it is best to use continuous artificial light from a desk lamp or similar source. The addition of fungicide to the water will avoid problems with fungi.

Birch seed has been successfully stored for several years at moisture contents of 1 to 5 percent at temperatures of $-4^{\circ}\text{C}.$ - $-25^{\circ}\text{F}.$ (Food and Agriculture Organization 1955). Recommendations in the *Woody Plant Seed Manual* are for dry storage at temperatures of 33° to $38^{\circ}\text{F}.$ (USDA Forest Service 1948).

Stratification of birch seeds is not necessary if they are sown in the fall. And fall-sown seeds often germinate early in the spring—sometimes even before the soil can be prepared for spring sowing. This early start provides a longer growing season. For these reasons, many nurserymen prefer fall sowing.

However, spring sowing is also successful. The need for stratification before spring sowing varies among seed lots. Stratification is usually not necessary if the seeds have been stored at low temperature. However, some lots

benefit by a stratification pre-treatment for 30 days before sowing. Stratification is accomplished by soaking the seed lot in tap water for 24 hours. The excess water is then drained off and the seeds are placed in a plastic bag under refrigeration at $34^{\circ}\text{F}.$ for 30 days. When the seed is removed, it should be surface-dried to facilitate sowing. If sowing is delayed, the seed should be returned to cold storage.

Sowing Methods

Birch seeds may be either broadcast or sown in drills. Either way the seed should not be covered too deeply: $1/8$ -inch covering is the maximum that permits uniform seedling emergence. Seed that is covered too deeply may fail to germinate or it may take a long time to germinate, resulting in very uneven seedlings and high cull percent in 1-year-old planting stock. Satisfactory germination will result from sowing without covering if wind and excessive drying are not problems or can be controlled successfully.

Fall sowing is accomplished on prepared seedbeds when temperatures fall below the level where germination will occur. Birch species germinate satisfactorily at temperatures above $59^{\circ}\text{F}.$

For producing ornamental birch clumps, Pinney and Peotter (1966) germinate untreated paper birch seeds in flats in the greenhouse. When seedlings produce their second true leaf, they are transplanted three in a $2\frac{1}{4}$ -inch peat pot. When danger of frost is past the pots are lined out in the field and the seedlings are grown to produce birch clumps for ornamental planting.

Seedbed Preparation

Seedbeds are generally prepared by plowing to a depth of 8 inches or more, followed by disking and harrowing. Some general leveling of the seedbeds is normally performed before bed layout to insure good drainage. Seedbeds may be elevated above the level of paths to permit drainage. This is usually done in fine-textured soils or in areas where heavy rainfall is expected. Raising seedbeds is accomplished by a device using two disks that pull soil from paths located 66 to 72 inches apart, and deposit it on the bed. A shaper then forms the slightly crowned surface of the bed some 4 inches above the path level and 52 to 68 inches wide. Pre-planting fertilizer applica-

tions are generally incorporated during the bed-making process.

Many nurserymen now fumigate all seed-bed areas before sowing. Various chemicals are used; many are fungicides, nematocides and seedicides providing protection against damping-off and other soil-borne diseases. They also protect against nematodes and provide early-season weed control.

Ingestad (1957) has indicated that birch is a nitrogen-requiring species relative to other deciduous trees, but quite undemanding of other nutrient elements. Performance of certain birch species such as river birch and European white birch on spoil banks and in other reclamation work indicates that these species will survive and grow under adverse conditions even though growth does not approach the optimum.

Wilde (1946) gives the following standards of soil fertility for growing yellow birch in the nursery: pH of 5.3; exchange capacity 12 meq. per 100 gm.; 16 percent total N. or 35 pounds per acre available N.; 60 pounds per acre available P_2O_5 ; 175 pounds per acre K_2O ; 5 meq. per 100 gm. replaceable calcium; and 1.5 meq. per 100 gm. of replaceable magnesium.

Birch seedlings tend to be fragile for a period after emergence and may benefit from

overhead shade. In Pennsylvania, shade is installed after sowing is complete and is retained throughout the summer.¹ Shading is common practice in birch nursery practices to protect against wind, prevent drying during germination, and for summer protection. In Indiana, river birch is not shaded, but frequent irrigation is practiced during the germination period.²

Stock for reforestation planting should be a minimum 7/32-inch stem caliper at the ground line, with an 8-inch top. Stock of smaller size is sometimes preferred for reclamation planting. At most nursery locations this size is reached in 1 year when fertility level, irrigation, and density control are practiced. In northern locations it may be desirable to keep seedlings in the nursery 2 years to attain optimum size for field planting.

Birch is palatable to deer and may need protection in nurseries where deer are not fenced out or otherwise controlled. Shade frames are sometimes left in place over winter to protect against deer browsing.

¹ Personal communication with Pat Lantz and Joe Hill, Pa. Dep. of Forests and Waters.

² Personal communication with Richard McNabb, Indiana Div. of Forestry.

Literature Cited

- Food and Agriculture Organization of the United Nations.
1955. TREE SEED NOTES. FAO, Rome.
- Harlow, William M., and Ellwood S. Harrar.
1950. TEXTBOOK OF DENDROLOGY. 3rd Ed., 555 pp. McGraw-Hill Book Co.
- Ingestad, Torsten.
1957. STUDIES IN THE NUTRITION OF FOREST TREE SEEDLINGS. I. MINERAL NUTRITION OF BIRCH. *Physiol. Plant.* 10: 418-439.
- Pinney, Thomas S., and Gene W. Peotter.
1966. THE PROPAGATION OF BIRCH. *Plant Propagators Soc. Proc.* 16: 193-202. Newport, R. I.
- Stoeckeler, J. H., and Jones, G. W.
1957. FOREST NURSERY PRACTICE IN THE LAKE STATES. U.S. Dep. Agr. Agr. Handb. 110. 124 pp.
- United States Forest Service.
1948. WOODY PLANT SEED MANUAL, U.S. Dep. Agr. Misc. Pub. 654. 416 pp.
- United States Forest Service.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U.S. Dep. Agr. Agr. Handb. 271, 761 pp.
- Wilde, S. A.
1946. FOREST SOILS AND FOREST GROWTH. *Chronica Botanica Co.*, Waltham, Mass.
- Yelenosky, George.
1961. BIRCH SEEDS WILL GERMINATE UNDER A WATER-LIGHT TREATMENT WITHOUT CHILLING. USDA Forest Serv. NE Forest Exp. Sta. Forest Res. Note 124, 5 pp. Upper Darby, Pa.

PROGRESS IN BIRCH GENETICS AND TREE IMPROVEMENT

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LITTLE INTEREST has been shown in genetic improvement of our native birches until fairly recently, except for the birch breeding and testing begun by the Northeastern Forest Experiment Station in 1940. Before we can begin improvement of a particular species or genus, we need to know how much genetic variation is present and how various characteristics are inherited. Most of the work with birch at the Institute of Forest Genetics at Rhinelander has sought to provide this kind of information. We will report first on the knowledge of birch genetics acquired so far and relate it to practical applications, then review the practical improvement work in progress, and finally discuss what we might expect from tree-improvement work with the birches in the future.

BIRCH GENETICS

Variation Studies

Since variation in a species is the key to its improvement, several studies of birch variation patterns have been conducted or are in progress. Clausen (1968a) found that catkin and fruit characteristics of yellow birch vary in an apparently random manner over the natural range of the species and differ greatly among individual trees within the stands. Although these results have no obvious practical application, they indicate that we might expect similar differences in growth rate or other desirable characteristics.

The observed geographical variation in a species may be due partly to differences in elevation. In a study now in progress, Sharik¹ found the zone of optimal develop-

ment for yellow birch to occur at lower elevations with increasing latitude. In the Balsam Range of southwestern North Carolina it was at 3,500 to 4,500 feet compared with 1,500 to 2,200 feet in the Green Mountains of Vermont and the White Mountains of New Hampshire. The comparable zone for sweet birch was 500 to 1,000 feet lower, and this species was seldom observed above 500 feet near its northern limit in the Champlain Valley, central New Hampshire, and southwestern Maine. Preliminary observations by Sharik¹ also indicated that yellow birch morphology is much more variable than that of sweet birch. The data collected along these elevational transects should provide much information about local variation, and will be helpful in selection of seed sources for particular localities.

Some of the morphological variation in traits such as size and shape of leaves, catkins, and seeds is due to natural hybridization and introgression (Clausen 1962, Braysshaw 1966, Dugle 1966, Brittain and Grant 1967a). Studies of natural hybrids tell us something about which species can be crossed with each other and which characteristics are transmitted to the hybrids. This information is important because natural hybridization between shrubby and tree-size birches is relatively common. Since these hybrids are usually smaller than their tree parents, the presence of shrubby species in or near a birch stand could have a deleterious effect on timber production.

Morphological variation in some species may be due partly to differences in chromosome numbers. Brittain and Grant (1965, 1966, 1967b, 1968a, 1968b) have shown that paper birch, a highly variable species, has 56, 70, or 84 chromosomes with 56 and 70 being most prevalent in eastern Canada and 84

¹Personal communication from T. L. Sharik, University of Michigan, December 1968.

more common in the Rocky Mountains and northwestern Canada. Whether similar chromosomal variation occurs in other birch species has not yet been determined. Paper birch populations with different chromosome numbers could vary not only in morphology but in their adaptation to particular environments. If that should be the case, it might not be enough to use a local seed source that would usually be suitable for the local climate. Instead, the source might have to be selected for the particular site and microclimate.

Growth characteristics appear to vary considerably in the birches. A range-wide study of natural variation in yellow birch initiated by the Institute of Forest Genetics includes 55 seed sources (fig. 1). Second-year height growth in the nursery at Rhinelander, Wisconsin, varied greatly but was essentially random (Clausen 1968*b*). At the end of the third year in the nursery, seedlings from the best source were twice as tall as those from

the poorest one, and averaged 59 percent greater in diameter (table 1). Total height was not correlated with latitude, longitude, length of growing season, annual precipitation, average January temperature, or average July temperature (table 2). Although seedlings from the northern sources showed some tendency to be thicker than those from the southern ones, diameter was only weakly correlated with latitude and length of growing season (table 2). Thus the variation in height and diameter of yellow birch appears to be random, at least in the seedling stage. The further growth and development of the seedlings will be studied in 10 test plantings established in the Lake States, New York, and New England, and in three plantings in Canada.

As mentioned previously, individual yellow birches growing in the same stand appear to vary widely. To determine whether the great height variability observed in the seed-source

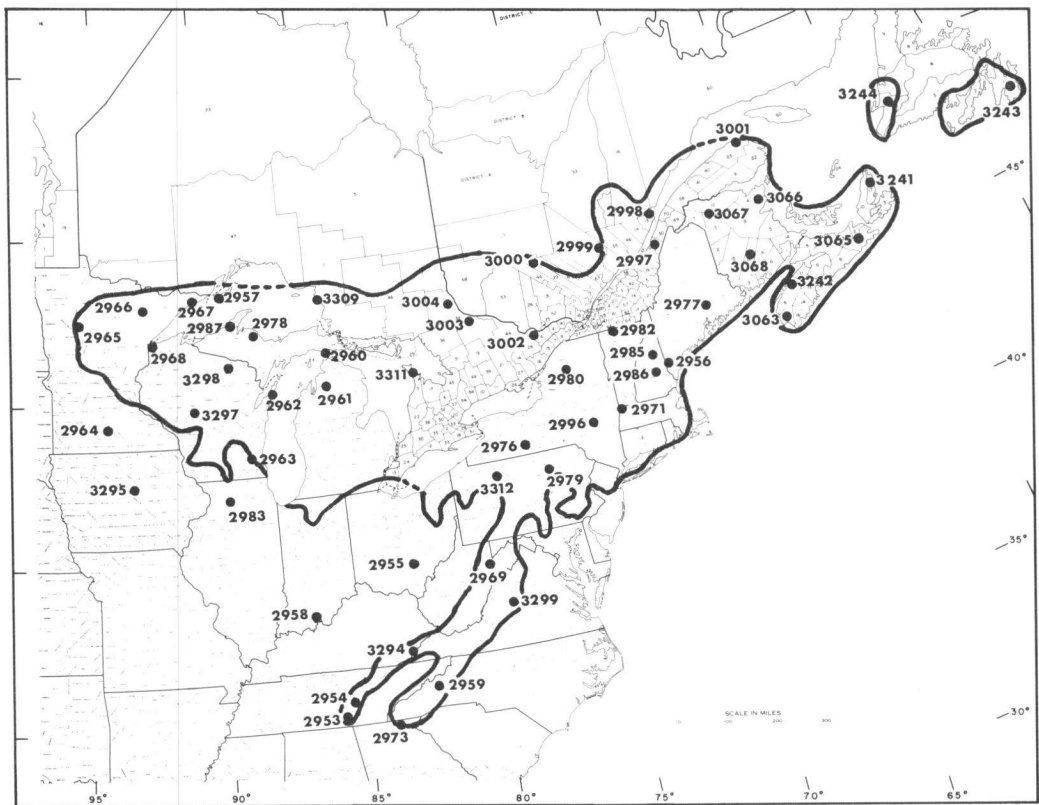


Figure 1.—Natural range of yellow birch, adapted from maps in USDA Forest Service (1965) and Dansereau and Pageau (1966), and location of 55 seed sources.

Table 1.—Origin, mean 3-year height and diameter, growth initiation, and winter injury of seedlings from 55 yellow birch seed sources

Source No.	State or province	Location		Elevation	3-year—		Growth initiation ²	Seedlings winter damaged
		Lat.	Long.		Height	Diam. ¹		
		<i>Degrees</i>	<i>Degrees</i>	<i>Feet</i>	<i>Cm.</i>	<i>Mm.</i>		<i>Percent</i>
3243	Newfoundland	47.2	53.4	50	46.0	6.3	2.89	18.6
3244	Newfoundland	48.6	58.2	400	51.9	6.5	3.57	14.3
3241	Nova Scotia	46.6	60.5	100	56.0	6.9	3.89	19.0
3065	Nova Scotia	45.4	61.8	450	38.9	5.6	3.86	10.5
3242	Nova Scotia	44.8	65.2	650	48.5	6.0	3.75	32.2
3063	Nova Scotia	44.1	65.8	350	44.8	6.1	3.38	23.4
3068	New Brunswick	46.0	66.4	300	47.9	6.3	4.00	47.0
3066	New Brunswick	47.4	65.2	300	46.9	6.5	3.56	20.4
3067	New Brunswick	47.5	67.4	925	46.2	6.7	4.00	28.1
3001	Quebec	49.2	65.1	300	41.8	5.8	4.14	6.2
2998	Quebec	48.2	70.2	1,000	36.5	5.8	4.56	17.8
2997	Quebec	47.0	70.3	400	39.7	6.0	4.00	23.7
2999	Quebec	47.4	72.6	1,000	46.9	6.4	3.75	11.6
3000	Quebec	47.5	75.0	1,500	41.8	5.9	3.71	17.5
3002	Ontario	45.1	76.9	1,000	50.3	6.2	3.33	25.2
3003	Ontario	46.1	79.0	1,000	46.6	6.0	3.50	28.5
3004	Ontario	46.7	79.6	1,000	51.2	6.6	3.33	14.2
3311	Ontario	45.0	81.4	625	52.8	7.1	3.88	20.3
3309	Ontario	47.5	84.8	1,000	45.8	6.0	3.38	9.8
2977	Maine	44.8	68.6	250	40.0	5.9	3.67	36.1
2956	Maine	43.7	70.9	1,000	46.1	6.2	3.56	19.6
2985	New Hampshire	44.0	71.4	1,900	44.1	5.5	3.22	18.4
2986	New Hampshire	43.5	71.4	1,300	52.4	6.6	3.71	23.2
2982	Vermont	44.7	72.6	1,250	54.7	6.8	2.88	30.2
2971	Massachusetts	42.7	73.2	1,610	47.6	6.1	3.25	25.8
2980	New York	49.2	74.9	1,620	52.8	6.3	3.78	13.4
2996	New York	42.5	74.2	2,100	54.0	6.5	3.44	17.5
2976	New York	42.3	77.3	1,300	52.4	6.3	2.33	40.0
2979	Pennsylvania	41.3	76.3	2,300	53.9	6.4	2.86	31.0
3312	Pennsylvania	41.6	78.7	1,800	57.4	6.6	2.44	47.2
2969	West Virginia	39.0	79.7	2,200	58.5	6.6	2.22	43.8
3299	Virginia	37.8	79.1	3,000	38.6	5.4	1.62	50.6
2959	North Carolina	35.7	82.3	5,160	52.2	6.3	2.00	18.7
2973	Georgia	34.8	83.8	4,700	44.1	5.7	1.78	24.1
2953	Tennessee	35.2	85.7	1,740	32.1	4.7	1.50	91.4
2954	Tennessee	35.7	85.3	1,420	29.3	4.2	2.00	82.7
3294	Kentucky	36.9	82.9	3,600	54.3	6.1	1.62	53.7
2955	Ohio	39.5	82.5	830	49.8	6.1	2.44	74.6
2958	Indiana	38.3	86.5	700	44.0	6.2	2.33	52.7
2983	Illinois	41.9	89.4	680	42.4	5.6	3.75	28.0
3295	Iowa	42.4	93.1	1,050	59.9	6.6	2.89	24.2
2961	Michigan	45.0	85.0	1,000	63.6	7.1	3.38	34.4
2960	Michigan	45.9	84.8	625	49.4	6.3	3.33	21.6
2978	Michigan	46.7	87.9	1,675	41.1	6.1	3.44	17.0
2987	Michigan	47.0	88.7	1,250	45.6	6.1	3.62	6.7
2968	Wisconsin	46.5	92.1	1,150	45.7	6.1	3.67	9.9
3298	Wisconsin	45.7	89.0	1,710	42.1	5.5	3.86	17.6
3297	Wisconsin	44.5	90.4	1,100	49.6	6.2	2.22	17.8
2962	Wisconsin	44.9	87.2	600	55.5	6.7	3.88	27.9
2963	Wisconsin	43.1	88.4	900	49.2	6.2	2.78	19.0
2964	Minnesota	44.2	94.1	800	49.6	6.4	3.28	12.7
2965	Minnesota	47.2	95.2	1,480	50.7	6.8	3.60	23.2
2966	Minnesota	47.6	92.5	1,700	54.5	6.7	3.25	26.8
2967	Minnesota	47.8	90.2	1,400	49.7	6.6	3.50	18.7
2957	Isle Royale, Michigan	47.9	89.1	750	41.8	6.0	4.00	29.6

¹ Diameter measured 1 inch above the ground.

² Average flushing score on 5 May, 1967 (1 = late, 5 = early).

study might be due to the fact that the seed lots used were a mixture from an average of 10 trees per stand, a study of 199 individual tree progenies is now in progress. At the end of the first growing season there were highly significant differences in seedling height, not only among the 21 sources but also among the trees within each source. The results also showed that certain sources were much more variable than others (fig. 2).

For example, seedlings from Nova Scotia source 3063 had the greatest average height but the least height variation (the best progeny was only 23 percent taller than the poorest one). In contrast, the seedlings from Pennsylvania source 3312 ranked second in average height, and the best progeny was twice as tall as the poorest one. The greatest difference between progenies within a source, 127 percent, was in New Brunswick source 3066. Thus, which tree is selected as crop tree or superior tree would be less important in a tall and relatively uniform source such as 3063 than it would be in a variable source like 3066 or in a poor source like 2973 (Georgia).

The large amount of individual tree variation present in yellow birch indicates that a selection program in this species should focus on selection and testing of individual trees.

Yellow birch, in contrast to its random variation in height and diameter, exhibits a gradual north-south trend or clinal variation in growth initiation and cessation. Flushing

of seedlings from the 55 sources was scored in the nursery every 3 days between 21 April and 1 June, 1967. The best separation among the sources was on 5 May, when the northern sources were generally farther advanced than the southern sources (table 1). Growth initiation showed a high correlation with latitude, average January temperature, and length of growing season (table 2). Similarly, seedlings from the northern sources stopped growing earlier than those from the southern sources at the end of their second year in the nursery; growth cessation was also closely correlated with latitude (*Clausen 1968b*). However, growth initiation and cessation did not appear to be related to height.

Since seedlings from northern sources start growing early in the spring, they are more likely to be damaged by late spring frosts than seedlings from southern sources. On the other hand, seedlings from the southern sources, which continue growing until fall, are more susceptible to injury from early fall frosts.

The importance of frost resistance is illustrated by the seed-source study. The seedlings were scored for light, medium, and heavy winter injury after their second winter in the nursery. No attempt was made to distinguish damage caused by fall frosts from that caused by winter cold. Surprisingly enough, seedlings from all 55 seed sources showed some degree of winter injury (table 1). Although the percentage of injured trees often was high, the damage was normally light in most of the

Table 2.—Correlation between 3-year height, diameter, and flushing of seedlings from 55 yellow birch seed sources and environmental variables of the seed sources

Environmental variable	3-Year height	3-Year diameter	Flushing 5 May, 1967
Latitude	0.0678	0.4048**	0.8461**
Longitude	.0900	-.0469	-.2898
Length of growing season	-.1486	-.4139**	-.6536**
Annual precipitation	-.0672	-.2382	-.5166**
Average January temperature	-.0305	-.3300	-.7571**
Average July temperature	-.0439	-.3153	-.5751**

** Significant at the 1-percent level.

northern and eastern sources. Most severely damaged were seedlings from the Ohio, Indiana, Virginia, Kentucky, and Tennessee sources. Of the southern group, only the North Carolina and Georgia seedlings were relatively frost resistant; but these sources were from high elevations (table 1).

These results demonstrate that in yellow birch, as in other species, it is extremely important to choose the right seed source for a particular location. While seedlings originating farther south may have good growth, they may not be winter-hardy. On the other hand, if they come from too far north they may be susceptible to late spring frosts. Therefore, seed or seedlings should not be moved too far north or south of their origin.

The importance of seed origin was apparent in the great differences in performance of seedlings from different sources in the same state or province (table 1). For example, the height differences between seedlings from the best and poorest seed sources amounted to 32 percent for Wisconsin, 55 percent for Mich-

igan, 28 percent for Quebec and 44 percent for Nova Scotia. Even the two New Hampshire sources, which came from areas within about 40 miles of each other, were different. Seedlings from the southernmost source (2986) were 19 percent taller than those from nearby source 2985, and more comparable in height to seedlings from the much more distant sources from northern Vermont (2982) and northern New York (2980). Granted, these are only heights after 3 years in the nursery; but it has been shown that the seedlings of two European species (*Betula pendula* Roth and *B. pubescens* Ehrh.) that were tallest in the nursery maintained their superiority for at least 9 years in the field (Clausen 1963).

Crossability Studies and Tests of Hybrids

Before beginning a practical breeding program, it is important to know which trees can be selfed, crossed with other trees of the same species, or crossed with members of

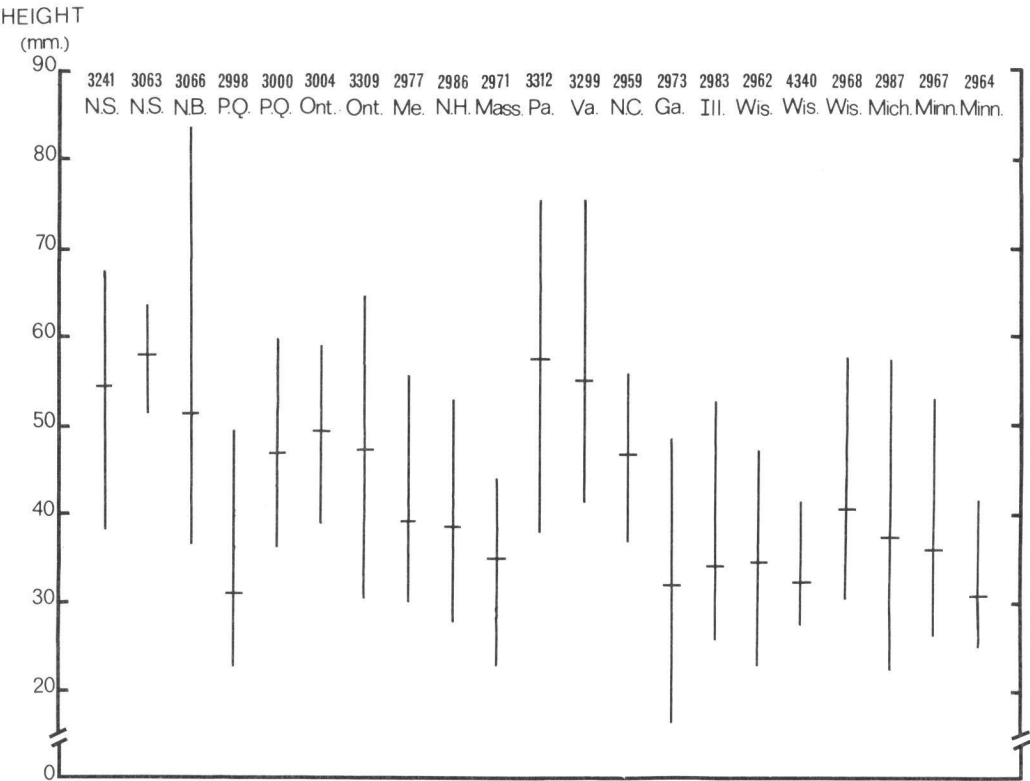


Figure 2.—Range of 1-year-old seedling heights (progeny means) and average height for each of 21 yellow birch seed sources.

other species. So far we know that self-compatibility is very low in most birches and only certain individuals will produce viable seed after selfing (Clausen 1966). Surprisingly enough, certain trees will not cross with other trees of the same species, and thus would be of limited use in a breeding program or a seed orchard. Hence compatibility tests of superior trees are important in birch. Interspecific crosses, which are aimed primarily at increasing understanding of species relationships, have shown that certain species can be crossed successfully, others only with difficulty, and some not at all. Certain crosses are successful only in one direction, often depending on the chromosome numbers of the parent species involved in the cross.

The first controlled birch crosses made in this country were carried out at the Northeastern Forest Experiment Station in 1940; the progenies from these crosses were planted at Standing Stone, Pennsylvania, in 1946. In 1963 the sweet birch x paper birch hybrids averaged 37.2 feet in height and 5.0 inches in diameter compared with 27.8 feet and 3.4 inches for open-pollinated paper birch. The reciprocal cross (paper x sweet birch) had slightly better form but was otherwise comparable to paper birch. The hybrids between gray birch (*B. populifolia* Marsh.) and paper birch were 10 feet taller and 1.8 inches thicker than the paper x gray hybrids, but both crosses were inferior to both paper birch and gray birch. The sweet birch x yellow birch hybrids that were taller than both parents at age five (Schreiner 1949) had fallen behind both parents when measured by Sharik¹ in 1968. The average height and diameter of the hybrid were 32.4 feet and 3.2 inches, respectively, compared with 36.1 feet and 4.2 inches for yellow birch, and 37.3 feet and 4.3 inches for sweet birch.

Other hybrid progenies planted at Williamstown, Massachusetts, in 1954 were measured in 1967 at age 17 years from seed. The *B. papyrifera* x *pubescens* hybrid was superior to its reciprocal but inferior to both parent species. The hybrids *B. papyrifera* x *maximowicziana* Reg. and *B. pubescens* x *maximowicziana* were as tall as progenies of their respective female parents. In the work at the Institute of Forest Genetics we have also noted large differences between reciprocal crosses, but the progenies are too young to

draw any conclusions from. Crosses made in Sweden involving paper birch showed that at 24 years of age the hybrids *B. pubescens* x *papyrifera* and *B. pendula* x *papyrifera* performed no better than pure paper birch, and were inferior to the two Swedish species (Johnsson 1967).

Although certain interspecific hybrids between the native birches thus far have shown better growth than the pure species, we need to do more crossing and testing before we can judge the value of interspecific hybridization as a means of increasing growth. Interspecific hybrids may, however, be of value in developing resistance to insects or disease. An example is the *B. populifolia* x *papyrifera* hybrid, which should be tested for possible resistance to birch dieback. Some hybrids appear to be resistant to birch leaf miner (*Fenusa pusilla* Lep.) and deserve further testing.

We have made crosses between trees of the same species, but since the progenies are still young about all we can say at present is that a lot depends on the individual trees used as parents. Older work in Sweden with *B. pendula* and *B. pubescens* also demonstrated that certain crosses were much more vigorous than others at age 20 to 24 (Johnsson 1967). The best results were obtained with parents located within a few degrees latitude of each other; progenies from crosses between northern and southern parents tested in the south showed decreased growth as latitude of the northern parents increased. Unfortunately, these crosses were not tested near the northern parents where they possibly could show superior growth.

Intraspecific hybrids, on the basis of our limited experience, appear to offer much promise. Crosses between different provenances should receive particular attention, but should probably be limited to provenances within relatively close latitude of each other. Thus far, the trees used in most crosses have been selected more for convenience than for particular attributes. If future crosses are made with trees selected for fast growth or other desirable characteristics, significant improvements should be possible.

Exotics

Although the genus *Betula* contains about 50 species, few exotic birches have been tested in this country so far. In 1954 the Northeast-

ern Forest Experiment Station established a planting at Williamstown, Massachusetts, that included two European species, *B. pendula* and *B. pubescens*, three Asiatic species and varieties, *B. davurica* Pall., *B. platyphylla* var. *japonica* (Miq.) Hara and *B. platyphylla* var. *szechuanica* (Schneid.) Rehd., and native paper birch for comparison. When measured in 1967, 17 years from seed, the two European species were slightly taller, the Korean variety of *B. platyphylla* was equal to, and the Chinese variety of *B. platyphylla* slightly taller than the paper birch lots (table 3). One lot of Japanese *B. davurica* was 33 percent taller than the paper birch, and one lot of the Japanese variety of *B. platyphylla* was 48 percent taller (table 3).

A height of 30 feet in 17 years is an impressive demonstration of the growth potential of certain exotics, but much more extensive tests are required before we can say much about the relative merits of various species. The success of an exotic depends largely on finding the right provenance for a particular locality, and the same provenance will seldom do equally well in all areas.

BIRCH TREE IMPROVEMENT

Selection and Progeny Testing

Clausen and Godman (1967) published a guide to selection of superior yellow birch trees. Recently we demonstrated that smooth-barked or heavily peeling yellow birches are younger and faster-growing than rough-

barked trees.² This finding should make it easier to identify potentially fast-growing trees that should be selected as crop trees or superior trees.

Region 9 of the Forest Service is selecting superior yellow and paper birches as part of its tree-improvement program. So far about 30 superior yellow birches have been selected on the National Forests in Michigan and Wisconsin, and work with paper birch has been scheduled for Wisconsin and Minnesota. In Vermont and New Hampshire, about 20 superior yellow birches and 30 paper birches have been selected. Plans call for progeny testing of all selected trees before seedling seed orchards are established.³

The importance of progeny testing should be emphasized. As mentioned previously, certain yellow birches seem to produce much faster-growing progeny than others. Swedish studies of *B. pendula* and *B. pubescens* have shown that significant differences between individual tree progenies persist for at least 20 years after planting, and in some cases become more pronounced with time (Johnsson 1967).

EXPECTATIONS

Although much basic work on variation, inheritance patterns, characteristics to breed for, and crossing compatibilities remains to be done in *Betula*, the information accumulated so far justifies practical improvement efforts with the two most important commercial species, yellow birch and paper birch. We apparently have ample geographic variation to work with and, at least in yellow birch, much local variation. Since we know that intra-specific incompatibilities exist in these species, selected trees should be tested for compatibility as well as for transmittance of desired characteristics to their progeny. Until further tests have been conducted, we cannot say whether or not exotics will be important in birch improvement, either as species or as parents in interspecific hybrids.

We are naturally interested in increasing the growth rate and hence the wood produc-

Table 3.—Height in 1967 of *Betula* species and varieties planted at Williamstown, Mass., in 1954

Species or variety	Origin	Height
		<i>Feet</i>
<i>B. pendula</i>	Sweden	23.0
<i>B. pubescens</i>	N. Europe	21.6
<i>B. davurica</i>	Japan	26.9
<i>B. platyphylla</i> var. <i>japonica</i>	Korea	20.3
<i>B. platyphylla</i> var. <i>japonica</i>	Japan	30.0
<i>B. platyphylla</i> var. <i>szechuanica</i>	W. China	23.0
<i>B. papyrifera</i>		20.2

² Clausen, K. E., and Godman, R. M. Bark characteristics as indicators of age and growth rate in yellow birch. USDA Forest Serv. Res. Note, North Central Forest Exp. Sta. (In press).

³ Personal communication from J. A. Pitcher, USDA Forest Service, Milwaukee, Wis. January 1969.

tion of the birches, but the greatest benefit from genetic improvement will probably come from improved tree quality. The importance of improvement in tree quality can be illustrated by the latest Wisconsin sawtimber prices shown below (medium price per thousand board feet):⁴

Species	Veneer log	No. 1 sawlog	No. 2 sawlog
Paper birch ..	\$150	\$100	\$55
Yellow birch..	\$227	\$150	\$62

Thus, an improvement in quality from No. 2 to No. 1 would almost double the price of a paper birch saw log and more than double the price of a yellow birch log. And improvement from No. 2 to veneer quality would almost triple the price of a paper birch saw log and more than triple the price of a yellow birch log. The difference in financial returns would be even greater if the growth rates were concomitantly improved by as little as

10 percent. Only through better quality will an investment in developing and planting genetically improved hardwoods pay off.

Tree-improvement work can be conducted on a less intensive scale than through an actual breeding program. Much improvement in tree quality can be accomplished through better silvicultural practices. Thus, if the forester will learn how to recognize high-quality and fast-growing birch trees and leave these as crop trees when making timber-stand-improvement cuttings or as seed trees when making regeneration cuttings, future tree crops will almost certainly be improved. However, this type of tree improvement does require that the forester look at individual trees rather than at the stand in general.

⁴ Data from Wisconsin Forest Products Price Review, Fall 1968, Forestry Department, University of Wisconsin.

LITERATURE CITED

- Brayshaw, T. C.
1966. WHAT ARE THE BLUE BIRCHES? Can. Field-Natur. 80: 187-194.
- Brittain, W. H., and W. F. Grant.
1965. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. I. *B. Papyrifera* IN EASTERN CANADA. Can. Field-Natur. 79: 189-197.
- Brittain, W. H., and W. F. Grant.
1966. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. III. *B. papyrifera* OF BRITISH COLUMBIA. Can. Field-Natur. 80: 147-157.
- Brittain, W. H., and W. F. Grant.
1967a. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. IV. *B. CAERULEA-GRANDIS* AND HYBRIDS. Can. Field-Natur. 81: 116-127.
- Brittain, W. H., and W. F. Grant.
1967b. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. V. *B. Papyrifera* AND *B. CORDIFOLIA* FROM EASTERN CANADA. Can. Field-Natur. 81: 251-262.
- Brittain, W. H., and W. F. Grant.
1968a. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. VI. *B. Papyrifera* FROM THE ROCKY MOUNTAINS. Can. Field-Natur. 82: 44-48.
- Brittain, W. H., and W. F. Grant.
1968b. OBSERVATIONS ON CANADIAN BIRCH (*Betula*) COLLECTIONS AT THE MORGAN ARBORETUM. VII. *B. papyrifera* AND *B. resinifera* FROM NORTHWESTERN CANADA. Can. Field-Natur. 82: 185-202.
- Clausen, K. E.
1962. INTROGRESSIVE HYBRIDIZATION BETWEEN TWO MINNESOTA BIRCHES. Silvae Genet. 11: 142-150.
- Clausen, K. E.
1963. NURSERY SELECTION AFFECTS SURVIVAL AND GROWTH OF BIRCH. USDA Forest Serv. Res. Note LS-31, 2 p. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Clausen, K. E.
1966. STUDIES OF COMPATIBILITY IN *Betula*. In Joint Proc. Second Genet. Workshop of Soc. Amer. Forest. and Seventh Lake States Forest Tree Improve. Conf.; USDA Forest Serv. Res. Paper NC-6: 48-52. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Clausen, K. E.
1968a. NATURAL VARIATION IN CATKIN AND FRUIT CHARACTERISTICS OF YELLOW BIRCH. Fifteenth NE. Forest Tree Improve. Conf. Proc. 25-26 July, 1967: 2-7.

- Clausen, K. E.
1968b. VARIATION IN HEIGHT GROWTH AND GROWTH CESSATION OF 55 YELLOW BIRCH SEED SOURCES. Eighth Lake States Forest Tree Improve. Conf. Proc. 12-13 Sept. 1967: 1-4.
- Clausen, K. E., and R. M. Godman.
1967. SELECTING SUPERIOR YELLOW BIRCH TREES, A PRELIMINARY GUIDE. USDA Forest Serv. Res. Paper NC-20, 10 p. illus. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Dansereau, P., and G. Pageau.
1966. DISTRIBUTION GEOGRAPHIQUE ET ECOLOGIQUE DU BETULA ALLEGHANIENSIS. Mem. du Jardin Bot. de Montreal 58, 56 p.
- Dugle, Janet R.
1966. A TAXONOMIC STUDY OF WESTERN CANADIAN SPECIES IN THE GENUS BETULA. Can. J. Bot. 44: 929-1007.
- Johnsson, H.
1967. AVKOMMEPRÖVNING AV BJÖRK. (Progeny tests of birch). Fören. Skogsträdsförädling, Uppsala, Arsbok 1966: 90-135.
- Schreiner, E. J.
1949. CREATING BETTER TREES. Forest Leaves 34: 3-4, 14.
- U.S. Department of Agriculture Forest Service.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U. S. Dep. Agr. Agr. Handb. 271, 762 p.



BIRCH SOIL-SITE REQUIREMENTS¹

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YELLOW BIRCH is among our more valued hardwood species. Yet only meager information about site requirements is available for this tree and for paper birch. Site studies for yellow birch and paper birch and for other northern hardwood species have been completed for the Green Mountains of Vermont by Curtis and Post (1962a, 1962b). A similar study for northern hardwoods recently was initiated for northern Michigan and northern Wisconsin. We will summarize the major results and observations from these two site studies.

Some well-known facts about the birches are worth reviewing. One contrast between these species is their life span. Paper birch is a relatively short-lived tree, maturing in 60 to 75 years; older trees deteriorate rapidly. Yellow birch on good sites may reach harvestable size by age 75, but many trees 100 to 200 years old are healthy and valuable.

Distribution

Another obvious difference is the distribution of these two species. Fowells (1965) reported that paper birch has a range that completely crosses North America (fig. 1). By contrast, yellow birch has a more limited distribution in the eastern half of the continent; and it is found as far south as the mountains of northern Georgia (fig. 2). New England and the Lake States are fortunate in having an abundance of both species; their best development occurs in these regions.

Northern limits of yellow birch are roughly 48° or 49°N. latitude. Usual assumptions for northern hardwoods are: (1) low temperatures are limiting on the northern edge of their range; (2) high temperatures are limiting at lower elevations at the southern edge of their range; and (3) low precipitation is

limiting at the western boundary. These ideas seem to apply to yellow birch.

Paper birch differs from yellow birch in the range of conditions to which it is adapted. Paper birch is found farther north than yellow birch. Also, paper birch is adapted to a wider range of precipitation patterns and soil conditions than yellow birch.

Elevation generally is related to the distribution of yellow birch. In the southern Appalachians yellow birch is almost always found above 3,000 feet; in the mountains of New England it is seldom found above 2,500 feet (Fowells 1965). The Lake States are less varied in elevation and lack the mountainous topography of New England; thus yellow birch occurs throughout these States.

In the more favorable parts of its range, paper birch occurs at all elevations, on all slopes, and all aspects (Fowells 1965). It is one of the few hardwoods found near timberline on the highest mountains in New England and New York. In the southern part of its range it is common only on the cooler sites—at higher elevations and on steep north- and east-facing slopes.

The greater environmental adaptability of paper birch is apparently due to the number of varieties developed. In genetic terminology, it is quite plastic, being much like red maple in this respect. Apparently no varieties of yellow birch have yet been identified.

¹Part of the work reported here was a cooperative project of the USDA Forest Service, Northeastern Forest Experiment Station, and the Department of Forestry, Vermont Agricultural Experiment Station, University of Vermont. Other portions were done by the USDA Forest Service, North Central Forest Experiment Station. The Vermont Agricultural Experiment Station participation was part of the Northeast Regional Research Project NE-27. University of Vermont Agricultural Experiment Station Journal Article No. 212.

Birch Site Index

The most acceptable method for estimating site quality in both hardwood and conifer stands is the direct measurement of site index. Satisfactory site-index estimates can be taken only from dominant and codominant trees that have been free-growing and uninjured throughout their lives. Such trees most commonly are found in even-aged, fully-stocked stands that have not been disturbed by past cutting. Such stands were used in the Green Mountains of Vermont to develop site-index curves for both yellow birch and paper birch, based on stem-analysis methods (*Curtis and Post 1962b*). Comparative site indices between the birches and northern hardwood species were also developed from these data. A more recent study has shown that these site curves for yellow and paper birch also are applicable to even-aged stands in the White

Mountains of New Hampshire (*Solomon 1968*).

We still do not know how applicable these site curves are to yellow and paper birch in other areas where soil, topography, and climate are different from Vermont and New Hampshire. Harmonized site-index curves developed for paper birch in northern Wisconsin (*Cooley 1958*) show a steeper pattern of height growth than do our curves for paper birch in Vermont.

When the two species grow together in a stand, yellow birch has a somewhat lower site index than paper birch. Neither of the birches is as sensitive to differences in site quality as is the associated species white ash: on poor sites white ash has the lowest site index while on good sites it has the highest site index. Paper birch has rather rapid early height growth but slow growth is evident

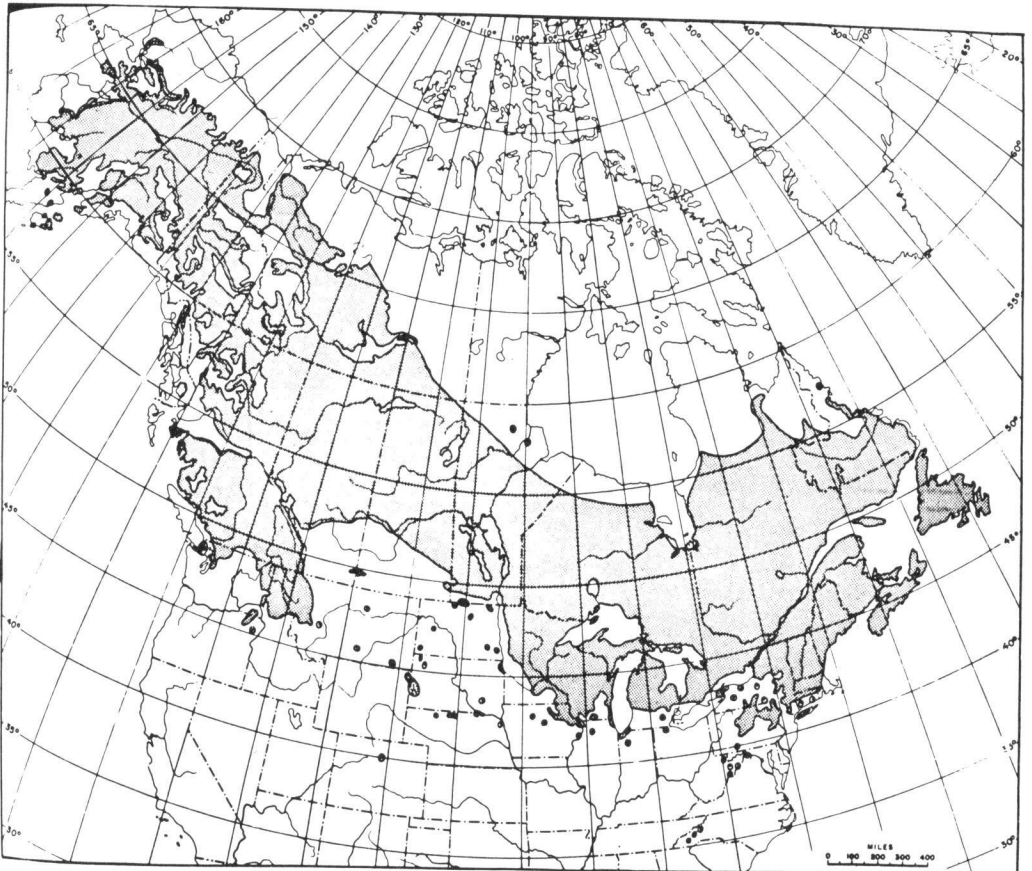


Figure 1.—The range of paper birch (From Fowells 1965.)

after 40 to 50 years. Yellow birch follows a somewhat similar pattern as does white ash. In contrast, sugar maple has rather slow early height growth, but growth persists longer without the slowing evident for the birches and white ash (*Curtis and Post 1962b*).

To evaluate differences in site quality between regions, we compared the ranges of environmental factors observed in undisturbed, well-stocked stands sampled in the course of site studies in Vermont and the Lake States. The Lake States observations are based on a recently initiated soil-site study for northern hardwoods in northern Michigan and Wisconsin. The Vermont data are from a study of northern hardwoods in the Vermont Green Mountains (*Post and Curtis, unpublished*), in which soils of the acid-till catena supporting even-aged northern hardwood stands were

related to tree growth. This obviously limits the range of conditions sampled to those acceptable to the species. In one sense these ranges might be considered as the requirements of these species for growth under normal competitive conditions.

Physical Soil Characteristics

Physical soil characteristics have a major influence in assessing site quality of northern hardwoods, as well as other species. The following characteristics affect moisture supply and aeration.

Soil texture has frequently been found to influence tree growth. In the Vermont data, 64 of 78 plots were sandy loam soils, 9 were loams, and 5 were loamy sands. The silt-plus-clay content ranged from 23 to 60 percent, with a mean of 40 percent. Thus the average

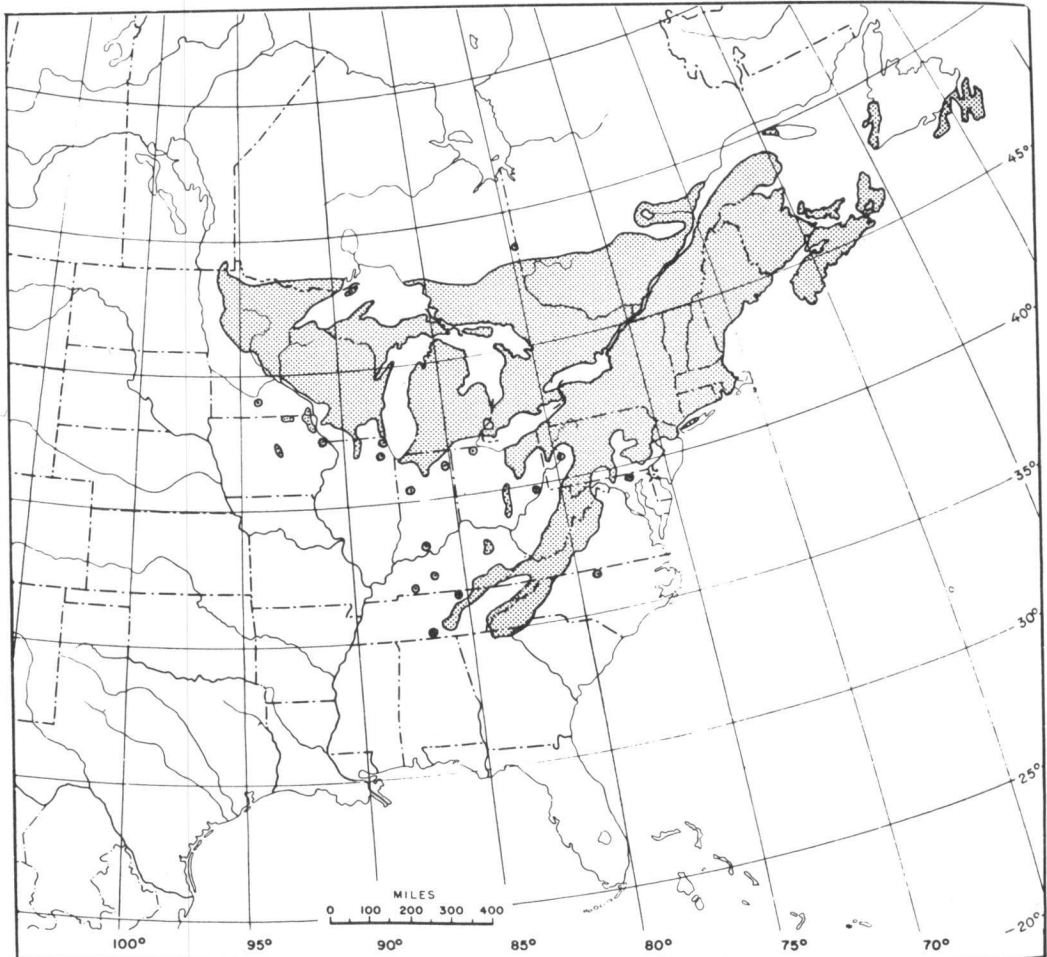


Figure 2.—The range of yellow birch (From Fowells 1965.)

sand content was about 60 percent. In statistical analyses, silt-plus-clay percentage was not a significant variable in explaining composite site index² at age 75, probably because of the limited range of the variable.

Soils of northern Michigan and Wisconsin are extremely varied in texture, drainage, and origin (*University of Wisconsin 1960*). Yellow birch and other northern hardwood species may be found on glacial tills and outwash sands, on fine-textured lacustrine deposits, on shallow loess deposits, and on residual soils derived from parent materials including limestone, sandstone, and igneous and metamorphic rock. Even though soils are extremely varied, site-quality relations are far from simple and may be related to many factors besides soil texture and drainage. These include the effects of soil development, fragipans, and possibly soil fertility.

The occurrence of yellow birch and other northern hardwoods in the Lake States is closely related to soil texture and drainage. Yellow birch commonly occurs on soils that range from well-drained to somewhat poorly-drained. Coarse-textured soils having little profile development (Grayling and Rubicon soil series), and poorly-drained soils rarely support hardwoods of any kind. Red maple occurs on most of the same soils as yellow birch; sugar maple is less common on the somewhat poorly drained soils, but is common on the well drained and moderately well drained ones.

Because the occurrence of northern hardwoods is restricted by soil texture and drainage, the observed range of yellow birch site quality in the Lake States also may be somewhat restricted, compared to other forest species. Even so, yellow birch site quality has been observed to vary by more than 30 feet between the best and the poorest sites.

As previously mentioned, yellow birch rarely occurs on very coarse-textured sandy

loam soils having little profile development. However, some of the best yellow birch sites in the Lake States are found on similar coarse-textured soils that have thick, dark-colored ortstein layers in the subsoil (Kalkaska series). Yellow birch growth and site quality are also generally excellent on the better drained lacustrine soils that are capped with a shallow layer of loess. The somewhat poorly-drained lacustrine soils (Ontonagon series) are poorer yellow birch sites; early height growth on these soils is adequate, but height growth slows markedly after 30 or 40 years.

Site quality for paper birch in northern Wisconsin was found to be closely related to topography. Poorer sites were found on steeper slopes and on ridgetops, while better sites were found on flats or in areas with rolling terrain. Site quality for paper birch also improved with increased content of silt plus clay. In addition, site quality was better when mottling was present in the upper 48 inches of soil (*Cooley 1962*).

Soil Drainage and Depth

In New England, soil drainage is one of the most important site factors affecting the growth of the birches. Fowells (1965) indicated that yellow birch grew best on moderately well drained sandy loams within the podzol and brown podzolic soil groups and on flats and lower slopes.

Data from the Green Mountains support this. Twenty-two moderately well drained plots had an average CSI₇₅ of 78 feet, the highest average for the five soil-drainage classes observed. Other drainage class CSI₇₅ averages and number of plots in the class are as follows: well-drained, 69 feet (40 plots); somewhat poorly drained, 67 feet (5 plots); somewhat excessively drained, 61 feet (6 plots); and excessively drained, 53 feet (5 plots). Plots were chosen in the last three categories for comparison purposes. The small number of plots is due to the fact that (1) these soils are often occupied by other types, and — when present — northern hardwood stands tend to be irregular, in part because of past selective removal of better trees from mixed or defective stands common on these drainage conditions; and (2) the areas occupied by well drained and moderately well drained soils are considerably larger than those classified otherwise.

² Curtis and Post showed that measured site indices of sugar maple, white ash, yellow birch, and paper birch occurring on the same plots are closely related. This suggested the use of a composite site index (CSI) to express site quality in these mixed stands (Curtis and Post 1964). Measured site index of each species present was converted to an estimated maple site index for each plot. The average of these estimates for a given plot (including measured site index of maple, if present) is composite site index.

In the Vermont study, drainage class was found to be statistically significant and useful in prediction equations.

Soil depth is known to be related to site quality of several species, including the birches. This measurement is directly related to several other soil and topographic variables that account for its importance. In the Green Mountain data, soil depth was positively correlated with percent slope, moisture-holding capacity, bulk density, and solum totals of nutrients, organic matter, and stone. Negative correlations included elevation and latitude.

Effective soil depth for tree growth is the thickness of a layer of fine soil wherein moisture, nutrients, and aeration conditions are suitable for root growth. Valid estimates of effective soil depth or volume must include a correction for the space occupied by stones. Correction for stone content makes a considerable difference in calculations of water and nutrient variables. And the proportion of the soil volume not occupied by stones (the volume of soil particles under 2 mm. expressed as a proportion of the total volume) added a small amount to the proportion of variance explained. The fact that laboratory analyses were necessary to obtain this information limits its value in practical applications. Generally site quality increases as soil depth increases. In Vermont, the depth of stone-free soil averaged 15.5 inches and ranged from 5.6 to 25.9 inches. Solum depth was found to be useful in prediction equations for CSI_{75} in the Green Mountains.

Thickness of the upper soil horizon, either the O2 or A1, was also found useful in predicting CSI_{75} in the Green Mountains. This variable has a negative coefficient in the equations. Upper horizon thickness is positively correlated with pounds of nitrogen per acre, inches of stone in the solum, and percentage volume of stone. Negative correlations were found with latitude, and the amount of organic matter in the B horizons. Most likely these relationships partially account for the inclusion of this variable in the prediction equations. Another partial explanation comes from Fraser (1956). He reported that on wet sites with thick organic horizons the spring warmup of the soil was delayed; this consequently retarded the start of growth. Poor site quality for paper birch was observed in northern Wisconsin in areas where bed-

rock occurred at depths less than 12 inches (Cooley 1962). Poor site quality for yellow birch and other northern hardwoods also existed in areas where only a shallow soil depth occurred over limestone ledges.

Chemical Soil Characteristics

It is frequently reported that northern hardwoods require fertile soil, but the nutrient contents of a fertile soil are not described. However, chemical soil characteristics have seldom been found useful in multiple regressions used to derive prediction equations for forest site quality. This situation probably prevails because of the large number of inter-correlations of nutrients with other variables. For example, calcium, expressed as pounds per acre in the solum, is significantly correlated with CSI_{75} in Vermont. When individually tested with the other variables, significant and positive correlations were found between calcium and soil depth, moisture-holding capacity, magnesium content, nitrogen content, phosphorus content, potassium content, aspect, organic-matter content, stand age, bulk density, and moisture content at 15 atmospheres pressure. Significant negative correlations were found with elevation, latitude and pore volume. A similar pattern existed with magnesium, which was also significantly correlated with CSI_{75} . Nitrogen, phosphorus, and potassium were not significantly correlated.

The observed ranges and means for the amounts of the elements analyzed (table 1) show the adaptability of northern hardwoods to a wide range of nutrient conditions. This does not imply that nutrient content of the soil is unimportant. Hoyle (1965a) in a detailed study of yellow birch on two plots, one a well-drained Hermon soil and the other a poorly-drained Whitman, showed that differences in foliage composition and diameter increase were related to soil conditions.

Table 1.—Pounds per acre of elements in the solum

Element	Mean	Range
Calcium	1,280	200- 2,650
Magnesium	9,978	1,100-31,230
Nitrogen	4,975	2,703- 8,379
Phosphorus	23	2- 115
Potassium	1,686	161- 8,507

In a pot-culture study using Hermon B₂₃ horizon soil, a layer 5 to 15 inches under the humus layer, Hoyle (1965b) demonstrated a response of yellow birch seedlings to added phosphorus and lime. He suggested that phosphorus deficiency in acid soils can be alleviated by fertilizing with phosphorus and by liming.

Few observations have been made in the Lake States on fertility relations for yellow birch or other northern hardwood species. But early results from fertilizer application to a well-stocked 35-year-old northern hardwood stand show a significant response to nitrogen.

Topographic Variables

Of the several site characteristics that are easily determined in the New England States, elevation is one that is prominently related to site quality. Fowells (1965) indicated that yellow birch has an upper limit of about 2,500 feet in New York and New England. In contrast, the species is normally restricted to elevations above 3,000 feet in the southern part of its range.

In the Green Mountains, elevation was highly correlated with CSI₇₅, with highest site indexes at the lower elevations. This is not unexpected, because elevation is undoubtedly related to the unmeasured climatic factors of temperature and rainfall; and it is negatively correlated with soil depth, aspect, bulk density, calcium content, and magnesium content.

Latitude was another significant topographic variable in the Green Mountains. Site quality generally decreased from south to north in Vermont. Intercorrelations found with latitude were primarily with soil conditions, and indicated that the northerly plots had shallower soils with less total nutrients.

Aspect was also useful in prediction equations, but it was not a major variable. The

expression of aspect having the highest simple correlation with CSI₇₅ was sine (azimuth + 45°), indicating that best growth is in the northeast quadrant and poorest in the southwest. Aspect influences tree growth through its affect on the temperature, water, and light relations of the site.

No other topographic factors were found to be related to site quality of northern hardwoods in Vermont.

The Lake States lack the steep, mountainous topography of New England. The landscape there includes level outwash sand or lacustrine plains, rolling moraines with occasional short slopes, and occasional ridges marking outcrops of residual rock. Relations between site quality and topography are not pronounced in such a uniform landscape.

Future Directions

As in other important species, soil-site studies of yellow birch and paper birch will be continued, using the best available techniques. These will include refined experiments in the ecology and physiology of the species to learn more of their requirements for nutrients, water supply, temperature of air and soil, and light.

The effects of nutrients probably cannot be demonstrated by the soil-site survey approach, because of the numerous intercorrelations of variables. Controlled nutritional studies and plot experiments will be needed.

The commercial range of yellow birch and other northern hardwoods covers several regions having diverse topography, geology, soil, and climate. Additional soil-site studies are needed to adequately describe the complex site relations for hardwoods throughout this great commercial range. These studies should include site comparisons among hardwood species and improved site-index curves based upon stem-analysis methods.

Literature Cited

- Cooley, J. H.
1958. SITE INDEX CURVES FOR PAPER BIRCH IN NORTHERN WISCONSIN. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 541, 2 pp. St. Paul, Minn.
- Cooley, J. H.
1962. SITE REQUIREMENTS AND YIELD OF PAPER BIRCH IN NORTHERN WISCONSIN. USDA Forest Serv. Lake States Forest Exp. Sta. Sta. Paper 105, 11 pp. St. Paul, Minn.
- Curtis, R. O., and B. W. Post
1962a. COMPARATIVE SITE INDICES FOR NORTHERN HARDWOODS IN THE GREEN MOUNTAINS OF VERMONT. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 171, 6 pp. Upper Darby, Pa.
- Curtis, R. O., and B. W. Post.
1962b. SITE-INDEX CURVES FOR EVEN-AGED NORTHERN HARDWOODS IN THE GREEN MOUNTAINS OF VERMONT. Vt. Agr. Exp. Sta. Bull. 629, 4 pp.
- Curtis, R. O., and B. W. Post.
1964. SOME COMPARISONS OF BASAL AREA, VOLUME, AND DIAMETER IN UNMANAGED EVEN-AGED NORTHERN HARDWOODS IN THE GREEN MOUNTAINS. J. Forestry 62: 864-870.
- Fowells, H. A. (Editor)
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U.S. Dep. Agr. Agr. Handb. 271. 762 pp.
- Fraser, D. A.
1956. ECOLOGICAL STUDIES OF FOREST TREES AT CHALK RIVER, ONTARIO, CANADA. Ecol. 37: 777-789.
- Hoyle, M. C.
1965a. VARIATION IN FOLIAGE COMPOSITION AND DIAMETER GROWTH OF YELLOW BIRCH WITH SEASON, SOIL, AND TREE GROWTH. Soil. Sci. Soc. Amer. Proc. 29(4): 475-480.
- Hoyle, M. C.
1965b. ADDITION OF PHOSPHORUS TO SUBSOIL PROMOTES ROOT DEVELOPMENT OF YELLOW BIRCH. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note NE-42, 7 pp. Upper Darby, Pa.
- Solomon, D. S.
1968. APPLYING SITE-INDEX CURVES TO NORTHERN HARDWOODS IN NEW HAMPSHIRE. USDA Forest Serv. Res. Note NE-79, 5 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- University of Wisconsin.
1960. SOILS OF NORTH CENTRAL REGION OF THE UNITED STATES. Univ. Wis. Agr. Exp. Sta. Bull. 544. 192 pp.

BIRCH NUTRITION

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MUCH OF THE slow growth and low quality of our birches and other northern hardwoods in New England can be traced to inadequate soil fertility. This problem can be overcome by remedial fertilization, which will enhance the production of healthy, vigorous birch trees.

What Are the Mineral Nutrients?

Yellow birch and paper birch, like all higher plants, require 15 elements in order to live and develop. Carbon and oxygen are obtained from the atmosphere, and hydrogen is derived from water; but the remaining 12 (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, boron, and molybdenum) must all be extracted from soil. These 12 elements are commonly referred to as the mineral nutrient elements. Nitrogen, though not a mineral, is always included with the 11 true minerals; so when we speak of mineral nutrition we mean nitrogen too.

Importance of Mineral Nutrients to Trees

If any one of the 12 nutrient elements is completely withheld from a tree, death will ensue. If one of the nutrient elements is deficient, then tree growth is retarded and the tree is unhealthy. Such a nutrient-deficient tree is physiologically weakened and is less able to ward off diseases and attacks by insects. The opposite condition, toxicity, occurs when too much nutrient element is present in the tree. This also produces an unhealthy, weakened tree that is much more susceptible to the adversities of its environment.

Trees grow and develop best when all 12 nutrient elements are taken up in optimum quantities. Six of the nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) are called macronutrients because

their optimum levels in plants are higher than optimum levels for the other six (copper, zinc, manganese, iron, boron, and molybdenum), which are called micronutrients.

Analyses are made of the various nutrient elements in tree leaves to determine whether deficient, optimum, or toxic levels are present. These levels are commonly predetermined experimentally by plotting the relation between birch seedling growth and nutrient element concentration in birch leaves (fig. 1). This approach is called a *foliar diagnosis* of a tree's nutrient status.

A simple deficiency (or toxicity) occurs when only one element is present in the deficiency (or toxicity) range, and all other nutrient elements are present in optimum amounts. This simple condition involving one nutrient can reduce tree growth and impair its health. However, for birch trees in their natural environment the situation is generally more critical, and deficiencies of several nutrients are often found.

A complex of multiple nutrient deficiencies and nutrient toxicities is possible also. The results of such an unbalanced nutrient status in birch trees are serious and numerous: (1) growth is retarded in roots, stems, and leaves; (2) both food production and food translocation can be impaired; (3) probability of insect attack is increased; (4) trees are predisposed to successful invasion by pathogenic microorganisms; and (5) the trees suffer more than normal from extremes of moisture supply, temperature, and high winds when these adversities are superimposed upon an already unhealthy physiological condition.

Forest Soil and Mineral Nutrition

Forest soil, the primary supplier of the twelve nutrient elements, plays a major role in determining the nutrient status of a tree and thereby indirectly controls the tree's

health. As a result, tree growth will be retarded to the extent that forest soils fall short in supplying optimum amounts of nutrient elements. If the soil is neglected, the tree is neglected.

Unfortunately, this has been the case too often, for several likely reasons: (1) the chemistry of forest soils is complex, so it is difficult to evaluate soil fertility status; (2) plant chemistry is complex, so it is difficult to evaluate tree nutrient status; and (3) there is a popularly held belief that forest trees are not very demanding of the soil because their nutrient requirements are thought to be minimal.

However, research in the past two decades has provided clear evidence to the contrary. We now know that trees suffer markedly from nutrient element disorders as a result of inadequate soil fertility. But on the encouraging side, we know also that trees respond nicely when these nutrient inadequacies are corrected by proper fertilization.

The first two problems can be resolved by intensified research and development effort, and the third problem can be eliminated by improved communication between soil scientists and foresters.

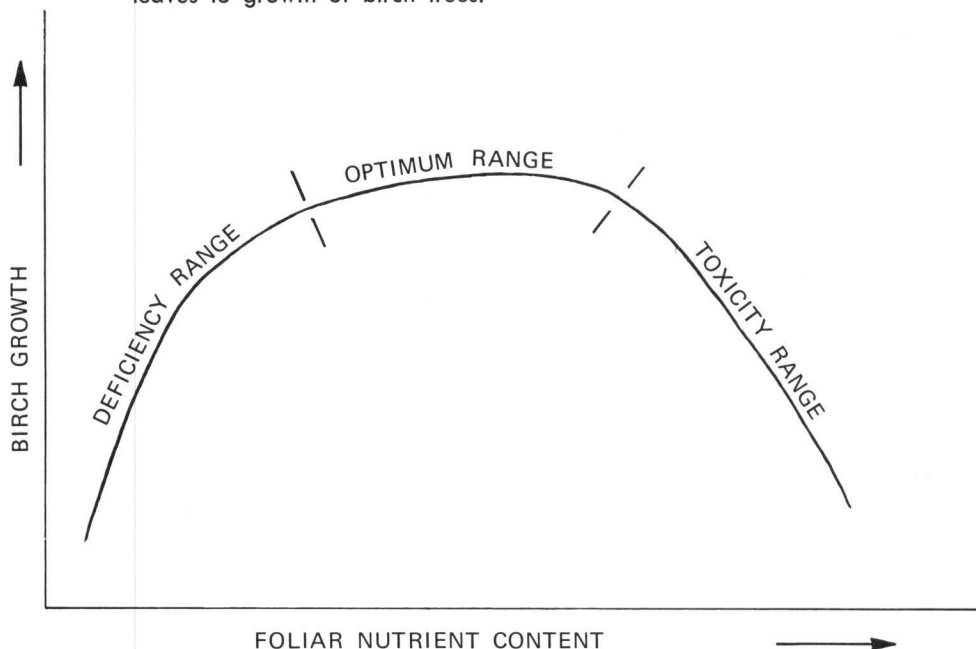
Present State of Knowledge in Nutrition Research

For the past several years, we have placed increasing emphasis on studies of mineral nutrition of paper and yellow birch. Our nutrition work with yellow birch has been in progress for 7 years; nutrition work on paper birch was initiated last year. Previously published work dealing with nutrition of paper and yellow birch is sparse (only a few papers from this country and Canada), so there is little information to use as a guide.

A notable exception has been the work at the Royal College of Forestry in Stockholm, Sweden, where fundamental nutrition studies of *Betula verrucosa* have been carried out.

Our work in birch nutrition has been conducted both in the field and in the laboratory. The work has varied from studies concerned with nutrition of the trees themselves to studies dealing with fertility status of forest soils supporting the birches. In general, answers to three questions have been sought: (1) What are the nutrient requirements of the particular species?; (2) What is the ability of our native forest soils to meet these requirements?; and (3) What can be done to correct the inadequacies?

Figure 1.—The relation of nutrient element content in birch leaves to growth of birch trees.



The information reported here deals primarily with yellow birch, but much of it is applicable to paper birch also.

Through foliar diagnosis of forest-grown yellow birch, we have elucidated the seasonal variation patterns for 10 of the 12 nutrient elements. With this information, we know when to sample birch foliage and derive nutrient data that is both statistically and biologically meaningful. Using this technique, we can evaluate field experiments, compare field experiments with greenhouse experiments, and most important, assess the nutrient status of birch trees in the native state.

Early results from this work suggested that native yellow birch in the White Mountains was deficient in nitrogen and the bases calcium and magnesium, and that manganese was present in toxic amounts.

Through several pot experiments designed to evaluate the fertility of granitic forest soils that are widely prevalent in the New England states and New York, a complex of several nutrient inadequacies was found. *Their combined effect on yellow birch is serious.* The results of these studies are summarized in the following:

- Yellow birch seedlings will grow very well on the organic material (humus) of the forest floor; they survive but in a dwarfed condition on surface mineral material; and they do not grow at all on subsurface mineral soil (much of this mineral material is exposed during scarification). Treatments to improve soil physical properties (moisture, aeration, bulk density) apparently do not help.
- Phosphorus was found to be the primary limiting element. Not only was seedling survival improved by adding phosphorus to mineral soil, but growth was increased also.
- Nitrogen was the secondary limiting element, but the maximum response to phosphorus and nitrogen was obtained only when soil additions of the bases—potassium, calcium, and magnesium — were included.
- To further complicate the picture, large amounts of aluminum (not a plant nutrient) in birch roots and manganese in birch leaves occurred when seedlings were

grown in forest soil. It appears that the high levels of these two elements may be toxic to birch.

- With regard to the forest soil itself, we found that deficiencies of nitrogen and phosphorus are moderate in the surface layer and severe in the deeper layers; calcium may be adequate in the surface layer but is usually deficient in the lower layers; potassium is moderately deficient in all soil layers while magnesium is severely deficient in all soil layers.
- Yellow birch in the native state does not develop many roots in the lower soil layers and is generally considered to be a shallow-rooted species. Our recent research now indicates that this lack of root development in subsoil is due primarily to calcium deficiency, especially in the subsoil, and is aggravated further by toxic amounts of aluminum.

These results show that serious nutritional disorders exist in yellow birch growing in many forest soils in the Northeast; so we ask:

What Can Be Done?

Fortunately, these nutrient inadequacies in forest soil can all be corrected by additions of the proper elements to the soil. The excessive supply of manganese and aluminum can be reduced to acceptable levels by using limestone.

Ideally, for granitic podzol soils, dolomitic limestone (slightly soluble source of calcium and magnesium) should be mixed into the mineral soil to a depth of several feet. This could be carried out when the old forest is harvested and new birch stands are to be regenerated. Only when the forest is removed can the heavy machinery that is necessary to do the job be used. Adding limestone to existing stands may perhaps best be accomplished by furrowing or boring holes. But one heavy application of limestone to mineral soil should suffice for one rotation.

The other macronutrients will have to be applied periodically (every 4 to 5 years) by broadcasting over the surface. Aerial application with helicopter seems the best choice.

Occasional touch-up treatments with some of the micronutrients are easily accomplished by spraying dilute aqueous solutions over the foliage. More long-lived effects can be ob-

tained by broadcasting along with the macro-nutrients.

What May We Expect?

At this point, we have to crawl out on the proverbial limb because field trials of research findings are just beginning. However, we do have some idea about the quality of the results.

Existing stands develop a very dense canopy as a result of the increased number of leaves having a darker color than normal. Most trees with crowns below the main canopy die off 3 to 4 years after heavy fertilization. We have observed an improvement in diameter growth in overstory trees, but we have not quantified it yet. The stand we fertilized was 70 to 80 years old; heights of dominants were

60 to 70 feet, and diameters of dominants were 8 to 12 inches d.b.h.

It is clear that forest fertilization can markedly improve the growth and vigor of birch trees. More intensive fertilization research is certainly needed to learn the amount of gain that is possible, and to evaluate the financial returns that may be expected under various circumstances. We feel that returns from fertilization will be large. It does not seem unreasonable to expect that yellow birch rotations might be cut to less than 60 years with prescribed fertilization and orchard-type management. Wood quality would be improved too. As management approaches this intensive level, the question changes from: "Can we afford fertilization?" to "Can we afford not to fertilize?"

References

- Hoyle, M. C.
1969. GROWTH AND NUTRITION OF YELLOW BIRCH AS AFFECTED BY THE NUTRIENT STATUS OF A PODZOL SOIL. IN *Forest-Soil Relationships in North America*. (Paper presented at the Third North American Forest Soils Conference, Raleigh, North Carolina, 1968). Ed. C. T. Youngberg, Oregon State University Press, Corvallis, Oregon.
- Ingstad, T.
1957. STUDIES ON THE MINERAL NUTRITION OF FOREST TREE SEEDLINGS. I. MINERAL NUTRITION OF BIRCH. *Physiol. Plant.* 10: 418-439.
- Mustanoja, K. J., and A. L. Leaf.
1965. FOREST FERTILIZATION RESEARCH, 1957-1964. *Bot. Rev.* 31: 151-246.



STOCKING, GROWTH, AND YIELD OF BIRCH STANDS

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INTENSIVE FOREST MANAGEMENT depends heavily upon our ability to measure, control, and predict the growth, yield, or general development of timber stands, regardless of whether the management goal is for timber, aesthetics, recreation, water, or wildlife.

A large amount of mensurational data about birch stands has been developed in recent years or synthesized from available information (Marquis et al. 1969, Leak et al. 1969). This information, which is summarized in this paper, covers site estimation, stocking, short-term growth, and yield. The information about paper birch applies to even-aged stands—in some cases to essentially pure stands that contain 50 percent or more paper birch. The data on yellow birch cover both even-aged and uneven-aged mixed northern hardwood stands with at least 5 percent yellow birch.

SITE

Growth and yield of birch are related to site quality. The better the site, the faster the growth and the greater the yield.

Site-index curves (fig. 1) have been developed for paper and yellow birch, as well as for sugar maple and white ash, growing in Vermont (Curtis and Post 1962b). These curves were found to be applicable to New Hampshire stands, with minor height corrections for precise estimation (Solomon 1968).

In mixed stands, it may be necessary to use measured site index for one species to predict site index of another. Figure 2 shows the relationship among site indices of paper birch, yellow birch, sugar maple, and white ash (adapted from Curtis and Post 1962a). For example, if the measured site index of yellow birch is 70, then the comparable site index for paper birch would be about 76 (fig. 2).

In New England, average site index for paper birch is about 60 to 70 feet. The potential production of a paper birch stand with a site index of 75 or better is high, while a site index of 55 or less represents fairly low potential. For yellow birch, average site index is 55 to 65, with a high of 70 or better and a low of 50 or less.

STOCKING

Even-aged and uneven-aged stands will be considered separately, because the measurement and interpretation of stocking differs between these two types of stands.

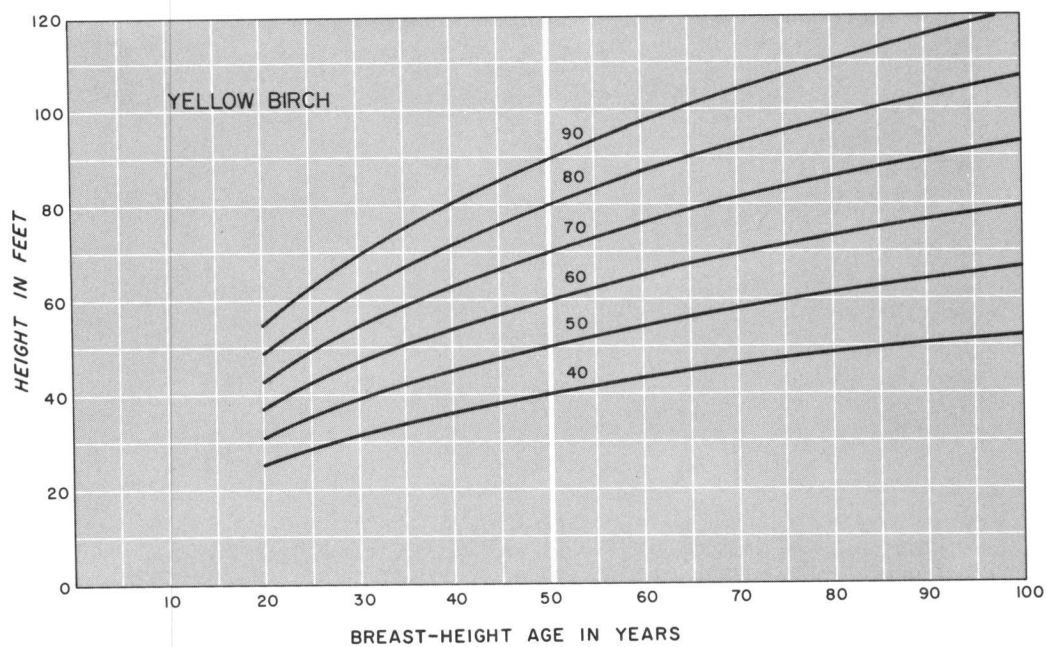
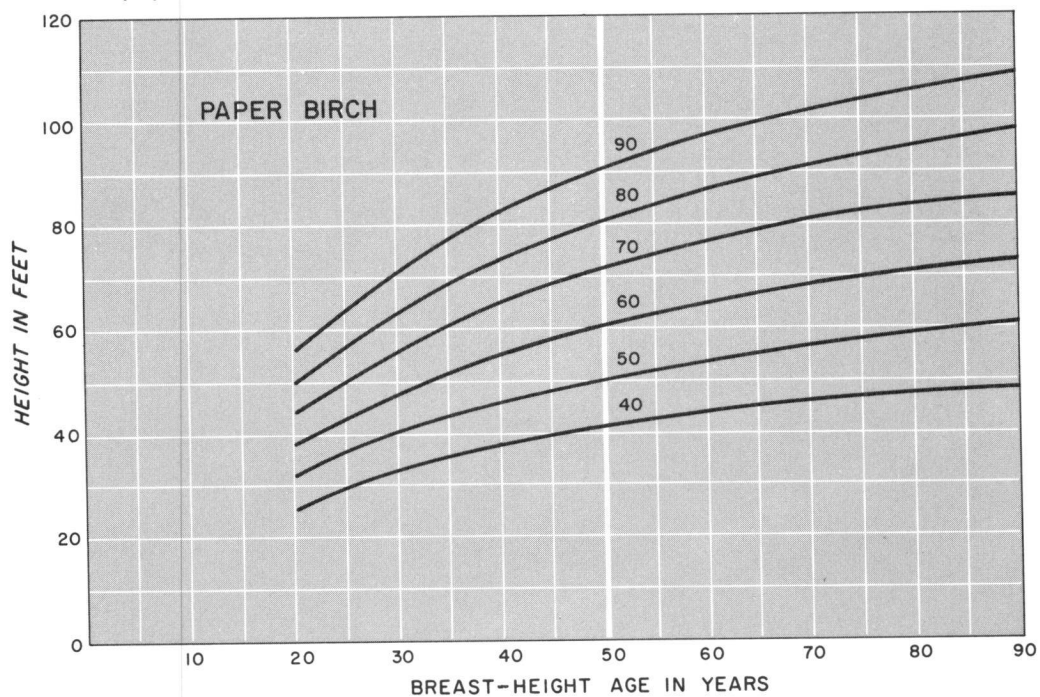
Uneven-Aged

Uneven-aged northern hardwoods contain a mixture of hardwoods, including a small to medium proportion of yellow birch, but little or no paper birch.

Choice of an appropriate or optimum stocking level in uneven-aged hardwoods is best determined by examining the relationship of growth to stocking or density. Gross annual basal-area growth per acre in trees over 5.0 inches as related to average basal area per acre (at the midpoint of the cutting cycle) is depicted in figure 3. This curve is based on a series of cutting experiments in the White Mountains of New Hampshire. Because of the varying length of cutting cycle, basal area at the midpoint of the cycle was considered a better measure of density than residual (initial) basal area per acre.

Gross basal-area growth is at a maximum between 80 and 100 square feet of basal area. However, growth response is very acceptable between 70 and 110 square feet. Thus we usually recommend a residual basal area after cutting of between 70 to 80 square feet in trees 5.0 inches and larger. Numerous

Figure 1.—Site-index curves (breast-height age 50) for yellow birch and paper birch.



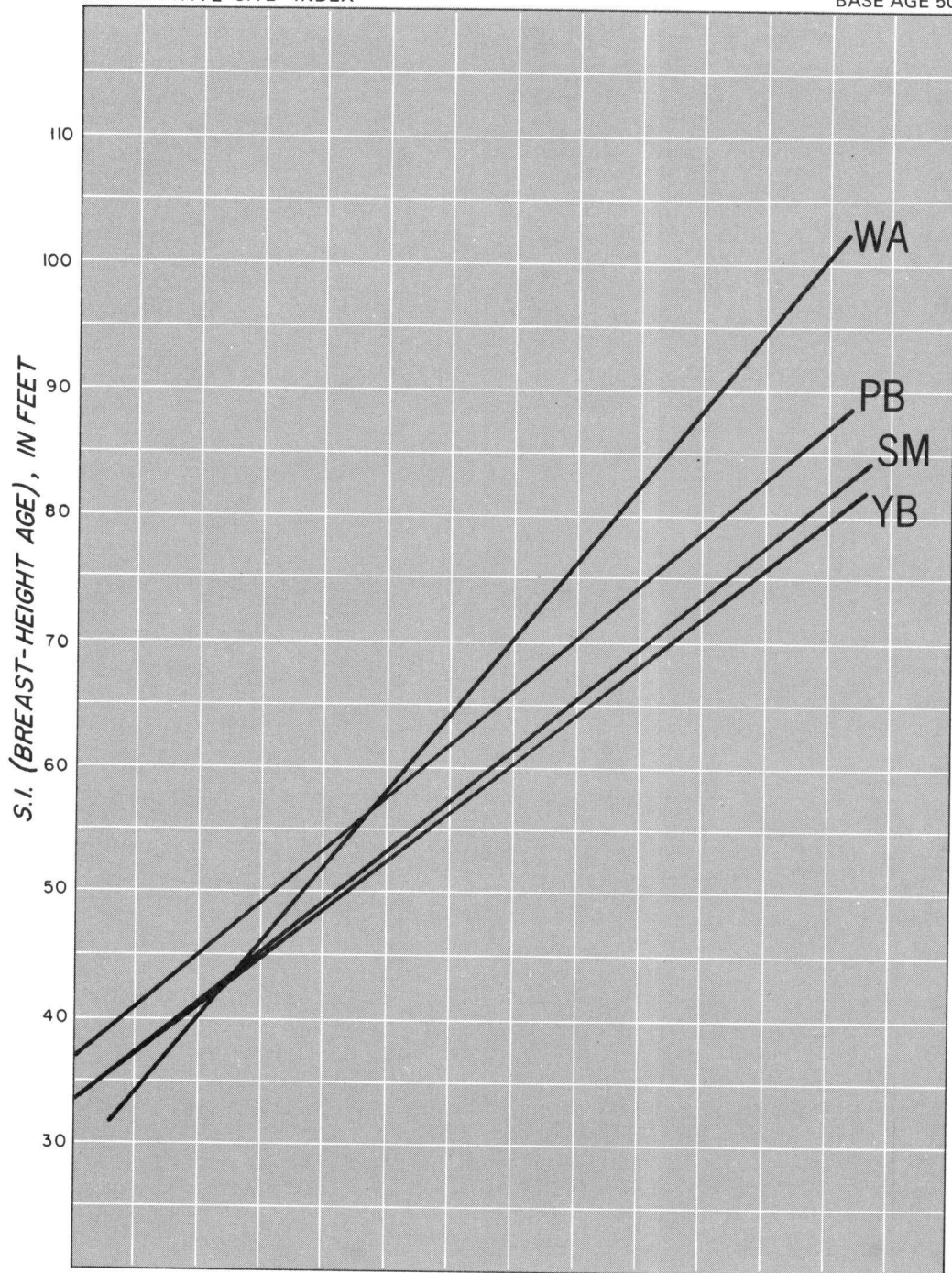


Figure 2.—Relationships among site index for four northern hardwoods. To estimate site index of species X from site index of species Y: find known site index on the curve for species Y; move vertically up or down to the curve for species X; read horizontally across to the left to find estimated site index for species X.

cutting experiments in New England indicate that losses in quality will not occur at residual basal areas within this range.

In addition to stocking, the stand structure—distribution of trees by d.b.h. classes—should also be controlled in uneven-aged stands. A typical structure for a stand at 80 square feet basal area is (Gilbert and Jensen 1958):

2-inch d.b.h. class (inches)	Trees (No.)	Basal area (sq. ft.)
6 — 10	60	20
12 — 16	30	28
18 +	15	32
All	105	80

This is in close agreement with the results in northern hardwoods in the Lake States (Arbogast 1957).

In applying cutting operations, an attempt should be made to work toward a structure similar to that outlined above. This will ensure that a high proportion of growth is placed upon sawtimber-sized trees. But sufficient smaller stems will be available to grow into the larger sizes.

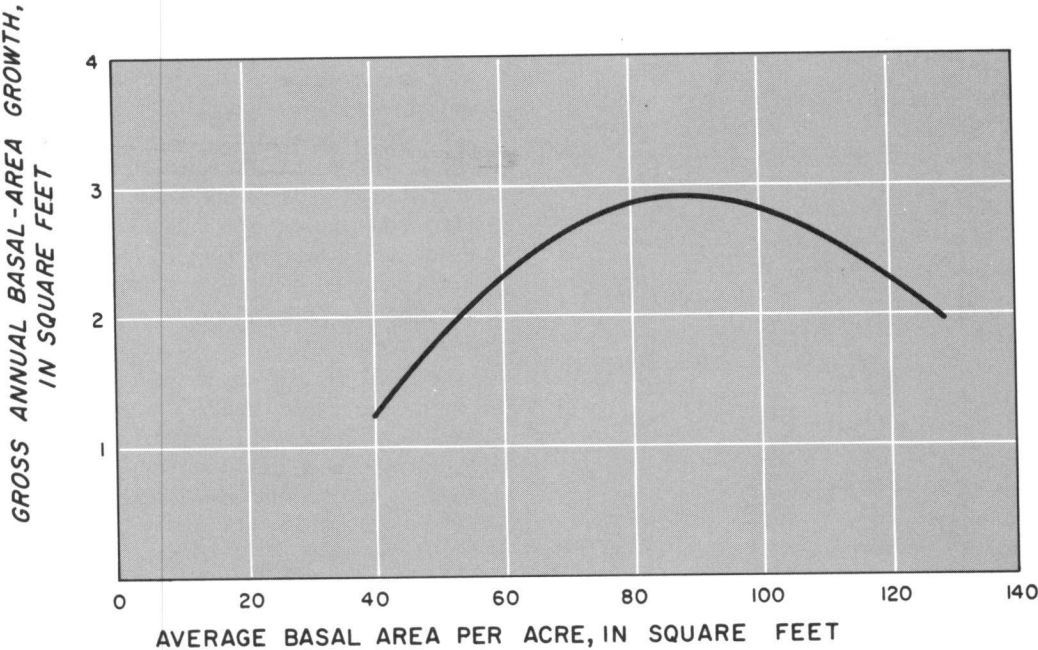
Even-Aged

Different methods are used to evaluate stocking in even-aged stands. An even-aged northern hardwoods stand usually contains a higher proportion of paper birch and yellow birch than an uneven-aged stand.

Sapling stands.—From plot tallies in unmanaged northern hardwood stands ranging from about 1.0 to 4.5 inches d.b.h., we determined the numbers of trees at a given initial diameter required to produce one tree at a given future diameter. Separate estimates were made for all commercial species, and for intolerant-intermediate species only. For example, average numbers of trees required to produce one tree when the species group reaches 5.0 inches mean d.b.h. are (Leak 1969):

Initial mean d.b.h. (inches)	Average numbers	
	All commercial species (No.)	Intolerant- intermediates (No.)
1.0	5.3	3.7
2.0	3.6	2.7
3.0	2.3	1.9
4.0	1.5	1.4

Figure 3.—Relationship of gross annual basal area growth to average basal area per acre in trees over 5.0 inches d.b.h. for uneven-aged northern hardwoods (average site).



Using statistical theory, we also determined the initial numbers of trees required to produce one tree at mean d.b.h. 5.0 inches with a high degree of confidence, ≥ 0.85 .

Initial mean d.b.h. (inches)	High-confidence numbers	
	All commercial species	Intolerants- intermediates
1.0	9	6
2.0	6	5
3.0	4	3
4.0	2	2

Stocking guides for older stands (to be discussed later), indicate that we should have a minimum of 387¹ well-distributed and well-formed northern hardwood or paper birch stems when the stand reaches mean d.b.h. 5.0 inches. Thus, if we sampled a stand using plots of 1/387 acre (113 square feet), it would seem reasonable to require that each plot contain at least the average number of good stems, or the high-confidence number required to produce at least one good stem when the stand reaches mean d.b.h. of 5.0 inches. Any plot that contains this minimum number is considered stocked. The percentage of stocked plots would reflect the percentage of the stand that was adequately stocked. Current recommendations are that 50 to 60 percent is adequate stocking.

Furthermore, using the average numbers and high-confidence numbers tabulated above, we can estimate the numbers of stems per acre required to produce 387 good stems at mean d.b.h. 5.0 for a northern hardwood or paper birch stand.

Initial mean d.b.h. (inches)	Average numbers/acre	
	All commercial	Intolerants- intermediates
1.0	2,051	1,432
2.0	1,393	1,045
3.0	890	736
4.0	580	542

	High-confidence numbers/acre	
	All commercial	Intolerants- intermediates
1.0	3,483	2,322
2.0	2,322	1,935
3.0	1,548	1,161
4.0	774	774

Any stand that did not contain enough stems to qualify as adequately stocked would

be considered as high priority for a cleaning treatment, to reduce mortality among the limited numbers of good stems. Conversely, any stand that qualified as adequately stocked would not require a cleaning treatment, although cleaning might still be justified on the basis of an improved growth response.

Poletimber and sawtimber stands.—In applying thinning and improvement cuttings in even-aged northern hardwoods, stocking control is of utmost importance. Although gross growth per acre is approximately equal over a range of densities for stands of similar site and species composition, diameter growth of crop trees is much higher, and mortality much lower, under something less than normal stocking. Conversely, if stocking gets too low, growth per acre and quality decline.

Stocking guides have been developed, for paper birch stands (50 percent or more of the basal area in paper birch) and northern hardwood stands, showing numbers of trees and basal areas per acre for stands of various mean d.b.h. (figs. 4 and 5). These guides apply to the main crown canopy of the stand—trees in a dominant, codominant or intermediate crown position that are touching the main overstory.

In these guides, the A line represents an average unmanaged stand. The B line represents minimum stocking for full site utilization and adequate growth without competition. The C line represents the level where 10 years of growth on an average site will raise the standard to B line stocking.

Stands above the A line are overstocked. Stands between the A and B lines are adequately stocked. Stands between the B and C lines are potentially adequately stocked, and those below the C line are understocked. Under most conditions, stands are considered for thinning when stocking is more than halfway between the A and B lines. Stocking after thinning should be near (above or below) the B line.

The concepts used in evaluating stocking in both regeneration stands and older stands have been combined in figure 6 to produce a stocking chart for paper birch stands between 1 and 5 inches mean d.b.h. Here too

¹ As illustrated in figures 4 and 5, stands with a mean d.b.h. of 5.0 inches contain 387 trees per acre at minimum full stocking (B line).

the A line represents the development of an unmanaged stand. The B line represents desirable stocking after thinning or weeding.

GROWTH

Growth of both uneven-aged and even-aged stands in terms of diameter, basal area, and height is useful as a basis for evaluating response to silvicultural treatment, and for comparing species differences in growth response. Although growth measures are not necessarily in merchantable units, growth data frequently can be used for developing yield estimates.

Diameter Growth

Uneven-aged.—Diameter growth of northern hardwoods in cut and uncut uneven-aged stands is illustrated in figure 7. Basal area of the cut stand varied from 77 to 94 square feet over the 15-year growth period, while the basal area in the uncut stand varied from 110 to 115 square feet. In the smaller sizes, diameter growth of trees in the cut stand was at least twice as great as that in the uncut stand. In the larger sizes, diameter growth was somewhere around 20 to 25 percent greater under cutting (*Gilbert et al. 1955*).

Yellow birch, which made up about 6 percent of the stand, grew somewhat slower than average, although they, too, responded to treatment. D.b.h. growth rates in the cut stand were:

Species	Annual d.b.h. growth rate (treated) (inches)
Hemlock	0.13
Sugar maple	0.14
Beech	0.13
Yellow birch	0.09

In addition to cutting treatment, individual characteristics related to tree vigor also affect diameter growth of yellow birch growing in uneven-aged stands. A sample of 200 yellow birch trees growing in essentially unmanaged stands were bored to determine past 5-year growth, and were rated for vigor according to the following classes:

Vigor Class I.—Trees with no injury and having dense crowns in a dominant or co-dominant position. One-half or more of the crown is exposed to full sunlight.

Vigor Class II.—Trees that are codominants or poor dominants, or with possible injury, and the crown is less than half exposed to full sunlight.

Figure 4.—Stocking guide for pure even-aged paper birch stands, showing basal area per acre, numbers of trees per acre, and mean d.b.h. for trees in the main crown canopy.

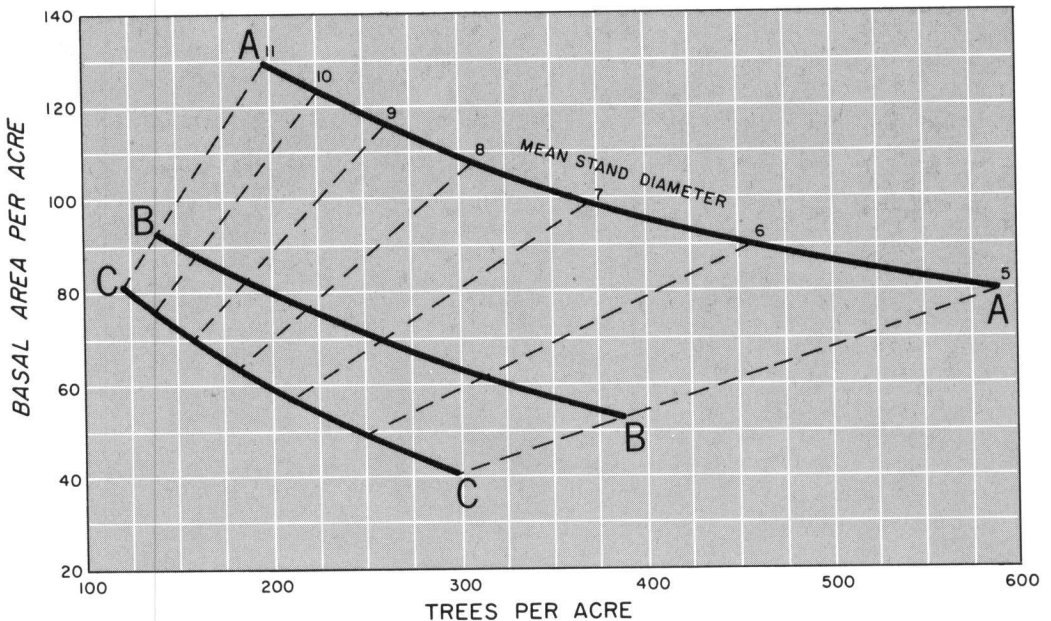
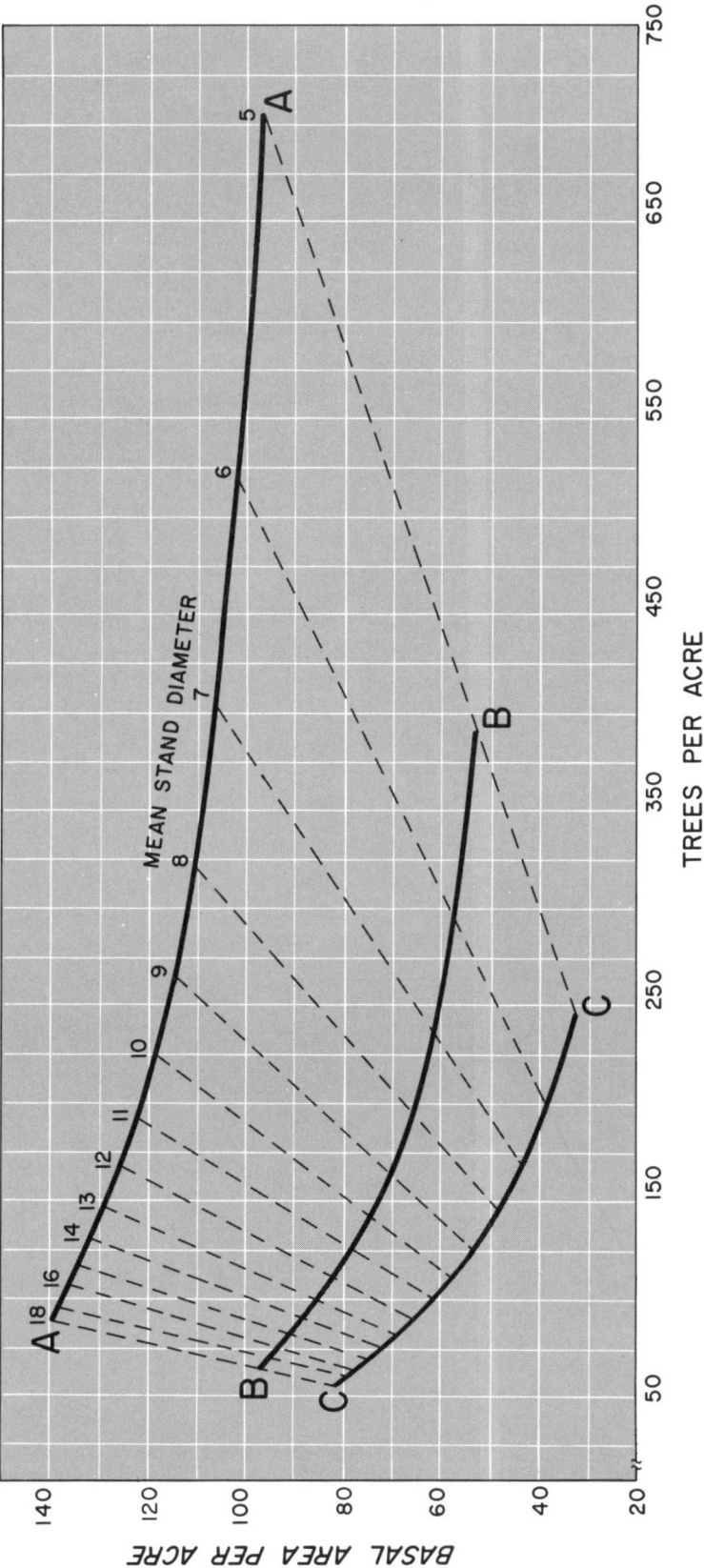


Figure 5.—Stocking guide for even-aged northern hardwood stands, showing basal area per acre, numbers of trees per acre, and mean d.b.h. for trees in the main crown canopy.



Vigor Class III.—Trees with a medium-size crown, usually in an intermediate position, with very little crown exposed to sunlight.

Vigor Class IV.—An overtopped and suppressed tree and any trees that do not meet the above class requirements.

Average annual diameter growth rates for yellow birch trees in these four vigor classes are given below, together with the standard deviation:

<i>Vigor Class</i>	<i>Average annual d.b.h. growth (inches)</i>	<i>Standard deviation (inches)</i>
I	0.087	0.018
II	0.075	0.011
III	0.068	0.010
IV	0.061	0.013

Trees in vigor class I grow on the average less than 1 inch in 10 years. Vigor I trees at two standard deviations above the mean have

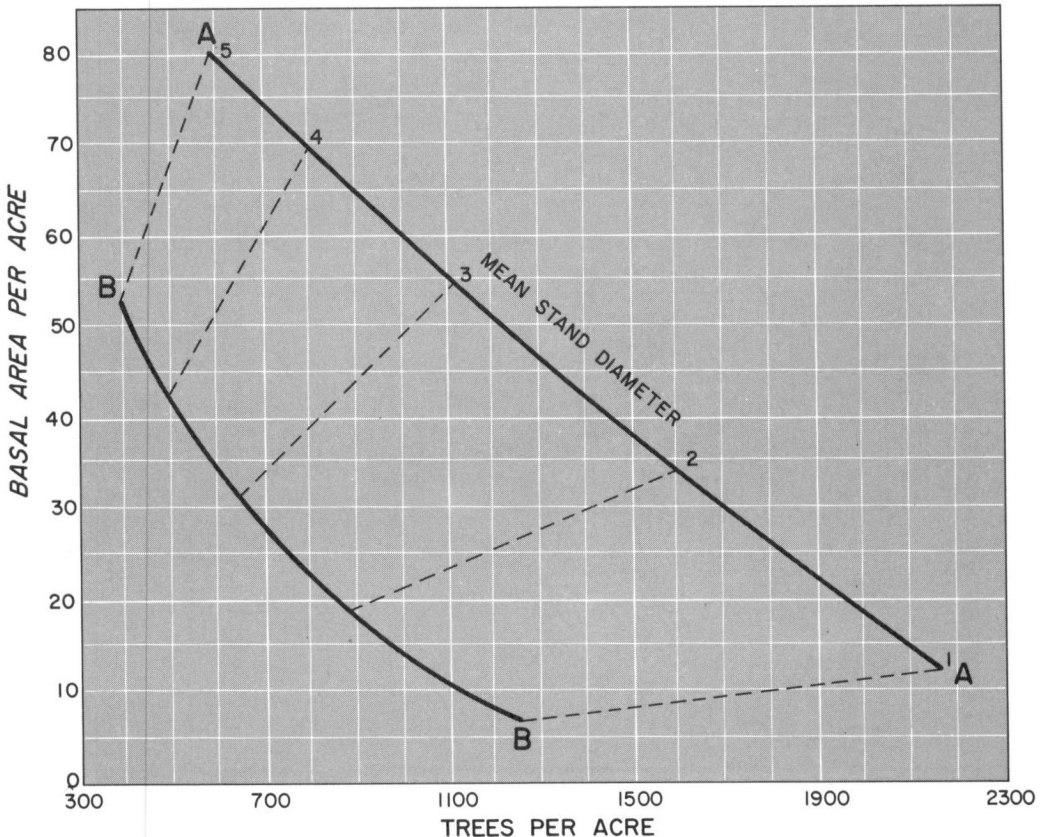
an estimated growth of only about 1.2 inches in 10 years.²

Even-aged.—Diameter growth rates of yellow and paper birch in even-aged stands vary considerably depending upon stand treatment, age, and site.

In unthinned northern hardwoods 25 years old on about site index 65 for sugar maple, diameter growth rate of yellow birch crop trees was found to be about 0.9 inch d.b.h. in 10 years, somewhat faster than that of beech and sugar maple, but slower than that of paper birch, white ash, and red maple. Under the same conditions, paper birch grew at 1.4 inches in 10 years, slightly less rapidly than white ash (table 1).

² Solomon, Dale S., and Stanley M. Filip. The prediction of diameter growth of yellow birch and log grades. 1968. Report on file at the Northeastern Forest Experiment Station, Durham, N.H.

Figure 6.—Stocking guide for even-aged sapling stands of paper birch.



After moderate thinning, which removed 25 to 30 percent of the basal area, d.b.h. growth of yellow birch increased only slightly to 1.0 or 1.1 inches in 10 years—slower than any other species except beech. Paper birch growth rate was 1.7 inches in 10 years, a little less than that of white ash and about the same as that of red maple. However, a heavy thinning, which removed about 40 percent of the basal area, increased yellow birch growth rates to 1.6 inches in 10 years, about 78 percent better than the unthinned rate. Paper birch growth rates were only slightly greater under heavy thinning as compared to moderate thinning.³

Thus, in young stands, yellow birch growth response is very appreciable after heavy thinning. Paper birch response is fair under both moderate and heavy thinning.

In a 65-year-old stand on a good site, paper and yellow birch growth rates after a moderate thinning of 20 to 30 percent were about 1 inch in 10 years, less than that of any other species (*Wilson 1953*). After a second thinning in this stand (which removed the

paper birch), the growth rate of yellow birch dropped to about 0.75 inch in 10 years. Apparently, after age 65, the ability of both paper and yellow birch to respond to thinning is less than at an earlier age.

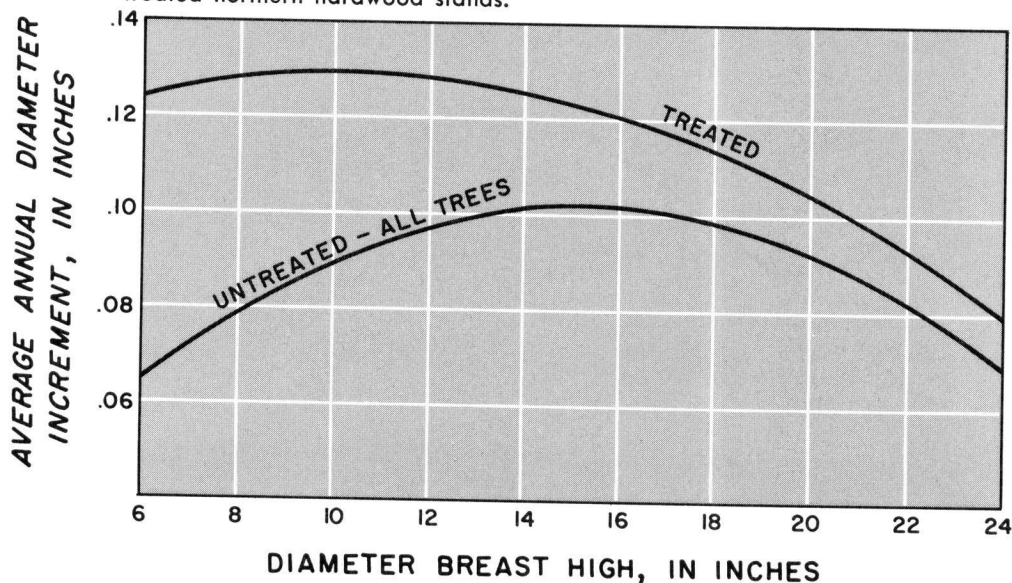
Basal-Area Growth

Uneven-aged.—Gross basal area growth of uneven-aged stands tends to follow a parabolic curve, reaching a maximum of about 3 square feet (on a good site) at a moderate average density of 80 to 100 square feet (fig. 3). On less productive sites, gross basal area growth may be 2.0 to 2.5 square feet per acre per year. In uncut uneven-aged stands, mortality may be 70 percent or more of the gross growth (*Gilbert et al. 1955, Filip et al. 1960*). In managed stands, mortality can usually be reduced to 35 percent or less of the gross growth. Thus observed production (net growth) rates commonly are 1.5 to 2.0 square feet per acre per year in northern hardwood stands of New England during the early stages of management. Similar growth rates apparently prevail in northern hardwoods of the Lake States (*Church 1960, Eyre and Zillgitt 1953*).

In typical northern hardwoods, the basal-area growth attributable to yellow birch is somewhat less than proportional, because this species grows somewhat more slowly than the

³ Marquis, David A. Progress report: Response of a 25-year-old northern hardwood stand to early thinning. 84 pp. 1967. Report on file at Northeastern Forest Experiment Station, Durham, N.H.

Figure 7.—Average annual diameter increment in treated and untreated northern hardwood stands.



average. However, in mixed softwood stands, growth rates of yellow birch often are equal to or better than its common associates (*Leak 1961a*).

Under uneven-aged management, a fairly large proportion of the total stand growth is placed upon trees in the sawtimber classes (11.0 inches d.b.h. and over). After several types of cutting in northern hardwoods, the following distribution of growth was observed (*Blum and Filip 1963*):

Type of cutting	Residual basal area (square feet)	Proportion of growth in sawtimber trees (percent)
Light selection	95	86
Moderate selection	83	69
Diameter-limit	64	58

Even-aged.—Basal area growth in a typical mixed even-aged hardwood stand varies greatly with stand age. After thinning in young stands 25 years old, net basal-area growth rates up to 4 to 5 square feet per acre have been observed. Gross basal-area growth in these young stands may reach as high as 6 or 8 square feet.³

In older stands, gross basal-area growth usually falls within the range of 2.5 to 3.5 square feet. Net basal-area growth, or production, in unmanaged even-aged stands 50 to 70 years old was found to vary from 1.2 to 2.3 square feet, in inverse proportion to the density of stocking (*Leak 1961b*). In thinned stands about 60 to 80 years old, net basal-area growth on good sites may attain about 2.5 square feet per acre (*Wilson 1953*).

Height Growth

Height-growth patterns vary somewhat among the species commonly found in northern hardwood stands. In young stands about 25 years old, paper birch and white ash usually are the tallest of the commercial species (excluding aspen); yellow birch commonly is intermediate in height, a little taller than the average crop tree of sugar maple and beech.

In older stands, perhaps the most meaningful comparisons are in terms of site index, height of dominants and codominants at breast-height age 50. On a given area, paper birch site index consistently is 4 to 6 feet higher than those of sugar maple and yellow birch. These latter two species show similar site indexes over a range in site quality. On poor sites, white ash site index is about the same as those of the other species; however, on better sites, white ash site index may exceed those of the other species by 10 feet or more (fig. 2).

YIELD

Yield of a stand or a forest is expressed in terms of volumes or products that can be harvested. Yield figures are given separately for uneven-aged and even-aged stands.

Uneven-Aged

Based on a gross annual growth rate of 2.75 square feet per acre for a stand with 80 to 90 square feet average basal area per acre, and 25 percent loss to mortality, estimated yield of a well-balanced stand on an annual

Table 1.—Annual d.b.h. growth rates for crop trees in a 25-year-old northern hardwood stand (initial age) under thinning of various intensities

Species	Degree of thinning		
	None	Moderate (25-30%)	Heavy (40%)
	Inches	Inches	Inches
Paper birch	0.14	0.17	0.18
Yellow birch	.09	.10-.11	.16
White ash	.16	.18-.21	.22
Sugar maple	.06	.11-.13	.14
Red maple	.12	.16-.18	.20
Beech	.07	.09	.15
All	0.11	0.15	0.18

basis is about 200 board feet of sawlogs and veneer plus 15 cubic feet of pulpwood per acre. This total yield is equivalent to at least 1/2 cord per acre annually. Sustained yield potentials in managed uneven-aged stands in the Lake States are similar (*Eyre and Zillgitt 1953*). The expected yield of yellow birch would, of course, be proportional to the amount of yellow birch in the stand.

Logging economics dictates a desirable cut per acre of 6 to 10 cords; thus the appropriate cutting cycle would be 12 to 20 years.

Clearcutting of uneven-aged stands, in preparation for some form of even-aged management, produces both heavy volume yields and a variety of products (*Filip 1967*). The following products and volumes were obtained from clearcutting a 50-acre area on the Bartlett Experimental Forest (*Filip and Williams 1968*).

Product	Board feet per acre (or equivalent)
Veneer logs (birch)	221
Handle stock (ash)	147
Bobbin stock (sugar maple)	1,987
Core logs (hardwood)	1,628
Pallet logs (hardwood, softwood)	924
Softwood logs	608
Millwood (birch)	448
Pulpwood (hardwood, softwood)	6,040
	12,003

Even-Aged

Gross yields in board feet or cubic feet from well-stocked even-aged paper birch and northern hardwood stands are given in tables 2 and 3. The cubic-foot yields are for trees 4.5 inches plus; the board-foot yields are for trees 10.5 inches plus. Yields are for average site conditions (site index 70 for paper birch, and 60 for northern hardwoods). For a different site, multiply the yields in tables 2 and 3 by S.I./70 or S.I./60 for paper birch and northern hardwoods, respectively. Yields for paper birch or yellow birch alone would be in proportion to species composition.

Years to reach various mean stand diameters are given for a range of site index under both managed and unmanaged conditions. The yearly figures for managed stands are considered attainable under currently feasible schedules of intermediate cutting.

Paper birch stands should be grown to a mean d.b.h. of 8 to 9 inches where boltwood is the objective, or to larger size if veneer or sawlogs are desired. Thus, the rotation age on site 60 would be 75 years or more without management and 60 years or more under management.

Northern hardwoods should be grown to a mean stand diameter of at least 13 to 14 inches d.b.h. This is equivalent to a rotation age (site index 60) of 120 or 160 years with or without management, respectively.

Table 2.—Merchantable volume yields per acre for stands of various mean diameter, and years to reach various mean diameters by site index (breast height age 50), for pure paper birch stands under scheduled thinnings or no thinnings

Mean ¹ diameter	Merch. ² volume per acre	Site index					
		50		60		70	
		Unthinned	Thinned	Unthinned	Thinned	Unthinned	Thinned
Inches	Cubic feet	Years	Years	Years	Years	Years	Years
5	900	43	34	35	28	27	22
6	1,390	53	42	43	34	33	26
7	1,870	65	52	53	42	38	30
8	2,560	79	63	62	50	47	38
9	3,170	95	76	75	60	58	46
10	3,830	—	89	90	72	70	56
11	4,240	—	—	—	86	85	67

¹ Trees 0.6 inches +.

² Merchantable volumes for site index 70. Volumes for site indexes other than 70 can be computed by multiplying the above yield by S.I./70. Volumes are to a 3- to 5-inch top d.i.b.

Under management, intermediate yields of northern hardwoods will be about equal to the yields shown in table 3. In other words, intermediate cuts will about double the yields. Although comparable estimates are not available for paper birch stands, evidence to date indicates that intermediate cuts will substantially increase the yields from paper birch stands as well.

SUMMARY

Available growth and yield information for yellow birch and paper birch growing as even-aged and uneven-aged northern hardwoods have been summarized, and guides for managing stands for their maximum potential have been presented.

Site estimation for both species in even-aged stands is facilitated by the availability of site-index curves, and a set of comparative site-index relationships.

Stocking guidelines for uneven-aged stands containing yellow birch, based on the relationship between gross basal-area growth and residual stocking, indicate that 70 to 80 square feet per acre (trees 5.0 inches plus) is a reasonable residual basal area after cutting.

Detailed stocking charts are presented for even-aged stands of pure paper birch and mixed northern hardwoods, showing basal areas, numbers of trees, and mean stand diameters that represent overstocked, adequately stocked, and understocked conditions.

Selection cutting in uneven-aged stands has been found to approximately double the

average d.b.h. growth of the smaller stems, while the growth of larger stems increased by about 20 to 25 percent. Yellow birch in such stands, although responding well to cutting, grows considerably slower than other northern hardwood species. Individual tree characteristics, such as vigor, have an important influence upon diameter growth rates of yellow birch in uneven-aged stands.

After heavy thinning in 25-year-old even-aged northern hardwoods, diameter growth rates of paper birch and yellow birch increased by nearly 30 percent and over 75 percent, respectively. In older stands, past age 65, the response of both birches to thinning is considerably less.

Gross basal-area growth rates in uneven-aged stands reach a maximum of about 3 square feet per acre per year on good sites. In managed stands, mortality can be reduced to less than 35 percent, resulting in a net basal-area growth rate of about 2.0 square feet. Under selection cutting, from 70 to 85 percent of the net basal-area growth is in sawtimber-size trees.

In even-aged stands, gross basal-area growth rates vary from as high as 6 to 8 square feet in young stands about 25 years old, down to between 2.5 and 3.5 square feet in pole and sawtimber stands. Net basal-area growth in even-aged stands varies in inverse proportion to the density of stocking.

Yields from an average well-balanced uneven-aged stand are estimated at about 200

Table 3.—Final yields per acre for a given mean stand diameter, and years to reach a given mean diameter, by site index for mixed northern hardwood stands under scheduled thinnings or no thinnings

Mean ¹ d.b.h.	Volume/acre ²		Basal area	Site index					
				50		60		70	
				Unthinned	Thinned	Unthinned	Thinned	Unthinned	Thinned
Inches	Bd. ft.	Cu. ft.	Sq. ft.	Years	Years	Years	Years	Years	Years
5.0	—	1,900	95	59	44	50	38	44	33
6.0	—	2,142	102	74	56	61	46	52	39
7.0	3,782	2,332	106	89	67	74	56	60	45
8.0	5,456	2,530	110	103	77	88	66	71	53
9.0	7,182	2,736	114	124	93	102	77	82	62
10.0	9,088	2,950	118	149	112	118	89	94	71
11.0	11,050	3,146	121	179	134	132	99	106	80
12.0	13,200	3,375	125	—	—	147	110	117	88
13.0	15,544	3,612	129	—	—	163	122	129	97
14.0	16,048	3,799	131	—	—	182	137	142	107
15.0	16,698	4,020	134	—	—	—	—	157	118

¹ Trees in the main canopy.
² Merchantable volumes for site index 60. Volumes for site indexes other than 60 can be computed by multiplying the above yield by S.I./60. Board-foot or cubic-foot volumes are to an 8-inch or 4-inch top d.i.b., respectively.

board feet of sawlogs per acre per year plus 15 cubic feet of pulpwood—equivalent to a total of at least one-half cord. Since current logging economics dictate a cut per acre of 6 to 10 cords, the appropriate cutting cycle is 12 to 20 years.

Harvest yields are presented in tabular form for even-aged mixed northern hardwoods and paper birch stands over a range in site quality. Preliminary estimates indicate that intermediate cuttings will as much as double the final yield from even-aged stands.

LITERATURE CITED

- Arbogast, Carl, Jr.
1957. MARKING GUIDES FOR NORTHERN HARDWOODS UNDER THE SELECTION SYSTEM. USDA Forest Serv. Lake States Forest Exp. Sta. Sta. Paper No. 56, 20 pp. St. Paul, Minn.
- Blum, Barton M., and Stanley M. Filip.
1963. A DEMONSTRATION OF FOUR INTENSITIES OF MANAGEMENT IN NORTHERN HARDWOODS. USDA Forest Serv. Res. Paper NE-4, 16 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Church, Thomas W.
1960. INITIAL EFFECT OF RESIDUAL STOCKING LEVELS ON BASAL AREA PRODUCTION IN NORTHERN HARDWOOD STANDS. USDA Forest Serv. Lake States Forest Exp. Sta. Tech Note 581, 2 pp. St. Paul, Minn.
- Curtis, Robert O., and Boyd W. Post.
1962a. COMPARATIVE SITE INDICES FOR NORTHERN HARDWOODS IN THE GREEN MOUNTAINS OF VERMONT. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 171, 6 pp. Upper Darby, Pa.
- Curtis, Robert O., and Boyd W. Post.
1962b. SITE INDEX CURVES FOR EVEN-AGED NORTHERN HARDWOODS IN THE GREEN MOUNTAINS OF VERMONT. Vt. Agr. Exp. Sta. Bull. 629, 11 pp.
- Eyre, F. H., and W. M. Zillgitt.
1953. PARTIAL CUTTINGS IN NORTHERN HARDWOODS OF THE LAKE STATES. U.S. Dep. Agr. Tech. Bull. 1076, 124 pp.
- Filip, Stanley M.
1967. HARVESTING COSTS AND RETURNS UNDER 4 CUTTING METHODS IN MATURE BEECH-BIRCH-MAPLE STANDS IN NEW ENGLAND. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper NE-87, 14 pp. Upper Darby, Pa.
- Filip, Stanley M., David A. Marquis, and William B. Leak.
1960. DEVELOPMENT OF OLD-GROWTH NORTHERN HARDWOODS ON BARTLETT EXPERIMENTAL FOREST—A 22-YEAR RECORD. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper No. 135, 7 pp. Upper Darby, Pa.
- Filip, Stanley M., and Frank W. Williams.
1968. VOLUME AND VALUE OF PRODUCTS HARVESTED FROM A NORTHERN HARDWOOD CLEAR CUTTING. N. Logger 17: 22-23.
- Gilbert, Adrian M., and Victor S. Jensen.
1958. A MANAGEMENT GUIDE FOR NORTHERN HARDWOODS IN NEW ENGLAND. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper No. 112, 22 pp. Upper Darby, Pa.
- Gilbert, Adrian M., Robert W. Wilson, Jr., and Russell J. Hutnik.
1955. GROWTH BEHAVIOR OF NORTHERN HARDWOODS AFTER A PARTIAL CUTTING. J. Forestry 53: 488-492.
- Leak, William B.
1961a. YELLOW BIRCH GROWS BETTER IN MIXED-WOOD STANDS THAN IN NORTHERN HARDWOOD OLD-GROWTH STANDS. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 122, 4 pp. Upper Darby, Pa.
- Leak, William B.
1961b. DEVELOPMENT OF SECOND-GROWTH NORTHERN HARDWOODS ON BARTLETT EXPERIMENTAL FOREST—A 25-YEAR RECORD. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 155, 8 pp. Upper Darby, Pa.
- Leak, William B.
1969. STOCKING OF NORTHERN HARDWOODS BASED ON EXPONENTIAL DROPOUT RATE. Forestry Chron. (accepted for publication).
- Leak, William B., Dale S. Solomon, and Stanley M. Filip.
1969. SILVICULTURAL GUIDE FOR NORTHERN HARDWOODS IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-143. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-130, 47 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Solomon, Dale S.
1968. APPLYING SITE-INDEX CURVES TO NORTHERN HARDWOODS IN NEW HAMPSHIRE. USDA Forest Serv. Res. Note NE-79, 5 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Wilson, Robert W.
1953. HOW SECOND-GROWTH NORTHERN HARDWOODS DEVELOP AFTER THINNING. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 62, 12 pp. Upper Darby, Pa.

THINNING AND PRUNING IN YOUNG BIRCH STANDS

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YELLOW BIRCH and paper birch are similar in that both are light-demanding throughout most of their life and require freedom from competition to produce high-value products. However, the two species differ markedly in other silvical characteristics. Yellow birch seldom constitutes a large proportion of the stand: it grows slowly and is long-lived. In contrast, paper birch sometimes makes up a high proportion of the stand: it has rapid early growth, and tends to be short-lived (Cooley 1962, Fowells 1965). Both birches are responsive to intermediate cuttings and other cultural practices that can increase their yield and value and shorten rotations. Although data for yellow and paper birch are somewhat limited, enough is known to indicate that their response to treatment is comparable to that of other hardwood species.

RELEASE CUTTING

Cleaning and Weeding

Many cutting practices are favorable for germination and establishment of yellow and paper birch. Unfortunately, sprouts and fast-growing undesirable species tend to overtop and crowd out the more valuable birches (Eyre and Zillgitt 1953, Hatcher 1966, Jarvis 1956, Jensen 1943, Leak 1961a, Marquis 1967, Wang 1968, Zillgitt and Eyre 1945, Zeedyk and Hough 1958). Early release thus becomes necessary if birches are to be an important part of the stand at maturity.

Early release is particularly important for yellow birch, because it often makes up only a small percentage of the reproduction, and its slower height growth causes it to lose dominance at an early stage of development. Paper birch has a greater tendency to retain dominance (Gilbert 1965, Leak 1961b, Mar-

quis 1965 and 1967), but it is frequently overtopped by sprouts and low-value species.

Methods of Release

Release work should be started as soon as the desirable trees show a decline in growth rate, or when other trees begin to overtop them. This occurs for most hardwood species between 10 and 20 years of age (Downs 1942, Gilbert and Jensen 1958, Stoeckeler and Arbogast 1947). The primary objectives in release work are to provide adequate growing space for the potential crop trees and at the same time to keep the investment in time and money as low as possible. Most studies have shown that crop-tree selection will most readily meet these objectives (Downs 1946, Church 1955, Jemison and Hepting 1949, Jensen 1943, and Stoeckeler and Arbogast 1947).

Careful selection of potential crop trees is necessary to assure that they will remain in a favorable crown position and develop good form. Such trees can usually be identified by their crown position, bole condition, and stem origin. Present crown position is the most important criterion. Dominant or codominant trees generally develop and maintain good growth and vigor after release, but intermediate trees are susceptible to stem breakage and mortality and often do not develop into high-quality stems (Downs 1946, Church 1955, Conover and Ralston 1959, Drinkwater 1960, Stoeckeler and Arbogast 1947).

Intensity of Release

Because the degree of release will influence both the growth rate and future quality of the stem, it is often necessary to compromise to achieve the best development in both growth and quality. Initial treatments can often be heavier in smaller and younger stands

than in larger and older stands. Current guidelines for the intensity of release are usually based on the amount of growing space to leave between competing trees rather than on a basal area or number of stems per acre.

The crown-space requirements for yellow and paper birch tend to be similar to those for sugar maple.¹ In a study of release treatments in an 11-year-old stand in the Lake States, a spacing of approximately 4 feet between stems, or about one-fifth the total tree height, was recommended for all hardwood species (*Stoeckeler and Arbogast 1947*). In a 25-year-old stand in Nova Scotia that contained a limited amount of yellow birch, removing competing stems to leave a space of 5 to 6 feet between crowns gave the best results (*Drinkwater 1960*). Similar crown spacing in stands of comparable age appeared to give the best results in the Northeast (*Church 1955, Downs 1946, Gilbert and Jensen 1958*).

Time Requirements

The time required for releasing crop trees tends to be high, but will vary with the method and intensity of release. In a study in the Northeast in which a combination of herbicides and cutting tools were used, approximately 12 man-hours were required to release 100 trees per acre in a predominantly yellow and paper birch stand. The time required per acre could be estimated by the formula: man-hours per acre = $4.06 + 0.088$ times the number of crop trees released (*Blum and Filip 1962*). In a mixed hardwood stand in the Lake States, the time required to release 180 trees per acre, using cutting tools, was 10.0 man-hours per acre if the trees were released to a radius of 2.5 feet between stems; to release the same number to a radius of 5 feet between stems required 25 man-hours (*Stoeckeler and Arbogast 1947*).

New tools, particularly herbicides and their applicators, hold promise for reducing the time required; and they have the added advantage of reducing or eliminating sprout growth that often follows cutting of the stems (*Smith 1962*). Because of the relatively high cost of release, crop trees should be picked carefully, and time should be spent

in removing only those trees that are retarding growth of crop trees.

Growth Response

The growth response that can be expected after treatment varies with the amount of release and the condition of the tree at the time of release. The heavier the release, the greater the diameter growth. Diameter growth rate of trees in a Pennsylvania stand that contained yellow birch increased markedly after moderately heavy weeding, but very little after light weeding (*Church 1955*). Paper and yellow birch crop trees grew faster after heavy thinning than after light thinning in a New Hampshire study (*Marquis 1969*).

Crown class or size of tree also affects diameter growth. In general, the larger and more dominant trees show the largest absolute growth increase after thinning, although the percentage increase may be greater for smaller trees (*Marquis 1969*). Suppressed or low-vigor trees often respond poorly to release (*Downs 1946*).

The effect of release on height growth has not been studied as intensively as the effect on diameter growth; but height growth is known to be influenced by the amount of overhead shade (*Jacobs 1965, Logan 1965*). Some studies have indicated that heavy release may cause a temporary reduction in annual height growth (*Ostrom and Hough 1944, Stoeckeler and Arbogast 1947*), but others have found little effect (*Downs 1946, Drinkwater 1960*).

Although both height and diameter growth rate of birches may be affected by release, the impact on volume yield has not been fully determined for birch stands. Detailed studies of associated species clearly show that volume growth can be effectively shifted to crop trees. However, these studies suggest that follow-up treatments are usually necessary to maintain the early increase in volume growth (*Conover and Ralston 1959*).

Tree Quality

The management objective for yellow and paper birch is to develop trees that will yield high-value products. The effect of release on stem quality has generally been considered negligible after short-term appraisals (*Drinkwater 1960, Ostrom and Hough 1944, Stoeckeler and Arbogast 1947*). However, heavy release treatments have been reported to ad-

¹ Unpublished data, U.S.D.A. Forest Serv. North Central Forest Exp. Sta., St. Paul, Minn.

versely affect the grade and value of trees as they approach commercial size, and the time period after the initial release has been extended. Sixteen years after a heavy release in a Wisconsin hardwood stand, clear bole length was 4 feet shorter on released trees than on the unreleased trees (*Conover and Ralston 1959*).

The merchantable length of birches and other species with indeterminate growth characteristics is often reduced because of the increased forking that is associated with low stand density. Such trees are undesirable in forest stands (*Clausen and Godman 1967, Conover and Ralston 1959*). Although competition between the crowns tends to correct forks, those in the upper stem persist for long periods and often cause an appreciable loss in merchantable volume. Forks at this position are also susceptible to splitting and complete crown loss, particularly when the crowns are opened up by later thinnings. Adequate densities must be maintained to stimulate early recovery from forking.

The thin bark of birches makes them highly susceptible to winter sunscald. Although this type of injury seldom results in mortality, it often causes volume and grade loss in potentially high-value trees (*Blum and Filip 1963*). Because sunscald is common in young trees with thin bark, the south and southwest sides of the stem must be protected in releasing birch (*Blum 1963, Godman 1959, Lake States Forest Experiment Station 1940*).

Liberation Cutting

Shade cast by holdover trees usually benefits yellow and paper birch seedlings during their establishment. However, retention of this shade, usually from cull or low-quality trees, will reduce seedling height growth and development. This shading effect usually extends about 1 foot from the stem of the overstory tree for each inch of its diameter (*Stoeckeler and Arbogast 1947*). Removal of the overstory—termed liberation cutting—is often necessary to ensure that yellow and paper birch will be components of the final stand.

Complete removal of the overstory after the regeneration is about 2 feet tall results in better growth and stand development than partial removal of the overstory (*Eyre and Zillgitt 1953, Hatcher 1966, Jensen and Wil-*

son 1951, Lake States Forest Experiment Station, 1940). Cutting the overstory before the seedlings reach this height may result in heavy seedling mortality because of the sudden exposure. Established yellow and paper birches in a Canadian study showed a 6.4-percent growth response after complete release, compared to only 1.8 percent for untreated trees (*Maclean 1949*).

Low-value overstory trees can be removed economically by girdling the stem or applying chemicals (*Smith 1962*). Both methods have the advantage of gradually reducing the shade cover, thus allowing the seedlings to adjust to increasing light intensity and reducing the chance of stem breakage (*Arbogast 1950, Eyre and Zillgitt 1953, Stoeckeler and Arbogast 1947*). However, stem breakage in seedlings is usually not serious because the stem deformities become corrected before the trees reach sapling size (*Switzenberg et al. 1955*).

Summary of Release Cutting

Release treatments thus appear to be necessary where the slow-growing yellow birch is an important stand component and where paper birch is either overtopped by more tolerant species or is growing in dense stands. It is generally agreed that moderate release treatments started early and repeated as often as necessary will stimulate and concentrate growth on the most desirable trees. Careful selection of individual trees on the basis of crown class and vigor can be expected to give the greatest success.

Because birch trees are sensitive to sudden exposure, moderate release—leaving trees on the south and southwest sides for protection—should minimize injury to the stem. Although few studies have been carried long enough to fully evaluate the economic benefits of release in terms of volume and grade, there is little doubt that release will be economically justifiable in managing birch stands to produce high-value products with short rotations (*Webster 1960*).

THINNING

Thinning pole-size birch stands is a complex practice because each cutting involves composition control, quality selection, and differential release. The best results are usually obtained by making a crown or crop-tree thinning around selected trees that have good

growth and quality potential. Because paper birch has a relatively short life span, stands where it is a major component should be thinned fairly early. Most paper birch trees are pathologically mature by age 80 on the better sites, and will seldom respond to thinnings after age 60 (*Gilbert and Jensen 1958*). Yellow birch also benefits from early thinning, but the treatments can be carried out over a longer period because of its longer life span and ability to respond to release at advanced ages.

Thinning of young hardwood stands implies that the composition and growth of the stand will be improved by providing more crown space for desirable species (which are often the least aggressive), and that the quality of the individual tree will be improved by increasing the volume and clearwood production. To achieve these objectives, early thinnings are recommended (*Webster 1960*). Normally, thinnings should be started before the live-crown ratio drops to 40 percent of the total height (*Gilbert and Jensen 1958*), and should be repeated at 10- to 15-year intervals to maintain desirable growing conditions.

The diameter-growth response of yellow and paper birch tends to be strongly related to the amount of release and to the size of the tree at the time of thinning. Larger trees grow faster after thinning than smaller trees, at least up to 16 inches in diameter; and the growth rate of trees in each diameter class increases as the intensity of the cut is increased (*Jensen 1943*).

In a more recent study in the Northeast, similar increases in diameter growth of yellow and paper birch were obtained during the first 5 years after thinning in a 25-year-old mixed-species stand (table 1).² The heavy thinnings resulted in a growth increase of 78 percent for yellow birch and 29 percent for paper birch. Perhaps more important than growth rate, the heavy early thinning resulted in a five-fold increase in the number of dominant crop trees and a two-fold increase in codominant crop trees compared to the control

treatment (*Marquis 1969*). Early thinnings that maintain crown position in the stand and stimulate diameter growth can be expected to appreciably increase the volume of less tolerant species in the final crop.

Short-term studies of quality change after thinning generally show little adverse effect on potential grade and value of the stem. However, maintaining heavy cuttings for extended periods tends to reduce potential quality of pole-size yellow birch (table 2).¹ Although the stem-quality trends for yellow birch shown in table 2 are based on a limited number of potential crop trees, they are substantiated by similar results from much larger samples of other hardwood species. Of the hardwoods studied, yellow birch was intermediate in frequency of all grade defects. Less tolerant species, such as basswood and white ash, had fewer defects, while sugar maple, the most tolerant species in the study, had the most defects.

The number of live limbs generally increased as residual stand density decreased, particularly in the second log. And live limbs present in the butt log tended to persist after heavy cuttings. These changes in live branches are a reflection of the deeper and larger crowns that develop in heavily thinned stands. Such crowns permit rapid diameter growth, but quality and net value may suffer because live branches persist and reduce the clear length of bole. Thus heavy thinnings should

Table 1.—Average annual diameter growth of yellow birch crop trees for 5-year period after thinning

Treatment	Diameter growth per year	
	Yellow birch	Paper birch
	<i>Inches</i>	<i>Inches</i>
Control	0.09	0.14
Crude thinning ¹	.10	.17
Light crop-tree thinning ²	.11	.17
Heavy crop-tree thinning ³	.16	.18

¹ All aspen, pin cherry, and striped maple in main canopy cut, and all red maple sprout clumps thinned.

² One of the trees competing with each crop tree removed.

³ All trees competing directly with crop trees removed.

² Unpublished report: RESPONSE OF A 25-YEAR-OLD NORTHERN HARDWOOD STAND TO EARLY THINNING. David A. Marquis, USDA Forest Serv. NE. Forest Exp. Sta., Upper Darby, Pa.

probably be avoided until the potential crop trees are pruned to the desired height. After these lower limbs die, the rate of quality improvement can be stimulated by thinning to lower densities.

Although epicormic branches are less of a problem in the birches than in many other species, they are still an important factor in quality development. Epicormic sprouting was most abundant in the untreated stand, probably due to intense competition between crowns of the crowded trees. However, factors other than stand density appear to affect the incidence of epicormic sprouting, especially the condition of the crown and its development after thinning. More study is needed on the tree and stand conditions that favor epicormic sprouting, but present indications are that proper tree selection and early thinning will help to minimize this problem.

Although natural pruning and subsequent healing of the wounds are the primary determinants of stem quality, other factors

should also be considered in determining the most desirable residual stocking for yellow birch (table 3).

Forks are a problem in even-aged stands and intolerant species, regardless of stand density. However, heavy thinnings tend to increase the proportion of trees with forks and the incidence of forks higher on the stem. There appears to be little chance of eliminating forks in stands managed at lower densities because of the lack of competition between crowns. As a result, merchantable length may be reduced and tree loss or growth reduction due to breakage may be increased.

Thinning guides for yellow and paper birch are now available that are applicable to a wide range of stand conditions or different methods of management (*Arbogast 1957, Leak et al. 1969, Marquis et al. 1969*). In even-aged stands common to the Northeast, the minimum recommended stocking varies with stand age and size. For example, recommended minimum stocking for mixed north-

Table 2.—Number of defects in yellow birch 15 years after thinning to different stand densities. Based on 54 trees originally 5 to 8 inches d.b.h.
(In number of defects per tree)

Defect type	Log position	Treatment (and residual basal area per acre)				
		Check	Selection cutting ¹			Crop ²
		93 sq. ft.	90 sq. ft.	75 sq. ft.	60 sq. ft.	60 sq. ft.
Live limbs	First 16'	0.0	0.4	0.0	0.5	0.7
	Second 16'	2.3	3.7	3.8	4.8	6.5
	Total 32'	2.3	4.1	3.8	5.3	7.2
Epicormic branches	First 16'	0.6	0.1	0.3	0.0	0.5
	Second 16'	2.8	0.2	1.3	0.2	1.7
	Total 32'	3.4	0.3	1.6	0.2	2.2
Dead limbs	First 16'	0.3	0.1	0.2	0.4	1.2
	Second 16'	2.6	1.5	0.7	2.0	1.9
	Total 32'	2.9	1.6	0.9	2.4	3.1
Bumps	First 16'	0.7	0.5	0.3	0.9	0.6
	Second 16'	3.2	1.8	1.7	2.9	1.1
	Total 32'	3.9	2.3	2.0	3.8	1.7
All defects	First 16'	1.6	1.1	0.8	1.8	3.0
	Second 16'	10.9	7.2	7.5	9.9	11.2
	Total 32'	12.5	8.3	8.3	11.7	14.2

¹ Treatments recut at end of 10 years to same density.

² Crop trees released individually; not recut; present stand density 105 square feet per acre.

ern hardwoods varies from about 55 square feet of basal area per acre for stands 5 inches average diameter up to 95 square feet of basal area per acre for stands 18 inches average diameter (*Leak et al. 1969, Marquis et al. 1969*). These guides are based on the level of stocking that will produce maximum growth of individual trees without loss of total stand growth — the point of full site occupancy.

We suggest that no more than 40 percent of the basal area be removed at one time. In the pole-size stands typical of the Lake States, where yellow birch is often an important component associated with the more tolerant species, a residual density of 80 to 85 square feet in trees 5 inches and larger is generally recommended and is an acceptable compromise between growth and development of stem quality (*Arbogast 1957, Eyre and Zillgitt 1953*). However, combining pruning with thinning would normally favor management of yellow and paper birch at lower stand densities to further stimulate diameter growth.

PRUNING

Pruning hardwoods is desirable for producing high-quality sawlogs and veneer bolts on short rotations. However, little pruning is done at present. The chief drawbacks appear to be the long-term investment required, and concern over the incidence of decay and stain that may be associated with pruning wounds. In some species the development of epicormic

branches after pruning has negated the removal of existing limbs.

Pruning hardwoods to produce high-grade products usually requires removing only a small number of branches from a few trees per acre (*Skilling 1958, 1959a*). Much of the early work in hardwood pruning involved removing large numbers of limbs on slow-growing trees in dense stands. These environmental conditions favored the entrance of decay fungi. Detailed studies have shown that only the slow-growing trees develop incipient decay (*Zeedyk and Hough 1958*), while the fast-growing trees develop little stain or decay (*Skilling 1958, 1959a, 1959b; Zeedyk and Hough 1958*). Discoloration and decay associated with pruning fast-growing hardwoods seldom extend beyond the annual ring in which the branch was pruned (*Ohman 1968, Skilling 1958*). The amount of unsound wood associated with artificial pruning is nearly always less than the amount associated with natural pruning because of decay pockets, overgrown bark, and unsound stubs common to natural pruning wounds (*Skilling 1958*).

Pruning has often been followed by a marked increase in epicormic sprouting and subsequent branch development on the bole (*Eyre and Zillgitt 1953; Conover and Ralston 1959; Skilling 1958, 1959a, 1959b; Stoeckeler and Arbogast 1947; Zeedyk and Hough 1958*). Though the cause of epicormic sprouting has not been studied intensively, there is evidence that sprouting is related to the vigor

Table 3.—Form and growth characteristics of yellow birch crop trees 15 years after thinning to different stand densities. Trees were originally 5 to 8 inches d.b.h.

Residual basal area per acre and thinning treatment	Stem form		Crown size		Diameter growth		
	Trees with forks	Forks at 37 feet or higher	Trees with clear bole length 25 feet or less	Crown diameter/stem diameter ratio	Ave. 15-year increase	Greatest 15-year increase	Trees growing 2 inches or more per decade
	Percent	Percent	Percent	Ratio	Inches	Inches	Percent
93 sq. ft. (check)	78	43	0	21	1.4	2.0	0
90 sq. ft. (selection) ¹	69	54	25	21	1.7	2.4	0
75 sq. ft. (selection) ¹	83	60	—	26	2.1	3.1	17
60 sq. ft. (selection) ¹	88	50	25	23	2.7	4.0	25
60 sq. ft. (crop-tree) ²	93	50	47	24	2.3	3.2	13

¹ Treatments recut at end of 10 years to same density.

² Crop trees released individually; not recut; present stand density 105 square feet per acre.

of the tree at the time of pruning and to the amount of previous release (*Skilling 1959a*). We feel that pruning should be delayed for a few years after the stand is thinned to allow a buildup in crown vigor, since growth hormones produced in the crown may control the suppression of epicormic sprouting.¹ Few epicormic shoots develop on dominant trees with vigorous crowns (*Cline 1935; Conover and Ralston 1959; Eyre and Zillgitt 1953; Marquis 1967; Stoeckeler and Arbogast 1947; Skilling 1958, 1959a, 1959b*).

The time required for healing of pruning wounds is strongly correlated with the rate of diameter growth, size of the wound, and length of the residual stub. When good pruning techniques are used, healing time depends almost entirely on the rate of diameter growth. There is a rule-of-thumb for estimating the time required to heal most wounds: a layer of wood about as thick as the width of the wound must be grown before clear wood will form over the pruning scar (*Lohrey 1963, Skilling 1959b, Moss 1937, Stoeckeler and Arbogast 1947, Zeedyk and Hough 1958*). Thus, fast-growing trees require fewer years than slow-growing trees to produce clear wood over the same size of wound.

Improved tools and equipment for hardwood pruning have yet to be developed. The best method now is by use of hand saws and ladders. Although this method is slower than using power tools, it is the best way to avoid injury to the stem, and it permits cutting the branch close to the trunk (*Moss 1937, Skilling 1959b*). The time required for pruning varies with both the size and the height of the branch (*Moss 1937*), but the costs will average about 50 cents per tree in typical second-growth stands under present labor rates.¹

Pruning yellow and paper birch could become a widespread cultural practice, particularly where stands are thinned heavily to obtain maximum diameter growth. Trees to be pruned should have a fairly rapid rate of diameter growth and should be capable of maintaining a favorable crown position in the stand. Under these conditions, the early investment will be carried for a shorter period, epicormic shoot development should not be a serious problem, and there should be little or no risk of stain or decay entering the stem. The greatest deterrent to pruning the high-value species at present appears to be the lack of efficient pruning tools.

LITERATURE CITED

- Arbogast, Carl, Jr.
1950. HOW MUCH DOES FELLING LARGE TREES DAMAGE THE UNDERSTORY. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 337, 2 pp. St. Paul, Minn.
- Arbogast, Carl, Jr.
1957. MARKING GUIDES FOR NORTHERN HARDWOODS UNDER THE SELECTION SYSTEM. USDA Forest Serv. Lake States Forest Exp. Sta. Sta. Paper 56, 20 pp. St. Paul, Minn.
- Blum, Barton M.
1963. EXCESSIVE EXPOSURE STIMULATES EPICORMIC BRANCHING IN YOUNG NORTHERN HARDWOODS. USDA Forest Serv. Res. Note NE-9, 6 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Blum, Barton M., and Stanley M. Filip.
1962. A WEEDING IN TEN-YEAR OLD NORTHERN HARDWOODS—METHODS AND TIME REQUIREMENTS. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 135, 7 pp. Upper Darby, Pa.
- Blum, B. M., and Stanley M. Filip.
1963. A DEMONSTRATION OF FOUR INTENSITIES OF MANAGEMENT IN NORTHERN HARDWOODS. USDA Forest Serv. Res. Paper NE-4, 16 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Church, Thomas W., Jr.
1955. WEEDING—AN EFFECTIVE TREATMENT FOR STIMULATING GROWTH OF NORTHERN HARDWOODS. J. Forestry. 53: 717-719.
- Clausen, K. E., and R. M. Godman.
1967. SELECTING SUPERIOR YELLOW BIRCH TREES, A PRELIMINARY GUIDE. USDA Forest Serv. Res. Paper, NC-20, 10 pp. North Cent. Forest Exp. Sta., St. Paul, Minn.
- Cline, A. C.
1935. IMPROVEMENT CUTTING AND THINNING AS APPLIED TO CENTRAL NEW ENGLAND HARDWOODS. Harvard Forest Bull. 155, 16 pp.
- Conover, D. F., and R. A. Ralston.
1959. RESULTS OF CROP-TREE THINNING AND PRUNING IN NORTHERN HARDWOOD STANDS AFTER NINETEEN YEARS. J. Forestry 57: 551-557.
- Cooley, John H.
1962. SITE REQUIREMENTS AND YIELD OF PAPER BIRCH IN NORTHERN WISCONSIN. USDA Forest Serv. Lake States Forest Exp. Sta. Sta. Pap. 105, 11 pp. St. Paul, Minn.

- Downs, Albert A.
1942. EARLY RESPONSES TO WEEDINGS IN SOME EASTERN MOUNTAIN HARDWOODS. *J. Forestry* 40: 865-872.
- Downs, Albert A.
1946. RESPONSE TO RELEASE OF SUGAR MAPLE, WHITE OAK, YELLOW POPLAR. *J. Forestry* 44: 22-27.
- Drinkwater, M. H.
1960. CROWN RELEASE OF YOUNG SUGAR MAPLE. Can. Dep. Forestry. Forest Res. Div. Tech. Note 89, 18 pp.
- Eyre, F. H., and W. M. Zillgitt.
1953. PARTIAL CUTTINGS IN NORTHERN HARDWOODS IN THE LAKE STATES. U.S. Dep. Agr. Tech. Bull. 1076, 124 pp., illus.
- Fowells, H. A.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U.S. Dep. Agr. Handb. 271, 762 pp.
- Gilbert, Adrian M.
1965. STAND DIFFERENTIATION ABILITY IN NORTHERN HARDWOODS. USDA Forest Serv. Res. Paper NE-37, 34 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Gilbert, Adrian M., and Victor S. Jensen.
1958. A MANAGEMENT GUIDE FOR NORTHERN HARDWOODS IN NEW ENGLAND. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Pap. 112, 22 pp. Upper Darby, Pa.
- Godman, R. M.
1959. WINTER SUNSCALD OF YELLOW BIRCH. *J. Forestry* 57: 368-369.
- Hatcher, R. J.
1966. YELLOW BIRCH REGENERATION ON SCARIFIED SEEDBEDS UNDER SMALL CANOPY OPENINGS. *Forestry Chron.* 42(4): 350-358.
- Jacobs, R. D.
1965. SEASONAL HEIGHT GROWTH PATTERNS OF SUGAR MAPLE, YELLOW BIRCH, AND RED MAPLE SEEDLINGS IN UPPER MICHIGAN. USDA Forest Serv. Res. Note LS-57, 4 pp. Lake States Forest Exp. Sta., St. Paul, Minn.
- Jarvis, J. M.
1956. AN ECOLOGICAL APPROACH TO TOLERANT HARDWOOD SILVICULTURE. Can. Dep. N. Affairs and Natur. Resources Tech. Note 43, 43 pp.
- Jemison, G. M., and G. H. Hepting.
1949. TIMBER STAND IMPROVEMENT IN THE SOUTHERN APPALACHIAN REGION. U.S. Dep. Agr. Misc. Pub. 693, 80 pp.
- Jensen, V. S.
1943. SUGGESTIONS FOR THE MANAGEMENT OF NORTHERN HARDWOOD STANDS IN THE NORTHEAST. *J. Forestry* 41: 180-185.
- Jensen, V. S., and R. W. Wilson, Jr.
1951. MOWING OF NORTHERN HARDWOODS NOT PROFITABLE. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 3, 4 pp. Upper Darby, Pa.
- Lake States Forest Experiment Station.
1940. DO YOUNG SECOND-GROWTH NORTHERN HARDWOODS NEED CARE? USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 167, 1 p. St. Paul, Minn.
- Leak, William B.
1961a. YELLOW BIRCH GROWS BETTER IN MIXED-WOOD STANDS THAN IN NORTHERN HARDWOOD OLD-GROWTH STANDS. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 122, 4 pp. Upper Darby, Pa.
- Leak, William B.
1961b. DEVELOPMENT OF SECOND-GROWTH NORTHERN HARDWOODS ON BARTLETT EXPERIMENTAL FOREST—A 25-YEAR RECORD. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Pap. 155, 8 pp. Upper Darby, Pa.
- Leak, William B., Dale S. Solomon, and Stanley M. Filip.
1969. A SILVICULTURAL GUIDE FOR NORTHERN HARDWOODS IN THE NORTHEAST. USDA Forest Serv. Res. Paper (in press). NE. Forest Exp. Sta., Upper Darby, Pa.
- Logan, K. T.
1965. GROWTH OF TREE SEEDLINGS AS AFFECTED BY LIGHT INTENSITY. I. WHITE BIRCH, YELLOW BIRCH, SUGAR MAPLE AND SILVER MAPLE. Can. Dep. Forestry Pub. 1121, 16 pp.
- Lohrey, R. E.
1963. HEALING TIME FOR PRUNING WOUNDS IN A RED PINE PLANTATION. USDA Forest Serv. Res. Note LS-24, 2 pp. Lake States Forest Exp. Sta., St. Paul, Minn.
- Maclean, D. W.
1949. IMPROVEMENT CUTTING IN TOLERANT HARDWOODS. Can. Dominion Forest Serv. Res. Note 95, 19 pp.
- Marquis, David A.
1965. REGENERATION OF BIRCH AND ASSOCIATED HARDWOODS AFTER PATCH CUTTING. USDA Forest Serv. Res. Paper NE-32, 12 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1967. CLEARCUTTING IN NORTHERN HARDWOODS: RESULTS AFTER 30 YEARS. USDA Forest Serv. Res. Paper NE-85, 13 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A.
1969. THINNING IN YOUNG NORTHERN HARDWOODS—5-YEAR RESULTS. USDA Forest Serv. Res. Paper (in press). NE. Forest Exp. Sta., Upper Darby, Pa.
- Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. USDA Forest Serv. Res. Paper NE-130, 47 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Moss, A. E.
1937. PRUNING SECOND-GROWTH HARDWOODS IN CONNECTICUT. *J. Forestry* 35: 823-828.
- Ohman, J. H.
1968. DECAY AND DISCOLORATION OF SUGAR MAPLE. USDA Forest Pest Leaflet 110, 6 pp.
- Ostrom, C. E., and A. F. Hough.
1944. EARLY WEEDING IN NORTHERN HARDWOODS. *J. Forestry* 42: 138-140.
- Skilling, D. D.
1958. WOUND HEALING AND DEFECTS FOLLOWING NORTHERN HARDWOOD PRUNING. *J. Forestry* 56: 19-22.
- Skilling, D. D.
1959a. PRUNING HARDWOODS IMPROVES QUALITY AND SHOWS LITTLE EVIDENCE OF FOSTERING DECAY. *Timberman* (May), 3 pp.
- Skilling, D. D.
1959b. RESPONSE OF YELLOW BIRCH TO ARTIFICIAL PRUNING. *J. Forestry* 57: 429-432.
- Smith, D. M.
1962. THE PRACTICE OF SILVICULTURE. 578 pp. John Wiley and Sons: New York.

- Stoeckeler, J. H., and Carl Arbogast, Jr.
1947. THINNING AND PRUNING OF YOUNG SECOND-GROWTH HARDWOODS IN NORTHEASTERN WISCONSIN. Soc. Amer. Forest. Proc. 1947: 328-346.
- Switzenberg, D. F., T. C. Nelson, and B. C. Jenkins.
1955. EFFECT OF DEER BROWSING ON QUALITY OF HARDWOOD TIMBER IN NORTHERN MICHIGAN. Forest Sci. 1: 61-67.
- Wang, B. S. P.
1968. THE DEVELOPMENT OF YELLOW BIRCH REGENERATION ON SCARIFIED SITES. Can. Dep. Forestry Pub. 1210, 14 pp.
- Webster, H. H.
1960. TIMBER MANAGEMENT OPPORTUNITIES IN PENNSYLVANIA. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 137, 371 pp. Upper Darby, Pa.
- Zeedyk, W. D., and A. F. Hough.
1958. PRUNING ALLEGHENY HARDWOODS. USDA Forest Serv. NE. Forest Exp. Sta. Sta. Paper 102, 14 pp. Upper Darby, Pa.
- Zillgitt, W. M., and F. H. Eyre.
1945. PERPETUATION OF YELLOW BIRCH IN THE LAKE STATES FORESTS. J. Forestry 43: 658-661.



AN ECONOMIC EVALUATION OF PRECOMMERCIAL THINNING IN PREDOMINATELY PAPER BIRCH STANDS

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BEFORE TIMBER MANAGERS invest their time and money in precommercial thinnings in paper birch stands, they should know what thinning options are open to them and should have some idea of the response they might expect from the alternatives. Equipped with a knowledge of these options, the manager can select the monetary and output goals that best suit his own situation in managing paper birch stands.

A study of three precommercial thinning practices by our timber-management research division in a paper birch stand provided the necessary physical data for making an economic evaluation of some thinning alternatives. The objective of this evaluation was to determine the real changes taking place in the stand tables under the applied practices for the first 5 years and to project these stand tables for 10, 15, and 20 years after thinning. These changes were then analyzed to determine: (1) What proportion of the stands met feasible production goals?; (2) What proportion of the stands could be subject to a commercial cutting during a given period?; and (3) What proportion of the stands made selected rates of return on precommercial thinning investment during the period analyzed? Even though the whole stand was analyzed, the main emphasis was on the development of paper birch and yellow birch and their response to the thinning practices applied.

THE STUDY EVALUATED

The study evaluated was a trial of precommercial thinning practices on the Bartlett Experimental Forest in New Hampshire, in a northern hardwood stand. The study, established in 1959, consisted of three thinning

practices of five ¼-acre plots each and five unthinned plots, a total of 20 plots. The plots were randomly arranged on the study area so that no bias would occur when thinning results were analyzed, hence the results would be unbiased for the area and would be representative of what might be expected elsewhere under similar conditions. The plots were remeasured every 5 years.

The stand conditions at the time of thinning and stand history were described by Marquis in 1967.¹ At the time of thinning the stand was 25 years old and contained the average number of stems per acre shown in table 1.

This stand table illustrates the tree distributions concerned with in this evaluation. They are the averages derived from all 20 plots in the experiment. On all the sample plots, tree numbers ranged from 3,900 to 4,200 trees per acre, and their distributions by species and size were similar to those shown in table 1. Individual plots did range above and below these averages, but differences were minor.²

The purpose of thinning these stands was to improve the growth and development of selected crop trees. Crop trees were chosen at

¹ Marquis, David A. CLEARCUTTING IN NORTHERN HARDWOODS: RESULTS AFTER 30 YEARS. USDA Forest Serv. Res. Paper NE-85. 13 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1967.

² After random assignment of plots to treatments, it was found that the heavy thinning plots had fewer paper birch trees in the 5- to 8-inch d.b.h. classes than the other three treatments (61 versus 90 to 104). Since paper birch represents the major part of the yields reported here, this initial difference in stocking has tended to reduce the early yields on the heavy thinning plots more than they would have been had all plots had equal initial stocking. No adjustments have been made for this difference in the data and discussion.

the rate of about 400 trees per acre. Most crop trees were either paper birch, yellow birch, white ash, or sugar maple, although exceptional individuals of other species were also included. Four distinct thinning alternatives were tested.

1. *No thinning.*—These plots were left undisturbed to develop naturally. They constitute a control or standard against which to measure the responses of other groups of plots.
2. *Light thinning.*—Trees competing with individual crop trees were noted and the one offering the greatest competition was removed in this form of precommercial thinning.
3. *Species thinning.*—Aspen, pin cherry, and striped maple were eliminated in this thinning procedure. Red maple sprout clumps were thinned. The relationship of thinned trees to crop trees was not considered.
4. *Heavy thinning.*—All trees competing directly with the crop trees were removed.

In addition to the beginning tally, the quantitative information provided by the experiment included a treatment record of the species and sizes of trees treated, an after-treatment inventory of the stand, a stand table 5 years later, and growth data from selected individual trees, which covered all tree sizes and species.

PROJECTED STAND DEVELOPMENT

Stand tables were projected for each plot to 10 years after thinning or a stand age of 35 years, to 15 years after thinning or a stand age of 40 years, and to 20 years after thinning or a stand age of 45 years. To make these projections, background information about diameter growth and mortality had to be acquired so that reasonable assumptions could be made about the projections.

Characteristic growth patterns were developed for each species for each thinning practice. For example, the diameter growth for paper birch appears in table 2.

Information like that shown in table 2 was used by assuming that a tree would maintain its first 5-year growth rate for the next three 5-year periods. For example, a 6-inch paper birch tree in the heavy thinning plots grew 1.13 inches in the first 5-year period, so we projected it to grow at this rate for the next three 5-year periods.

Basic assumptions for mortality estimates were based on a critical examination of stand-table changes between the after-treatment stand table and the one 5 years later to determine the magnitude of the mortality for each species and in what size classes it occurred. On the basis of this examination we assumed that:

1. Relative mortality would continue on a plot/species basis and would be measured

Table 1.—1958 average number of trees per acre on all thinning plots, by species and diameter class

Diameter class (inches)	Paper birch	Yellow birch	White ash	Sugar maple	Red maple	Beach	Aspen	Conifers	Others ¹	Total trees/acre
1	85	248	32	807	80	759	1	25	205	2,242
2	112	142	26	159	48	213	5	23	287	1,015
3	78	61	18	40	25	41	7	6	179	455
4	61	20	13	8	18	3	8	3	70	204
5	41	2	3	1	3	1	7	1	15	74
6	21	1	1	1	1	—	10	—	2	37
7	7	—	—	—	—	—	4	—	1	12
8	1	—	—	—	—	—	3	—	—	4
9	—	—	—	—	—	—	1	—	—	1
10	—	—	—	—	—	—	1	—	—	1
11	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—
Total	406	474	93	1,016	175	1,017	47	58	759	4,045

¹ Others consisted mainly of pin cherry and striped maple.

by the percentage of trees that died in the first 5 years.

2. Mortality would occur in the smallest size classes first.
3. No mortality would occur after trees had reached 6 inches d.b.h.

It was felt that this deduction for mortality would account for normal attrition of the whole population of stems. Essentially this phase of mortality is handled as a risk. Another kind of mortality—involving insects, disease, fire, and weather as causative agents—we considered to be an uncertainty; so we ignored it.

The stand-table projection was made by using tree-diameter-movement ratios developed from the growth data, using the method described by Davis.³ After the stand was projected, the mortality was subtracted according to the rules stated earlier. Our procedure then was to begin with the stand 5 years after thinning. We projected all the trees for the next 5 years, using the tree-diameter-movement method and then deducted mortality to give us the stand table at the end of the 10-year period. This was repeated for the 15- and 20-year projections. It was done for each species and each plot.

Timber volumes, measured in cords, were estimated by multiplying numbers of trees shown in the stand tables by appropriate volumes. Local volume tables were made by applying height-diameter relationships for the Bartlett Experimental Forest to the standard volume tables of Gevorkiantz and Olsen⁴ for northern hardwoods to a 4-inch top inside bark. Later these were converted to volumes to a 6-inch top for estimating outcomes for higher-grade products.

The final product of our projections was the volume of each plot by species and size classes, in cords, to a 4-inch top and a 6-inch top. With this as basic information we were ready to proceed to economic analyses and evaluations.

These projections must be reasonable if the rest of the evaluation is to be worthwhile. No one knows better than we do how far we have come from those plots on the ground, and how easily the results of assumptions about growth and mortality can pyramid into colossal errors in 20 years of projections. We took steps to be sure our results were reasonable. First we developed our procedure, using the first 5 years as a trial and compared our projections with what actually happened. Then, as we proceeded with the final projections, we tested them against available data for paper birch stands in these ages.

Since the form of the projected yields conforms to that of the independent set of data, and the divergences of yield for each thinning practice when compared to others is logical, the synthesized yields from the projection system are judged satisfactory for our purposes.

ECONOMIC ANALYSIS

An economic analysis should answer economic questions such as achieving production goals at least cost, or assessing flexibility for future actions, or maximizing benefits. In our economic analysis we consider the forest-management-research information as a series of performance tests. We test the performance of the thinning methods with economic measures. We pose economic questions, describe their solution, and present the results.

Achieving Output Goals

All outputs were measured in cords per acre. Four production goals were set; three products were recognized, and we asked first what proportion of the plots for each thinning

Table 2.—The diameter growth in inches of paper birch by diameters and precommercial thinning method for the first 5 years after thinning

D.b.h. (inches)	Thinning method			
	None	Light	Species	Heavy
2	0.11	0.20	0.44	0.53
3	.36	.36	.55	.63
4	.62	.64	.68	.72
5	.82	.88	.85	.94
6	.98	1.06	1.06	1.13

³ Davis, Kenneth P. *AMERICAN FOREST MANAGEMENT*. 482 pp. McGraw-Hill Book Company, Inc., New York, 1954.

⁴ Gevorkiantz, S. R., and L. P. Olsen. *COMPOSITE VOLUME TABLES FOR TIMBER AND THEIR APPLICATION IN THE LAKE STATES*. U.S. Dep. Agr. Tech. Bull. 1104, 51 pp., illus. 1955.

practice met the goals. Goals of 3, 5, 10, and 20 cords per acre were established as being reasonable harvesting limits for different management objectives and harvesting methods.

The results of each thinning plot were tested at each 5-year period to see if they met these goals for: (1) all roundwood to a 4-inch top; (2) paper and yellow birch to a 6-inch top; and (3) paper and yellow birch to a 6-inch top, with at least 20 trees 12 inches d.b.h. and larger.

These specifications represented: (1) reasonable merchantable limits for pulpwood; (2) reasonable limits for low-value boltwood; and (3) reasonable limits for medium-value boltwood with a modest proportion of veneer sizes.

Since there were five plots for each thinning method, each plot represents 20 percent of the population. If all five plots meet our criterion, 100 percent of them achieved the production goal. The results of this procedure are posted in table 3.

Cost information is needed to appraise the least-cost way of attaining these goals. Cost estimates were based on the tally of live trees that were killed on each plot during the thinning operations, but not marking or supervisory costs. The number of diameter inches treated in each case was determined from this tally. Thinning costs were estimated at 1 cent per diameter inch.

Table 4 shows the costs for thinning the plots with these assumptions. This table shows that costs per acre were materially lower for the light thinning method. The heavy and species thinning were 70 to 100 percent higher. Of course the no-thinning or let-it-

grow alternative does not require precommercial thinning investment, so it is least expensive of all.

These cost differences are large enough and the pattern of goal achievement is clear enough that a vigorous least-cost analysis was not needed for our purposes. We see by inspection that no thinning is the least-cost option for producing cordwood to a 4-inch top at all ages. When we consider the higher value products exemplified by the data in the lower section of table 3, a light thinning shows up best because none of the unthinned plots met 5- or 10-cord goals. These views do not change even if we set a probability limit to our inspection such as not considering a goal unless say 60 percent of the plots met the goal.

Tables 3 and 4 provide preliminary information for forest managers to use for their own special cases. A forest manager constrained by acreage limitations, the timing of cuts, and product requirements can use such information in a simulation program or linear program to calculate an optimum precommercial thinning solution for his particular problem. For these purposes the manager can equate the cost of achieving the goals by dividing the average cost by the percentage of plots that met the goals.

Flexibility for Making a Partial Commercial Cutting

Many managers may want to see an early intermediate commercial cutting as the fruit of a precommercial thinning investment. We analyzed the data with this in mind. We asked: "When do we gain the flexibility to

Table 3.—Achieving output goals: percent of plots meeting selected harvest criteria by age and thinning method

Harvest criteria (cords/acre)	Age in years															
	30				35				40				45			
	Light	Species	Heavy	None	Light	Species	Heavy	None	Light	Species	Heavy	None	Light	Species	Heavy	None
ALL TREES TO A 4-INCH TOP																
3	100	80	40	80	100	100	100	100	100	100	100	100	100	100	100	100
5	60	60	20	80	100	100	100	100	100	100	100	100	100	100	100	100
10	—	—	—	—	60	60	20	60	100	100	100	100	100	100	100	100
20	—	—	—	—	—	—	—	—	40	60	—	20	60	80	100	80
PAPER BIRCH AND YELLOW BIRCH TREES TO A 6-INCH TOP																
3	80	60	20	60	100	80	60	80	100	100	100	100	100	100	100	100
5	20	20	—	—	80	60	40	80	100	80	60	80	100	100	100	100
10	—	—	—	—	—	—	—	—	20	60	40	40	80	60	40	80
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PAPER BIRCH AND YELLOW BIRCH TREES TO A 6-INCH TOP WHEN AT LEAST 20 PER ACRE ARE 12 INCHES D.B.H. AND LARGER																
3	—	—	—	—	—	—	—	—	20	—	—	—	80	40	20	—
5	—	—	—	—	—	—	—	—	20	—	—	—	80	40	20	—
10	—	—	—	—	—	—	—	—	—	—	—	—	60	20	20	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

make a commercial cutting and still maintain recommended stocking levels of paper birch?" The B stocking level in *A Silvicultural Guide for Paper Birch in the Northeast*⁵ was used as a criterion for judging stocking success after a commercial cutting.

The number of paper birch trees 6 inches and larger was tested against this criterion. We selected a 5-cord-per-acre commercial cutting as a reasonable goal. The results indicated that we could make a commercial cutting to a 4-inch top (pulpwood) and meet the criterion for B-level stocking. Table 5 shows the proportion of the plots that can sustain a 5-cord cutting to a 4-inch top and leave enough paper birch 6 inches d.b.h. and larger to meet the B level stocking criterion.

From table 5 we see that this intermediate cutting goal is probable 15 years after thinning at age 40 under the light and species thinnings; and the light thinning is less expensive and performs better. Even these results would not be accepted if we required a probability limit of 60 percent before considering the results to be successful. The intermediate cutting goal was achieved for all four methods at age 45, and their cost effectiveness would rank then (1) no thinning, (2) light thinning, (3) species thinning, and (4) heavy thinning.

Achieving Goals for the Precommercial Thinning

Price information for estimating values for the different products is required for determining rate of return to the thinning investment. The specifications used earlier for pro-

Table 5.—Percentage of plots that sustain a 5-cord intermediate cut of material to a 4-inch top and meet recommended stocking levels of paper birch

Precommercial thinning method	Age of stand (years)			
	30	35	40	45
None	0	0	0	60
Species	0	0	20	40
Heavy	0	0	0	40
Light	0	0	40	40

duction goals were established with unit values in mind. The unit prices themselves were selected by matching specifications and quotations from the wood-procurement departments of wood-products manufacturers with the potential product specifications of the stands with which we were dealing. The following price schedule was decided upon:

Forest Specifications	Potential products	Unit price
All trees to a 4-inch top.	Pulpwood.	\$2/cord
Trees to a 6-inch top; paper and yellow birch only.	Birch boltwood.	8/cord
Trees to a 6-inch top; the stand must have 20 trees per acre 12 inches d.b.h. and larger. Paper and yellow birch only.	Birch boltwood, with some veneer potential.	14/cord

These unit values are benchmark values — they are good for generalizing because they are in the right neighborhood but not especially good for any particular sale area.

The number of cords per acre for each plot at each 5-year interval was multiplied by the above unit prices to determine the total plot value per acre. The five thinned-plot values for each thinning practice were then compared with the unthinned-plot values to see how much the practices had increased the stand value above the unthinned stand values. In all we made 25 comparisons for each thinning practice, a total of 75 comparisons for the three practices.

Table 4.—Thinning costs for the precommercial thinning tests at 1 cent/diameter inch removed

Replication	Costs per acre		
	Species	Light	Heavy
1	\$19.50	\$12.40	\$22.80
2	19.00	10.70	19.80
3	18.60	10.60	19.60
4	17.40	10.50	18.60
5	14.70	10.30	18.00
Average	17.84	10.90	19.76

⁵ Marquis, David A., Dale S. Solomon, and John C. Bjorkbom. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. In press, NE. Forest Exp. Sta., Upper Darby, Pa., 1969.

The comparisons showing positive value differences were then divided by thinning costs to determine the value ratio between a thinned plot and each unthinned plot. Each ratio was then used to determine the rate of return.⁶ The percentage of these tests that met a rate of return criterion then was calculated. The results of these calculations are shown in table 6.

For example, the 48 percent at the right-hand side of the top row (table 6) means that 48 percent or 12 out of 25 possible comparisons showed a positive return at age 45 in a combination pulpwood and low-value boltwood market. In 52 percent of the cases the no-thinning alternative showed up better than the thinning practices. The rate of return criteria were selected to reflect different

⁶ Rate of return = $(1 + i)^n = \frac{V_n}{V_0}$. The symbol "i" = interest rate; n = period of years; V_n = income due after n years; and V₀ = present capital value of investment. For example, if the thinning practice cost \$18.00/acre and the stand value/acre after 20 years was \$90.00/acre, then $\frac{\$90.00}{\$18.00} = \frac{V_n}{V_0} = 5.0$. From the interest tables, $1.084^{20} = 5.019$, or the rate of return equals a little less than 8.4 percent.

economic points of view. Zero and 2 percent were used for those in departmentalized or multiple-use situations; 4 and 6 percent were used to reflect the usual (in a historical sense at any rate) rates of return from alternative investments; the 10 percent was included to represent a highly attractive investment return.

EVALUATION OF PRECOMMERCIAL THINNING ALTERNATIVES

In this evaluation 245 separate analyses were made. They really do not lend themselves to tabulation as a summary evaluation because the table would be too long and cumbersome. We can describe the general performance characteristics of these thinning alternatives. And we can propose a method so that the quantitative data can be helpful to a forest manager who is trying to decide what to do in his particular case.

NO THINNING appears best when roundwood to a 4-inch top is the product desired in the shortest possible time.

LIGHT THINNING may be preferred when an early future commercial cutting is desired, or when paper birch to a 6-inch top is the goal, or when an early return to the thinning investment is desired.

Table 6.—Achieving rate of return goals for the precommercial investment: percentage of comparisons meeting selected rates of return on the precommercial thinning investments

Treatments compared	Potential market							
	Pulpwood, \$2/cord, at age—	Boltwood					Pulpwood and boltwood, \$2/cord and \$8/cord, at age—	
		\$8/cord, at age—			\$14/cord, at age—			
		45	30	35	40	45	45	40
0 PERCENT RATE OF RETURN								
Species vs. none	52	20	52	64	64	76	56	48
Heavy vs. none	0	0	8	24	36	44	24	28
Light vs. none	24	20	44	52	44	64	44	44
2 PERCENT RATE OF RETURN								
Species vs. none	40	20	48	64	64	76	64	48
Heavy vs. none	0	0	8	24	24	36	20	28
Light vs. none	16	20	40	52	40	64	44	44
4 PERCENT RATE OF RETURN								
Species vs. none	16	20	40	56	56	76	60	44
Heavy vs. none	0	0	8	20	16	28	16	12
Light vs. none	4	20	32	40	36	60	36	36
6 PERCENT RATE OF RETURN								
Species vs. none	0	20	28	44	48	72	44	24
Heavy vs. none	0	0	8	16	8	24	12	8
Light vs. none	0	20	20	32	24	60	28	20
10 PERCENT RATE OF RETURN								
Species vs. none	0	20	12	12	8	60	12	4
Heavy vs. none	0	0	8	8	0	4	0	0
Light vs. none	0	20	16	20	8	44	20	4

SPECIES THINNING achieved the best record for meeting usual rate-of-return goals, though the flexibility for a commercial cutting and the possible attainment of unusually high rates of returns for this option were slightly higher than those for light thinning.

HEAVY THINNING performed poorly for the first 15 years but had nearly closed the gap in some respects in 20 years and shows promise of outperforming the others in the future. If only one cultural practice is being contemplated for a paper birch stand, it may have merit with respect to any of the criteria in the long run.

The woodland manager planning a pre-commercial thinning investment under the conditions described here needs to decide how much time he can allow to elapse before getting substantive results from the investment and the product and market situation he may find himself in at that time. Using these

(time, product, market) as restraints, he can array the results of these performance tests to help him decide which course of action suits him best.

An example: The manager seeks to use the performance-test data to help guide him for 10 to 15 years in the future. He expects the present boltwood market to persist. He is willing to use the low value quoted, and feels he can thin at the costs used here. He arrays the performance test data as shown in table 7.

With this information, he would probably discard the heavy thinning as not being fruitful in his planning time horizon. He would select the light or species thinning if he were most interested in the 15-year horizon, or the light or species thinning if most interested in the 10-year time span. He could still select the no-thinning alternative if he were not satisfied with expected returns under the thinning practices.

Table 7.—*Tested outcomes of precommercial thinnings for boltwood production, in percent success*

Thinning treatment	5-cord goal?	Commercial cut feasible?	Recover thinning costs?	4-percent rate of return on thinning investment?	10-percent rate of return on thinning investment?
IN 10 YEARS					
None	80	0	—	—	—
Light	60	0	44	32	16
Heavy	32	0	8	8	8
Species	68	0	52	40	12
IN 15 YEARS					
None	80	0	—	—	—
Light	72	40	56	44	20
Heavy	52	0	24	24	8
Species	68	20	68	64	12



FINANCIAL MATURITY OF PAPER BIRCH

by JOSEPH J. MENDEL, *Principal Forest Economist, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Columbus, Ohio.*

ONE OBJECTIVE in forestry is to earn the greatest possible return on the capital invested in growing timber. To do this, the forester not only must know which silvicultural methods to use, but also ought to know the methods of economic analysis that will help him make the decisions that will lead to the greatest return.

The financial maturity concept provides a method of economic analysis by which the forester can evaluate the business aspects of timber growing. This concept is based on the rates of value increase that can be expected of trees over a given period of time. From this, marking guides can be prepared to prescribe the diameters at which trees of given vigor, grade, and merchantable height are financially mature; that is, they have reached the stage beyond which the expected rate of value increase no longer equals or exceeds the timber owner's desired rate of return.

The rate of value increase, which is the backbone of the financial-maturity concept, is determined by three components: (1) the present value of the tree; (2) the future value of the tree, which incorporates growth increase in diameter as well as in merchantable height and possible improvement in quality; and (3) the time period considered between the present value and the prospective value. Given these data, the rate of value increase is determined from the compound-interest formula:

$$(1 + r)^n = \frac{V_n}{V_o}$$

where r is the rate of interest.

n is the time period.

V_n is the future value.

V_o is the present value.

The relative simplicity of the compound-interest formula belies the difficulties encoun-

tered in assembling the data to calculate the various components of the formula. It was necessary to develop considerable basic data for lumber grade yields as well as prices to formulate the base for determination of present and future value. Also, growth data were necessary for projecting the development of the tree or stand over the 10-year time period considered, to establish prospective value.

PAPER BIRCH SAWTIMBER

The methodology employed in developing these values for paper birch sawtimber is documented in several recent Northeastern Forest Experiment Station Research Papers on the rate of value increase for several species in the Northeastern region. A summary of the steps required to calculate the rate of value increase is as follows:

1. Use lumber grade yields and price relatives to develop the log quality index and then the tree quality index, which when multiplied by the current price of No. 1 Common lumber, will yield the gross value per thousand board feet.
2. From the gross value per thousand board feet subtract all the variable costs (conversion costs) involved in harvesting, transporting, and processing the tree into lumber. The result is the conversion value per thousand board feet.
3. To obtain the present or future value of the tree, multiply the volume of the tree by the conversion value per thousand board feet.
4. Once the present and future values are determined, calculate the ratio V_n/V_o and check the result in interest tables to determine the rate of value increase.

Table 1 illustrates some of the numerous situations that evolve when all the possibilities

of quality and merchantable height are considered for both the present and the future of a single diameter class.

Many assumptions had to be made in completing these calculations. For instance, we assumed that the tree can improve only one log grade during the 10-year time period involved. Also, trees with a d.b.h. growth of 2.0 inches and over could increase a full 16-foot log in merchantable height. Trees growing less than 2.0 inches in d.b.h. in 10 years were restricted to a 1/2-log increase in merchantable height.

Assume that we have a 16-inch d.b.h. paper birch, vigor I, with a butt-log grade of 2, and 16 feet merchantable height. From the growth table we find we can expect a diameter increase of 2.7 inches in the next 10 years (table 2). Therefore the future tree has six different possibilities of grade and height:

<i>Present</i>		
<i>D.b.h. (inches)</i>	<i>Butt-log grade</i>	<i>Merchantable height (feet)</i>
16.0	2	16

Table 1.—Rate of value increase computations for paper birch sawtimber

VIGOR I

Present				Future				Ratio V_n/V_o	Percent rate of return	Ten-year value increase \$
D.b.h. (inches)	Butt- log grade	Log height (feet)	Conversion value \$	D.b.h. (inches)	Butt- log grade	Log height (feet)	Conversion value \$			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
16.0	1	16	13.86	18.7	1	16	25.79	1.860981	6.4	11.93
					1	24	32.33	2.332736	8.8	18.47
					1	32	34.38	2.480794	9.5	20.52
16.0	2	16	10.06	18.7	2	16	17.71	1.759469	5.8	7.65
					2	24	23.93	2.378201	9.0	13.87
					2	32	27.96	2.778510	10.8	17.90
					1	16	25.79	2.562772	9.9	15.73
					1	24	32.33	3.212429	12.4	22.27
16.0	3	16	6.11	18.7	1	32	34.38	3.416320	13.1	24.32
					3	16	11.89	1.944977	6.9	5.78
					3	24	16.01	2.619173	10.1	9.90
					3	32	18.63	3.046966	11.8	12.52
					2	16	17.71	2.896111	11.2	11.60
					2	24	23.93	3.914554	14.6	17.82
					2	32	27.96	4.573467	16.4	21.85
16.0	4	16	2.08	18.7	4	16	4.47	2.145091	7.9	2.39
					4	24	6.38	3.058788	11.8	4.30
					4	32	7.89	3.787037	14.2	5.81
16.0	1	24	16.95	18.7	1	24	32.33	1.907074	6.7	15.38
					1	32	34.38	2.028115	7.3	17.43
					1	40	33.39	1.969981	7.0	16.44
16.0	2	24	13.62	18.7	2	24	23.93	1.757209	5.8	10.31
					2	32	27.96	2.052990	7.5	14.34
					2	40	30.66	2.251068	8.5	17.04
					1	24	32.33	2.373605	9.0	18.71
					1	32	34.38	2.524257	9.7	20.76
16.0	3	24	8.16	18.7	1	40	33.39	2.451900	9.4	20.77
					3	24	16.01	1.961634	7.0	7.85
					3	32	18.63	2.282029	8.6	10.47
					3	40	20.32	2.489771	9.6	12.16
					2	24	23.93	2.931810	11.4	15.77
					2	32	27.96	3.425305	13.1	19.80
					4	24	6.38	2.128011	7.8	3.38
16.0	4	24	3.00	18.7	4	32	7.89	2.634657	10.2	4.89
					4	40	9.22	3.077278	11.9	6.22
					1	32	34.38	1.926958	6.8	16.54
16.0	1	32	17.84	18.7	1	40	33.39	1.871723	6.5	15.55
					1	48	30.59	1.714523	5.5	12.75
					2	32	27.96	1.706328	5.5	11.57
16.0	2	32	16.39	18.7	2	40	30.66	1.870959	6.5	14.27
					2	48	33.07	2.018354	7.3	16.68
					1	32	34.38	2.098018	7.7	17.99
					1	40	33.39	2.037880	7.4	17.00
					1	48	30.59	1.866725	6.4	14.20

<i>D.b.h.</i> (inches)	<i>Future</i>	
	<i>Butt-log grade</i>	<i>Merchantable height (feet)</i>
18.7	2	16
	2	24
	2	32
	1	16
	1	24
	1	32

The conversion value is found for each of these situations and the ratio V_n/V_o is calculated, which determines the rate of value increase. Thus for our sample tree we find that on the basis of diameter alone we can expect a rate of value increase of 5.8 percent. If the tree increases 1/2-log in merchantable height, the rate of value increase is 9.0 percent; with a 1-log increase in merchantable height, the rate of value increase is 10.8 percent.

Considering possible quality improvement, we find that the tree can increase one grade to a butt-log grade 1; so we have three additional possibilities: (1) a butt-log grade 1, 16 feet in merchantable height, which gives a rate of value increase of 9.9 percent; (2) a butt-log grade 1, 24 feet in merchantable height, which provides an expected rate of value increase of 12.4 percent; and (3) a butt-log grade 1, 32 feet in merchantable height, with an expected rate of value increase of 13.1 percent.

Thus we find that our sample tree has a potential rate of value increase ranging from 5.8 percent to 13.1 percent, depending upon what occurs in increase in merchantable height and improvement in quality. Table 1 indicates the many possibilities that must be considered for a 16.0-inch paper birch, both in the present situation and for the 10 years hence.

Similar calculations are made for other diameter classes to be considered.

Results

Any presentation of detailed rates of value increase for general use would not depict the situation for all users. Lumber grade recovery and conversion costs undoubtedly differ from those used in this study. Also, prices for lumber vary by locality and season. Therefore the rates of value increase are presented in four tables as a range of rates for a range of vigor classes. Table values vary as price and conversion costs change (tables 3 to 6).

A user of these tables needs only to select the basic situation and the diameter and vigor of the tree, or the average diameter and vigor of the stand, to determine the range of rates of value increase in the next 10 years. If only growth in diameter and height are anticipated, the left part of the table is used. If an improvement to a higher butt-log grade class is expected, the table section titled "Due to growth and quality increase" is used.

Two noteworthy generalities are illustrated in these tables (table 3):

1. The rate of tree earning power decreases with increasing size. For example, an 18-inch vigor-I tree has the potential of earning at an annual rate during the next 10 years as much as 7 percent, based on growth alone, and 12 percent based on growth and quality improvement. On the other hand, a 22-inch vigor-I tree will earn only about 5 percent in growth alone and a maximum of 8 percent if a grade improvement occurs.
2. Improvement in log quality greatly increases tree earning power. Due recognition must be given to quality improvement potential in selecting the tree to remain in the stand. For example, a 16-inch vigor-I paper birch can have a rate of value increase of 11 percent due to growth alone (table 3). However, if a log-grade improvement takes place in the next 10 years, a rate of value increase of as much as 16 percent can be expected.

Table 2.—10-year d.b.h. growth rate for paper birch sawtimber, in inches

Initial d.b.h. (inches)	Vigor class I ¹	Vigor class II	Vigor class III
12	3.0	2.2	1.2
14	2.8	2.1	1.1
16	2.7	2.0	1.1
18	2.5	1.9	1.0
20	2.4	1.8	1.0
22	2.2	1.7	9

¹ Vigor classes are arbitrary classes based on assumed growth rates.

Table 3.—Expected rate of value increase for paper birch trees with price and conversion costs remaining stable ¹
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase ²		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	16-33*	13-30*	11-24*
14	7-12	5-10	3-6	7-28*	5-26*	3-20*
16	5-11	4-9	2-6	6-16*	4-15*	2-11*
18	3-7	3-5	2-4	4-12	4-10	1-8
20	3-6	2-5	1-3	4-10	3-8	1-6
22	2-5	2-4	1-2	4-8	3-7	1-6

¹ Based on 4/4 factory-grade lumber recovery under the following circumstances:

			V_o	V_n
Price No. 1C	—		\$210/M	\$210/M
Conversion costs	—		70/M	70/M

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

² The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o . For this reason butt-log grade 3 logs have not been considered in the estimates "due to growth only."

* The high rates of value increase in the 12- to 16-inch diameter classes are due to two factors: (1) the butt-log grade 3 trees becoming positive in present value, and (2) the improvement of butt-log grade 3 trees to butt-log grade 2.

Table 4.—Expected rate of value increase for paper birch trees with conversion costs remaining stable but with prices increasing ¹
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase ²		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	16-35*	14-31*	12-25*
14	7-13	6-11	3-7	8-29*	6-27*	4-21*
16	6-12	4-10	3-6	7-17*	5-14*	3-12*
18	4-8	4-6	2-4	4-13	4-11	2-9
20	4-7	3-5	1-3	4-10	4-9	1-7
22	3-6	3-5	1-3	4-8	3-8	1-7

¹ Based on 4/4 factory-grade lumber recovery under the following circumstances:

			V_o	V_n
Price No. 1C	—		\$210/M	\$220/M
Conversion costs	—		70/M	70/M

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

² The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o . For this reason butt-log grade 3 logs have not been considered in the estimates "due to growth only."

* The high rates of value increase in the 12- to 16-inch diameter classes are due to two factors: (1) the butt-log grade 3 trees becoming positive in present value, and (2) the improvement of butt-log grade 3 trees to butt-log grade 2.

Table 5.—Expected rate of value increase for paper birch trees with prices remaining stable but conversion costs decreasing ¹
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase ²		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	17.36*	15.33*	12.26*
14	8.13	6.11	4.7	9.30*	6.28*	4.22*
16	6.12	5.10	3.7	7.17*	5.16*	3.12*
18	4.8	4.6	3.4	4.13	3.11	2.9
20	4.7	3.6	2.4	4.11	3.9	2.7
22	3.6	3.5	1.3	4.9	3.8	2.6

¹ Based on 4/4 factory-grade lumber recovery under the following circumstances:

		V_o	V_n
Price No. 1C	—	\$210/M	\$210/M
Conversion costs	—	70/M	60/M

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

² The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o . For this reason butt-log grade 3 logs have not been considered in the estimates "due to growth only."

* The high rates of value increase in the 12- to 16-inch diameter classes are due to two factors: (1) the butt-log grade 3 trees becoming positive in present value, and (2) the improvement of butt-log grade 3 trees to butt-log grade 2.

Table 6.—Expected rate of value increase for paper birch trees with prices increasing and conversion costs decreasing ¹

D.b.h. (inches)	Due to growth only			Due to growth and quality increase ²		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	18.37*	15.34*	13.28*
14	8.14	7.12	4.8	9.31*	7.29*	5.23*
16	7.12	6.11	4.7	8.18*	6.17*	4.13*
18	5.9	5.7	3.5	5.14	4.11	3.10
20	5.8	4.6	2.4	5.11	4.9	3.8
22	4.7	4.6	2.4	5.9	4.8	3.7

¹ Based on 4/4 factory-grade lumber recovery under the following circumstances:

		V_o	V_n
Price No. 1C	—	\$210/M	\$220/M
Conversion costs	—	70/M	60/M

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

² The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o . For this reason butt-log grade 3 logs have not been considered in the estimates "due to growth only."

* The high rates of value increase in the 12- to 16-inch diameter classes are due to two factors: (1) the butt-log grade 3 trees becoming positive in present value, and (2) the improvement of butt-log grade 3 trees to butt-log grade 2.

Marking Guides

Tree earning power as depicted by the rate of value increase provides a means for establishing marking guides based on an economic consideration as well as silvicultural and management needs. Tables 3 to 6 can be used in establishing marking guides for selection cutting once an alternative rate of return is established; that is, the interest rate which the forest owner expects for the use of his capital and against which a tree's rate of value increase is compared in estimating financial maturity.

The rate-of-value-increase concept can also be used to determine rotation size in harvest cuttings under even-aged management. These guides presented in tabular form (tables 7 to 10) are given for three interest-rate objectives—2, 4, and 6 percent.

The diameters given are average stand diameters. Assume that an owner requires a return of 4 percent on his capital invested in paper birch trees of sawtimber size; and that the general diameter growth rate and condition of the stand indicate vigor class II. The top d.b.h. limit to leave would be 18 inches if prices and conversion costs remain stable for 10 years. Trees grown larger than 18 inches would fail to provide a return of 4 percent (table 7). In this same example, where a return of only 2 percent is required, the top d.b.h. would be 22+ inches; and for a 6 percent return the d.b.h. limit would be 14 inches. In vigor class III, returns of 4 and

**Table 7.—Paper birch d.b.h. for financial maturity:
WHEN LUMBER PRICE AND CONVERSION
COST REMAIN STABLE ¹**

Vigor class	Basis:		
	Lumber price No. 1C	V ₀ \$210/M	V _n \$210/M
	Conversion cost	70/M	70/M
Rate of return			
	2%	4%	6%
	<i>Inches d.b.b.</i>	<i>Inches d.b.b.</i>	<i>Inches d.b.b.</i>
I	22+	20	17
II	22+	18	14
III	20	—	—

¹ Diameters are based on value increase as determined by growth only, and for trees with butt-log grades of 1 and 2.

**Table 8.—Paper birch d.b.h. for financial maturity:
WHEN LUMBER PRICE INCREASES BUT
CONVERSION COST REMAINS STABLE ¹**

Vigor class	Basis:		
	Lumber price No. 1C	V ₀ \$210/M	V _n \$220/M
	Conversion cost	70/M	70/M
Rate of return			
	2%	4%	6%
	<i>Inches d.b.b.</i>	<i>Inches d.b.b.</i>	<i>Inches d.b.b.</i>
I	22+	21	17
II	22+	19	14
III	22	15	—

¹ Diameters are based on value increase as determined by growth only, and for trees with butt-log grades of 1 and 2.

6 percent cannot be obtained with any size sawtimber trees of butt-log grades 1 and 2.

This table reflects the earning power of trees only with butt-log grades of 1 and 2. Butt-log grade 3 trees earn little money, and it is reasonable to assume that they would be discriminated against in marking for early improvement cuts.

Tables 7 to 10 illustrate the variation in financial maturity diameters due to different lumber prices and conversion costs projected at the end of the 10-year period.

It should be emphasized that all of the interest rates presented here are based on trees already existing in a stand and on their projected value increase over the next 10 years. Costs of growing the stand to sawtimber-size were not considered.

PAPER BIRCH BOLTWOOD

Determining the rate of value increase is considerably simpler for boltwood than for sawtimber. Quality does not play as prominent a role in influencing the rate of return, with the possible exception that the bolts that meet the specifications of the buyer may result in higher overall prices. Thus we have two considerations to be made in determining future value: diameter growth and increase in merchantable height.

In making the 10-year projections of value (V_n), the growth predictions of a thinning study were used (table 11). Five different

Table 9.—Paper birch d.b.h. for financial maturity:
WHEN LUMBER PRICE REMAINS STABLE BUT
CONVERSION COST DECREASES ¹

Vigor class	Basis:		
	Lumber price No. 1C	V_0 \$210/M 70/M	V_n \$210/M 60/M
Rate of return			
	2%	4%	6%
	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>
I	22+	22	18
II	22+	20	16
III	22	15	—

¹ Diameters are based on value increase as determined by growth only, and for trees with butt-log grades of 1 and 2.

levels of increase in merchantable height were considered possible: no increase, and increases of 1, 2, 3, and 4 five-foot bolts. A roadside value of \$30 per cord was used as the product price, and an average of \$16 per cord in conversion costs accounted for all of the variable costs involved in cutting and skidding to the roadside.

Using a volume table, graduated in 5-foot lengths, and a set of compound-interest tables, it is now possible to make the rate of value increase calculations. As previously mentioned, we have five possible situations of the 10-years hence status of the tree (table 12). For example, a 10-inch paper birch with a present merchantable height of 15 feet may evolve in 10 years into one of the following situations:

<i>Present d.b.h. (inches)</i>	<i>Present merchant-able length (feet)</i>	<i>Future d.b.h. (inches)</i>	<i>Future merchant-able length (feet)</i>
10.0	15	12.9	15
		12.9	20
		12.9	25
		12.9	30
		12.9	35

Once the volumes are determined for these possible situations, it is a simple matter to determine the conversion value by multiplying the volume by the net value, in this case \$14/cord (\$30 — \$16) (table 12). Then

the ratio V_n/V_0 can be calculated, and the rates of value increase can be determined from the compound-interest tables. Similar calculations are made for each of the diameter classes.

Results

Calculation of the rates of value increase for this example indicates that very desirable returns can be expected. Assuming even the most illogical situation where no increase in merchantable length is achieved in the next 10 years, rates of value increase ranging from 4 to 5 percent can be made on the basis of diameter growth alone (table 13).

Where it is anticipated that in the next 10 years a gain of one 5-foot bolt in merchantable length will be made, rates of value increase will range from 5 to 9 percent, the largest gain made in trees of lower merchantable height at the beginning of the growth period. Similarly, where increases of two 5-foot bolts will be made, the rates of value increase will range between 6 to 12 percent; for increases of three 5-foot bolts the rates of value increase range between 7 to 13 percent. And finally—the most desirable but least likely situation—where gains of four 5-foot bolts of merchantable length are made, the rates of value increase will range between 8 and 14 percent.

A table of financial-maturity diameters for boltwood can be constructed in a manner similar to that for sawtimber (table 14).

Table 10.—Paper birch d.b.h. for financial maturity:
WHEN LUMBER PRICE INCREASES AND
CONVERSION COST DECREASES ¹

Vigor class	Basis:		
	Lumber price No. 1C	V_0 \$210/M 70/M	V_n \$220/M 60/M
Rate of return			
	2%	4%	6%
	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>
I	22+	22+	19
II	22+	20	16
III	22+	16	—

¹ Diameters are based on value increase as determined by growth only, and for trees with butt-log grades of 1 and 2.

Only the minimum expected rates of value increase (table 13) were considered, and the maximum d.b.h. of boltwood was limited to 12 inches. Given these, we find that an 8-percent return can be obtained only if a height increase of three 5-foot bolts is made and that the financial-maturity diameter would be 10 inches. A 7-percent return would be achieved only if a height growth of two or more 5-foot bolts is made. For a 6-percent return, a height increase of one or more 5-foot bolts must be made. A 5-percent return can be made on the basis of diameter growth alone. It should be emphasized again that these financial-maturity diameters are based on the minimum expected rates of value increase.

Table 11.—Ten-year d.b.h. growth for paper birch, in inches

D.b.h. (inches)	Growth
6.0	2.1
7.0	2.4
8.0	2.6
9.0	2.7
10.0	2.9
11.0	3.0
12.0	3.0
13.0	3.0

Table 12.—Determination of annual rate of value increase over a 10-year period for 10-inch d.b.h. paper birch boltwood

Present				Future				Ratio (V_n/V_o)	Rate of value increase %	Ten-year value increase \$
D.b.h. (inches)	Merchant- able length (feet)	Volume (cords)	Conver- sion value (V_o) \$	D.b.h. (inches)	Merchant- able length (feet)	Volume (cords)	Conver- sion value (V_n) \$			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
10.0	15	0.083	1.16	12.9	15	0.140	1.96	1.68966	5.4	0.80
					20	.175	2.45	2.11207	7.8	1.29
					25	.201	2.81	2.42241	9.2	1.65
					30	.229	3.21	2.76724	10.7	2.05
					35	.252	3.53	3.04310	11.8	2.37
10.0	20	.109	1.53	12.9	20	.175	2.45	1.60131	4.8	.92
					25	.201	2.81	1.83660	6.3	1.28
					30	.229	3.21	2.09804	7.7	1.68
					35	.252	3.53	2.30719	8.7	2.00
					40	.274	3.84	2.50980	9.6	2.31
10.0	25	.124	1.74	12.9	25	.201	2.81	1.61494	4.9	1.07
					30	.229	3.21	1.84483	6.3	1.47
					35	.252	3.53	2.02874	7.3	1.79
					40	.274	3.84	2.20690	8.2	2.10
					45	.295	4.13	2.37356	9.0	2.39
10.0	30	.140	1.96	12.9	30	.229	3.21	1.63776	5.0	1.25
					35	.252	3.53	1.80102	6.1	1.57
					40	.274	3.84	1.95918	7.0	1.88
					45	.295	4.13	2.10714	7.7	2.17
					50	.316	4.42	2.25510	8.5	2.46
10.0	35	.153	2.14	12.9	35	.252	3.53	1.64953	5.1	1.39
					40	.274	3.84	1.79439	6.0	1.70
					45	.295	4.13	1.92991	6.8	1.99
					50	.316	4.42	2.06542	7.5	2.28
					55	.337	4.71	2.20100	8.2	2.56
10.0	40	.166	2.32	12.9	40	.274	3.84	1.65521	5.2	1.52
					45	.295	4.13	1.78017	5.9	1.81
					50	.316	4.42	1.90517	6.6	2.10
10.0	45	.183	2.56	12.9	45	.295	4.13	1.61328	4.9	1.57
					50	.316	4.42	1.72656	5.6	1.86
					55	.337	4.71	1.84000	6.3	2.15
10.0	50	.200	2.80	12.9	50	.316	4.42	1.57857	4.7	1.62

Table 13.—*Expected annual rate of value increase over a 10-year period for paper birch trees utilized for boltwood*¹
(In percent)

Present d.b.h. (inches)	Expected increase in merchantable length, in number of 5-foot bolts —				
	0	1	2	3	4
6	5	6-9	7-12	8-13	9-14
7	5	6-9	7-12	8-13	9-14
8	5	6-7	7-9	8-11	9-12
9	5	6-7	7-9	8-11	9-12
10	5	6-7	7-9	8-11	9-12
11	4-5	5-7	6-9	7-10	8-11
12	4-5	5-7	6-8	7-10	8-11

¹ In this case, the boltwood considered is in 5-foot lengths to a 4-inch top diameter inside bark with a roadside value of \$30/cord and conversion cost of \$16/cord.

Table 14.—*Paper birch boltwood d.b.h. for financial maturity, based on minimum expected rate of value increase*

Basis:		V ₀	V _n		
Roadside price		\$30/cord	\$30/cord		
Conversion costs		\$16/cord	\$16/cord		
Expected merchantable height increase (number of 5-foot bolts)	Rate of return				
	5%	6%	7%	8%	
	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>	<i>Inches d.b.h.</i>	
0	10	—	—	—	
1	12	10	—	—	
2	12	12	10	—	
3	12	12	12	10	
4	12	12	12	12	

SUMMARY

The financial maturity guides presented here are the result of generalizations about mill recovery yields, prices, conversion costs, etc., and they must be considered as regional guides. Their applicability to a specific situation is of questionable value. What has been presented here is a system for the development of financial-maturity guides by a firm, the results of which would be most responsive to the needs and expectations of that firm.

The financial-maturity concept presents an unusual opportunity to more closely relate the decisions of the timber cruiser and forest manager with the profit-and-loss situation of the firm. It presents a quantified decision of financial maturity rather than the subjective decision of the past.

It has been some 20 years or more since the financial-maturity concept has been fully presented to the forestry profession. Its adoption has been slow, probably because of the laborious calculations that must be made. Today, however, with advent of the computer and programs designed to produce rate of value increase calculations, such work can be held to a minimum. It is within the realm of feasibility for large timber-growing firms to develop and adjust existing computer programs to suit their individual situations. Smaller firms and even small woodland owners could seek to have such services developed and provided by extension and service foresters.



FINANCIAL MATURITY OF YELLOW BIRCH

by WILLIAM B. LEAK, Principal Silviculturist, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Durham, N.H.

THE METHODS used to compute financial maturity of yellow birch sawtimber are similar to those used for paper birch sawtimber, except for minor differences in detail. The procedure followed for yellow-birch veneer-log trees was also similar, except that local veneer grades¹ and local veneer-log prices were used as the basis for the financial maturity computations.

Rates of value increase for yellow birch were computed on the basis of assumed vigor classes and growth rates, as follows:

Vigor class	10-year d.b.h. growth (inches)
1	2.0
2	1.5
3	1.0
4	.5

Initial stumpage value of the hypothetical trees was determined by the appraisal procedures outlined previously; then future value was determined by the same procedures, incorporating the appropriate d.b.h. growth figure for each vigor class. We also determined the effects of an increase of $\frac{1}{2}$ log in merchantable height, and an increase of one butt-log grade, on rates of value increase over the 10-year period.

Computed rates of value increase were expressed as an annual compound interest rate, using initial stumpage value as the basis.

Results

First, consider the effects of growth alone, without any increase in merchantable height or log grade. Compound interest rates of 3 per-

cent or better were exhibited by vigor-1 saw-log trees smaller than 20 inches d.b.h. and vigor-2 sawlog trees smaller than about 17 inches d.b.h. Rates for vigor-3 trees seldom were better than 2 percent. Rates for vigor-4 trees were about 1 percent. Rates for veneer-log trees generally were less, not quite 3 percent even for the fastest growing trees.

An increase in merchantable height of $\frac{1}{2}$ log over the 10-year period produced a slightly increased rate of interest—roughly $\frac{1}{2}$ to 1 percent greater than trees that did not increase in height. However, merchantable height increases commonly occur only in smaller trees between 12 and 16 inches.

An increase in butt-log grade over the 10-year period was found to have a major effect upon interest rates. Rates for saw-log trees were found to be 2 to 4 times greater than the unaugmented rates, while a butt-grade change in veneer-log trees resulted in roughly double the normal rate. For example, a vigor-3, 2-log sawlog tree whose butt grade increased from grade 2 to grade 1 was found to produce a compound interest rate of over 8 percent (table 1). The comparable rate for trees that did not increase in grade was between 1 and 2 percent.

In summary, the results indicated that fairly small, very fast-growing yellow birch trees may produce interest rates of 3 percent or better. Larger or slower growing trees produce considerably lower rates. Rates will be augmented a little by increases in merchantable height. However, the most important determinant of value increase is grade improvement.

Applications

The results of this investigation have important applications to the silviculture and management of northern hardwood stands containing yellow birch.

¹ The six veneer grades in order of descending quality are: AA, Aircraft, Select, 1, 2, and 3, as currently used by one of the large veneer industries in New Hampshire.

- Since rate of value increase depends heavily upon grade improvement, yellow birch trees with high quality potential cannot be grown beyond about 22 inches d.b.h. without sacrificing rates of interest. Where surface defect rules out the possibility of top-grade sawlogs and veneer logs, 18 inches d.b.h. is a reasonable maximum size. Trees of these sizes will have reached or passed the peak of grade improvement.
- Trees left as growing stock after a harvesting or thinning operation should be those that show the best possibilities for future grade improvement.
- In evaluating a specific stand and prescribing appropriate silvicultural treatments, particular attention should be paid to the possibilities of grade improvement. Yellow birch trees and stands that exhibit high grade-improvement potential are the ones that warrant intensive silvicultural work. Conversely, trees and stands that will produce low-value bulk products now and in the future do not warrant intensive care, and should be scheduled for commercial treatment only.

Table 1.—Compound interest rates for yellow birch sawlog and veneer-log trees increasing by one butt-log grade over a 10-year period—for 2-log vigor-3 trees

D.b.h. (inches)	Veneer-log trees ¹			Sawlog trees		
	Initial butt grade	Final butt grade	Interest rate (percent)	Initial butt grade	Final butt grade	Interest rate (percent)
16	Select	Aircraft	3.7	2	1	8.8
	Aircraft	AA	3.1			
18	Select	Aircraft	3.1	2	1	8.7
	Aircraft	AA	2.4			
20	Select	Aircraft	3.1	2	1	8.5
	Aircraft	AA	2.5			
22	Select	Aircraft	2.8	2	1	8.3
	Aircraft	AA	2.1			
24	Select	Aircraft	3.0	2	1	8.1
	Aircraft	AA	2.4			

¹ All veneer-log trees are assumed to have a select top log.

DISEASES OF BIRCH

by ALEX L. SHIGO, *Research Pathologist, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Durham, N.H.*

PAPER BIRCH and yellow birch are not attacked by pathogens that cause widespread killing. Most of their diseases are associated with accidents and negligence. The major problems are discoloration and decay associated with wounds on low-vigor trees. Many of these problems could be alleviated through better management. And better management depends on better understanding of the problem.

The purpose of this paper is to outline briefly the major diseases of birch. Detailed accounts of the diseases of birch (*Hepting 1969*), the processes that result in discoloration and decay (*Shigo 1967*), and a photo guide to these defects (*Shigo and Larson 1969*) have been published.

Discoloration and Decay

Discoloration and decay are the major internal defects in birch. The processes that result in these defects are initiated by wounds. On low-vigor trees wounds heal more slowly and the defects develop faster.

Some discoloration results from chemical processes initiated by wounds in the absence of microorganisms. When the wounds remain open, microorganisms invade them. The first to infect are bacteria and non-decay fungi. These in turn are followed by decay fungi if conditions favorable for infection persist. A sequence of events and successions of organisms follow wounding. Many factors affect the incidence and severity of the defects. Tree vigor, environment, severity of wound, and time are the most important. In early stages of the processes, the wood is sound but discolored; in later stages it is discolored and altered slightly; and in still later stages it is decayed.

Where It Begins

These are the major beginning points for the processes that result in discoloration and decay:

Branch stubs.—All trees have branches, and all trees lose some branches during their lives. When trees are vigorous and branches are small, openings left by the dead branches heal quickly and no defect forms. This is the rule and not the exception. But the time for branch wounds to heal increases as tree vigor decreases and branch size increases. The longer the healing period, the longer the time for defects to develop. Because tissues formed after wounding are seldom discolored, the diameter of the central core of discolored wood is the diameter of the tree when it was wounded.

Mature trees with small, well-healed stub scars have small central cores of discoloration. Trees with large, poorly healed stub scars have large central cores of discoloration.

Stem stubs.—Defects associated with stem stubs have the same diameters as the stub, and they go downward.

Basal stubs.—Defects associated with basal stubs that are above the root collar are the same as those associated with branch stubs. Basal stubs that join the stem below the root collar seldom cause defects in the main stem. These stubs sometimes are entrance points for root-and butt-infecting organisms.

Sprout stems.—Indicators above the base should be considered first, and then the condition of the base. Small basal sprouts can be cut with little harm to the dominant stem.

Logging wounds.—Wounds on low-vigor trees cause more defect than wounds on high-vigor trees. Wounds on trees with well-healed branch stubs cause less defect than wounds on trees with many poorly healed branch stubs. Less defect is associated with wounds that have rough dark wound faces. Wounds that are not severe usually have white, hard wound faces. More defect is associated with small deep wounds than with large shallow wounds. Insect holes in the wound indicate

slightly more defect than would be expected from an uninfested wound.

The shallow roots of birch make it susceptible to root wounds near skid trails. This is a major cause for the decline of birch in logged areas. These weakened trees are attacked by many weakly parasitic organisms. The danger here is to give these organisms more attention than the primary cause of the decline. Trees, like all organisms, can withstand only so much stress.

Root and butt rots.—Birch will grow on shallow soils and in mixtures with conifers in stands that have had a long history of cutting. The roots of the cut conifers often are infected with *Armillaria mellea*. Here are all the ingredients for a root-rot problem. When the roots of birches are infected and weakened by *A. mellea*, the bases of the trees may crack, a condition called collar crack. Other decay fungi may infect the basal cracks. Infected trees on shallow soils often are broken or uprooted by the wind. Fallen trees with rotted roots are indicators of root-rot areas. Basal cracks on fir also are good indicators of such areas. Birches with collar crack should be cut as soon as possible.

Increment-borer wounds. — Discolorations develop faster in birches than other northern hardwoods. Discolored streaks several feet long can develop in a few years from increment-borer wounds. Increment borers should not be used on high-quality trees.

Red heart.—This term is often used to describe tissues in a wide variety of disease conditions. Yet, red heart does have a specialized meaning: it denotes tissues infected by bacteria alone, or by bacteria and non-decay fungi. The wood has a foul odor and is high in moisture content, pH, and minerals. But the tissues in the early stages of the discoloration processes and the discolored cores of birch that are sound should not be called red heart. Red heart tissues usually collapse upon drying, and a condition called honey-combing sometimes results. The tissues will check along the rings rather than in a radial direction. True red heart should be avoided for quality products.

Cankers.—Target-shaped cankers are common on low-vigor trees. These cankers are good indicators of both poor vigor and poor sites. Young cankered trees should be discriminated against, and when many such trees

occur in an area, the area should be considered unsuitable for growing quality birch.

Most cankers are incited by *Nectria galligena*. The fungus, which usually infects through branch stubs, produces minute bright red lemon-shaped fruit bodies at the margins of the canker.

When trees infected with *Poria obliqua* are cankered by *Nectria galligena*, the black masses of fungus tissue produced by *P. obliqua* sometimes push out through the cankers. These trees are of no value.

Sapsuckers.—The yellow-bellied sapsucker, *Sphyrapicus varius*, causes a variety of injuries on birch. The birds may drill short rows of holes scattered about the bole, which results in streaks of discoloration. Or they may drill rows of holes at one locus on the bole, which may cause discolorations and ring shakes; on paper birch, black swollen bands are indicators of such defects. Or the birds may girdle the tree by drilling many holes around the bole at one locus, which usually kills the tree, particularly if it is weakened first by other agents. Because sapsuckers often nest in aspens, weakened birches near aspen sites are especially vulnerable.

Squirrel wounds.—The red squirrel *Tamiasciurus hudsonicus* bites the thin bark on young trees. These wounds may be infected by microorganisms.

Ambrosia beetle wounds.—The ambrosia beetle, *Xyloterinus politus*, infests trees weakened by various agents. When the weakened trees die, the beetles complete their life cycle in these trees. But, when infested trees recover, the beetles leave. However, the minute increment-borer-like holes remain, and discolorations develop. Small holes in the lenticels are indicators of such defects. These holes may be infested by a scale insect, *Xylococcus betulae*, which woodpeckers peck out for food.

Other Diseases

Seed diseases.—Little is known about the diseases of seeds and seedlings. Many insects feed on the seeds while they are still on the tree. And, many fungi infect the seeds injured by the insects. Some of the more important fungi belong to the genera *Coniothyrium* and *Alternaria*.

Leaf diseases.—Although many fungi infect the leaves of birch, they cause very little damage.

Birch dieback.—The cause of birch dieback has never been determined to everyone's satisfaction. But most workers agree that this disease, which decimated large areas of birch in the Maritime Provinces of Canada and throughout northern New England in the 1930's, was probably initiated by one or more stress factors. The literature on this disease is voluminous.

Principal wood-inhabiting microorganisms in birch.—Three types of microorganisms infect birch: bacteria, non-decay fungi, and decay fungi. In the past, almost all attention was given to the decay fungi. But now some attention is being given to the other microorganisms.

Bacteria are some of the first microorganisms to infect wounds. They abound in wet-wood and are often associated closely with non-decay fungi. The wood that harbors these microorganisms is high in moisture content, pH, and minerals. The principal bacteria are species of *Bacillus* and *Pseudomonas*. Detailed studies are needed to elucidate the role of bacteria in the processes that result in discoloration and decay.

Most of the non-decay fungi are dark in color. Some produce pigments that are water-soluble. Certain metals, especially manganese, affect pigmentation. The principal non-decay fungi are species of *Phialophora* and *Trichocladium canadense*. Other important non-decay fungi in birch are species of *Fusarium* and *Ascochyne*. Species of *Hypoxylon* are also important discoloring fungi. These fungi can also cause decay.

Many decay fungi also infect birch. The most conspicuous of these is *Poria obliqua*, which forms large black masses of fungus material on the infection sites. *Fomes igniarius* forms large black shelf-like fruit bodies. A variety of this fungus, *F. igniarius* var. *laevigatus*, is associated with advanced decay and sunken cankers on mature and overmature trees. The fruit body of this fungus is flat. One of the most important decay fungi, *Pholiota squarrosa-adiposa*, produces fruit bodies that last only a few weeks. The fruit body is light tan to orange and is the shape of a mushroom. Other species of this fungus may also be important.

Stereum murraii and other species of *Stereum* cause some decay. *Polyporus versicolor* will infect the dead wood on wound

faces, as will other species of *Polyporus*. *Lenzites betulinus* is of minor importance.

Armillaria mellea is an important fungus that decays the roots of trees and may also act as a root parasite when the tree is under great stress. The fruit body is a mushroom. Black strands of fungus material, called rhizomorphs or shoestrings, are formed by this fungus. White thin fans of fungus material form under infected bark. An orange moist spot at the base of a tree is a good external sign of infection. *Fomes applanatus*, which produces the so-called artist's conk, will also infect the roots and base of birch.

Fomes pinicola is worth mention because it is one of the few fungi that will infect both hardwoods and conifers. It incites a brown rot in birch. The fruit body is shelf-like and hard, and because it has a tan to light red upper margin, it is sometimes called the red-belt fungus.

Many other fungi attack birch after the tree is killed. Most noticeable are *Fomes fomentarius*, which has a white, hard, hoof-like fruit body; and *Polyporus betulinus*, which has a white, leathery, shelf-like fruit body.

Conclusions

What can we do now with the information we have? For young growing stock we can determine with fair accuracy the poor-risk trees. Some important indicators of such trees are poorly healed branch stubs and cankers. Such trees should be removed from the stand or the stand should receive special attention, including fertilization and pruning. For mature trees we can determine with fair accuracy the internal defects associated with external signs. Then trees should be selected for the highest value product that their quality will yield. These are things that can be done. Of course, whether they are done or not depends on many other factors.

The major responsibility now for the pathologist is to continue to probe more deeply into the diseases of birch to expose further the mysteries and to clarify the confusion in terminology. With better understanding of the diseases, better methods for prevention and control of defects can be established. And this is the key to better management.

Literature Cited

- Hepting, G. H.
1969. DIAGNOSIS OF DISEASES IN AMERICAN FOREST AND SHADE TREES. (In Press).
- Shigo, A. L.
1967. SUCCESSIONS OF ORGANISMS IN DISCOLORATION AND DECAY OF WOOD. Internatl. Rev. Forest Res. II: 237-299. Academic Press.
- Shigo, A. L., and E. vH. Larson.
1969. A PHOTO GUIDE TO THE PATTERNS OF DISCOLORATION AND DECAY IN NORTHERN HARDWOOD TREES. USDA Forest Serv. Res. Paper NE-127, 100 pp. NE. Forest Exp. Sta., Upper Darby, Pa .



INSECT ENEMIES OF BIRCH

by JAMES G. CONKLIN, *Chairman, Department of Entomology,
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NATIVE BIRCHES are subject to attack by insects at all stages of growth from the germinating seedling to the mature tree. All parts of the tree — roots, stem, branches, foliage, and even the developing seed — may be utilized as feeding sites by insects of one kind or another.

An enumeration of the many insects recorded in the literature as feeders on birch might be impressive in numbers but would contribute little to this symposium. Rather, it would seem more appropriate to consider a few representative kinds of insects that are responsible for particular types of injury, to indicate their relative importance and the need for control.

Much of the literature dealing with insect damage to tree seedlings emphasizes damage to conifers, and especially to seedlings in forest nurseries. Insect damage to seedling hardwoods appears to have attracted relatively little attention on the part of research workers up to the present.

Under natural conditions birch seedlings may be destroyed by such root-feeding insects as white grubs, weevil larvae, and wireworms, or by above-ground feeders such as cutworms or miscellaneous other stem or leaf feeders. At this early stage of growth a seedling may be killed by the activity of a single insect, but insect damage to birch seedlings is rarely reported. This may be accounted for by the fact that the suspect insects normally occur in relatively small numbers under forest conditions and have limited mobility during their larval feeding stages, or it may be that the loss of a small percentage of seedlings is more or less taken for granted.

Linteau (1948) found that insects were responsible for a mortality of about 9 percent of yellow birch seedlings. Nearly all of the injury was attributed to the spring cankerworm, *Paleacrita vernata* (Peck), and occurred under conditions of full canopy. No seedlings

were killed in plots in the open or under partial canopy. Godman and Krefting (1960) found that insects caused little damage to yellow birch in upper Michigan. Graham and Knight (1965) caution against too complacent an attitude toward insect pests of seedlings but indicate that applied control measures are rarely necessary except in forest nurseries.

Beyond the seedling stage, the birches— in common with other hardwoods—are fed upon by an almost endless variety of insects. By far the great majority occurring on yellow or paper birch are scarcely known outside the field of taxonomy. Some, because of their frequent occurrence in outbreak form or because of obviously destructive feeding habits, have long occupied the attention of workers in forest entomology and timber improvement.

Root-feeding insects ordinarily cause little damage to birch saplings or to the older trees. The extensive root system is able to tolerate without serious effect the feeding of the relatively limited population of underground insects.

The birch canopy provides a particularly attractive feeding ground for a large array of insects. Some, having a piercing beak or proboscis, suck the sap from the leaves. Others, having mandibulate mouth parts, mine within the leaf tissues, or devour the entire leaf structure.

The sap-sucking insects belong to two major groups, the Hemiptera and the Homoptera. The Hemiptera are represented especially by the lace bugs (Tingidae) and the plant bugs (Miridae). A number of species of lace bugs are known to feed on birch. They sometimes occur in great numbers, and because of their sedentary habits are readily observed. The young nymphs feed on the underside of the leaves, the adults on either surface. Although they will feed on trees of all sizes, they seem to prefer saplings and pole-sized

trees (Graham and Knight 1965). Drake (1922) studied the birch tingid *Corythuca pallipes* Parshley in the Cranberry Lake area in New York, and concluded that it was the most injurious leaf feeder on yellow birch in that vicinity.

Little information is available on the mirid plant bugs that feed on birch. So far as known they overwinter as adults and lay their eggs in the leaf veins or stems. Under forest conditions the plant bugs occur in relatively small numbers and are not considered to be important pests of trees.

The leafhoppers that occur on birches have attracted only a limited amount of research attention even though certain species are sometimes numerous over wide areas. Varty (1963, 1964) indicated that the species feeding on birch occur chiefly in the genera *Oncopsis* and *Erythroneura*. The biologies and host-relationships of the leafhoppers of forest trees warrant careful study since a number of species belonging to that family are known vectors of important plant diseases.

Foliage-infesting aphids often appear on birches over extensive areas and in great abundance. In variety of species as well as individuals they are the dominant group of sap-sucking insects. Birch aphids do not kill trees directly (Graham and Knight 1965) and their abundance in a given locality may fluctuate greatly from year to year. Under conditions of heavy aphid populations they interfere with the normal functioning of the foliage and thus weaken the trees.

Investigations of birch aphids, largely of a survey nature, have been carried on in the Maritime provinces of New Brunswick by Varty (1963, 1964) and in Quebec by Quedneau (1966).

Among the chewing insects of birch foliage the birch skeletonizer, *Bucculatrix canadensisella* Chambers, periodically appears over extensive areas in outbreak numbers, causing complete defoliation (Simpson 1932). The tiny moths are most numerous in July, and the young larvae start off as miners within the leaf. After 3 or 4 weeks they emerge from their mines and after molting feed for another 3 or 4 weeks on the underside of the leaves as skeletonizers, eating only the softer leaf tissues. Since defoliation by this species occurs late in the growing season, its effect on

growth is not likely to become evident until the following year.

At least three species of leaf-mining sawflies occur commonly on birch. Probably the most widely observed is *Fenusa pusilla* (Lep.). Year after year this species is likely to be abundant over wide areas. It prefers gray birch, although it does attack white birch also. The birch leaf miner appears within the first expanding leaves in the spring and may have two generations and, in some areas, three complete generations a year. The biology of this species was reported in detail by Friend (1927, 1933).

The birch leaf-mining sawfly *Heterarthrus memoratus* (Fallén) shows a preference for paper birch. In severely infested trees there may be noticeable killing of top branches, annual growth is reduced, and the quality of the wood may be inferior (Craighead 1950). The species has a single generation annually, but because it is parthenogenetic it is capable of rapidly developing very large populations.

A third species, *Profenusa thomsoni* (Konow), prefers paper and yellow birch. In the past it has been confused with other species found on birch. Recent studies by Martin (1960) show that the adults begin to appear about the middle of July, and larval feeding is most evident in August and September. Males are unknown, indicating that the species is parthenogenetic. Martin considered that this sawfly causes little or no noticeable injury to birch because of the lateness of the larval feeding period.

The typical defoliators are the insects that devour the entire leaf, or most of it. The more important kinds on birch are the larvae of Lepidoptera, such as the forest tent caterpillar, *Malacosoma disstria* Hbn., and the saddled prominent, *Heterocampa guttivitta* (Walk.). The larvae of certain sawflies, and certain Coleoptera, mostly chrysomelid leaf beetles and their larvae, are sometimes numerous enough to cause noticeable defoliation.

The forest tent caterpillar is perhaps the best known and most important of the defoliators attacking birch, even though its most spectacular outbreaks are ordinarily associated with other hardwoods (Anderson 1944, Craighead 1950, Graham and Knight 1965, Redmond 1957). Studies in Minnesota by Hodson (1941) and in Ontario by Sippell (1962) indicate that major outbreaks have

occurred in the past about every 10 years, but the interval is not consistent. The last major outbreak in New Hampshire occurred over 30 years ago.

Barter and Cameron (1955) studied the effects of forest tent caterpillar defoliation on aspen and paper birch. They found that radial growth in paper birch was reduced 22, 68, and 86 percent compared with 23, 87, and 52 percent defoliation in the 3 consecutive years of the outbreak. Growth retardation following defoliation was more pronounced on birch than on aspen even though defoliation of birch was less and occurred later in the season. They reported that 21 percent of the birch had died since the start of the outbreak, largely as a result of bronze birch borer attack on the defoliation-weakened trees.

It is generally known that vigorous hardwoods, unlike the conifers, may survive three or more consecutive years of practically complete defoliation. That is true largely because of the ability of hardwoods to refoliate immediately after defoliation occurs. The effect on growth and vigor of the tree is influenced not only by the amount of defoliation but also when it occurs.

Although the immediate effects of defoliation are measurable to some extent in terms of reduced growth increment, the indirect effects may be even more important but much more difficult to express. Defoliating insects appear to be incapable of direct killing of birch stands, but by weakening the trees they may induce heavy attack by secondary insects such as bark beetles and ambrosia beetles and various borers. When that happens the tree is usually doomed.

The bronze birch borer, *Agrilus anxius* Dru., is by far the most important of the borers affecting paper and yellow birch. Ordinarily it occurs in modest numbers, breeding in storm-damaged or otherwise injured, overmature, or decadent trees. Throughout much of its range it has a 2-year life cycle, although in some situations it may complete its development in 1 year.

The devastating birch dieback outbreak that began to develop in the late 1930's focused

attention on the bronze birch borer, which was then appearing in unprecedented numbers in the affected stands. The fact that many young birches were being attacked by the borer led to some speculation as to whether the insect was solely responsible for death of the trees.

Early studies of the dieback problem by Balch and Prebble (1940) indicated that in some areas previous defoliation of birch stands in 1927 and 1928 had weakened the trees, thus favoring an increase in borer activity. Hawbolt and Skolko (1948) noted that many yellow birches were already in advanced stages of decline without having been attacked by the borer. The findings of these and other investigators of the problem were reviewed by Redmond (1957). There is general agreement that the bronze birch borer played a secondary role in birch dieback, although as Barter (1957) had indicated, its activity may have been an important factor in determining whether a tree died or recovered from a serious decline.

In the management of birch stands to prevent bronze birch borer attack, the recommendations of Balch (1944) and Redmond (1957) appear to be equally applicable today. Major emphasis should be placed on the prompt elimination of weakened and mature trees. Operations should be planned so that vigorous trees are not injured or subjected to overexposure to sun and wind.

It would appear that, up to the present, the use of insecticides on birch stands has seldom been found necessary except during outbreaks of defoliators such as the forest tent caterpillar, the saddled prominent, or the gypsy moth. Even then, the treatment of birch has apparently been incidental to the need for treating other hardwoods, which are preferred hosts of these insects.

That is not to suggest that insecticides can be dispensed with in the management of birch stands in the future. On the contrary, the continued depletion of the older stands and the need to maintain vigorous growth in the younger trees may well require more frequent use of insecticides than has been true in the past.

Literature Cited

- Anderson, R. F.
1944. THE RELATION BETWEEN HOST CONDITION AND ATTACKS BY THE BRONZE BIRCH BORER. J. Econ. Entomol. 37: 588-596.
- Balch, R. E., and J. S. Prebble.
1940. THE BRONZE BIRCH BORER AND ITS RELATION TO THE DYING OF BIRCH IN NEW BRUNSWICK FORESTS. Forestry Chron. 16: 179-201.
- Barter, G. W., and D. G. Cameron.
1955. SOME EFFECTS OF DEFOLIATION BY THE FOREST TENT CATERPILLAR. Can. Dep. Agr. Sci. Serv., Bi-Mo. Prog. Rep. 11(6): 1.
- Barter, G. W.
1957. STUDIES OF THE BRONZE BIRCH BORER *Agilus anxius* GORY IN NEW BRUNSWICK. Can. Entomol. 89: 12-36.
- Craighead, F. C.
1950. INSECT ENEMIES OF EASTERN FORESTS. U.S. Dep. Agr. Misc. Pub. 657. 679 pp.
- Drake, C. J.
1922. THE LIFE-HISTORY OF THE BIRCH TINGID *Corythuca pallipes* PARSHLEY. N.Y. State Coll. Forestry (Syracuse) Tech. Pub. 16 vol. 22: 111-116.
- Friend, R. B.
1927. THE BIOLOGY OF THE BIRCH LEAF SKELETONIZER *Bucculatrix canadensisella* CHAMBERS. Conn. Agr. Exp. Sta. Bull. 288.
- Friend, R. B.
1933. THE BIRCH LEAF-MINING SAWFLY *Fenusa pumila* KLUG. Conn. Agr. Exp. Sta. Bull. 348: 293-364.
- Godman, R. M., and L. W. Krefling.
1960. FACTORS IMPORTANT TO YELLOW BIRCH ESTABLISHMENT IN UPPER MICHIGAN. Ecol. 41: 18-28.
- Graham, K.
1963. CONCEPTS OF FOREST ENTOMOLOGY. 388 pp. Reinhold Publishing Corp., New York.
- Graham, S. A., and F. B. Knight.
1965. PRINCIPLES OF FOREST ENTOMOLOGY. 4th ed., 417 pp. McGraw-Hill, New York.
- Hawboldt, L. S.
1947. ASPECTS OF THE YELLOW BIRCH DIEBACK IN NOVA SCOTIA. J. Forestry 45: 412-422.
- Hawboldt, L. S., and A. J. Skolko.
1948. INVESTIGATIONS OF YELLOW BIRCH DIEBACK IN NOVA SCOTIA IN 1947. J. Forestry 46: 659-671.
- Hodson, A. C.
1941. AN ECOLOGICAL STUDY OF THE FOREST TENT CATERPILLAR, *Malacosoma disstria* HB., IN NORTHERN MINNESOTA. Minn. Agr. Exp. Sta. Tech. Bull. 148.
- Lindquist, O. H.
1959. A KEY TO THE LARVAE OF LEAF-MINING SAWFLIES ON BIRCH IN ONTARIO WITH NOTES ON THEIR BIOLOGY. Can. Entomol. 91: 625-627.
- Linteau, A.
1948. FACTORS AFFECTING GERMINATION AND SURVIVAL OF YELLOW BIRCH IN QUEBEC. Forestry Chron. 24: 27-36.
- Martin, J. L.
1960. THE BIONOMICS OF *Profenusa thomsoni* (KONOW) A LEAF-MINING SAWFLY ON *Betula* SPP. Can. Entomol. 92: 376-384.
- Quednau, F. W.
1966. A LIST OF APHIDS FROM QUEBEC WITH TWO NEW SPECIES. Can. Entomol. 98: 415-430.
- Raizenne, H.
1957. FOREST SAWFLIES OF SOUTHERN ONTARIO AND THEIR PARASITES. Can. Dep. Agr. Pub. 1009. 44 pp.
- Redmond, D. R.
1957. THE FUTURE OF BIRCH FROM THE VIEW-POINT OF DISEASES AND INSECTS. Forestry Chron. 33: 25-30.
- Simpson, L. J. M.
1932. EFFECT OF THE BIRCH LEAF SKELETONIZER AND SAWFLY LEAF MINER ON THE GROWTH OF BIRCHES IN NEW BRUNSWICK. Forestry Chron. 8: 89-92.
- Sippell, W. L.
1962. OUTBREAKS OF THE FOREST TENT CATERPILLAR, *Malacosoma disstria* HBN., A PERIODIC DEFOLIATOR OF BROAD-LEAVED TREES IN ONTARIO. Can. Entomol. 94: 408-416.
- Snyder, T. E. 1927.
DEFECTS IN TIMBER CAUSED BY INSECTS. U.S. Dep. Agr. Bull. 1490. 47 pp.
- Varty, I. W.
1963. A SURVEY OF THE SUCKING INSECTS OF BIRCHES IN THE MARITIME PROVINCES. Can. Entomol. 95: 1097-1106.
- Varty, I. W.
1964. THE MORPHOLOGY, LIFE HISTORY AND HABITS OF *Betulaphis quadrituberculata* (KALT.) ON BIRCH IN NEW BRUNSWICK. Can. Entomol. 96: 1172-1184.
- Wong, H. R.
1966. A NEW SPECIES OF *Allantus* PANZER ON BIRCH (HYMENOPTERA. TENTHREDINIDAE). Can. Entomol. 98: 852-854.

ANIMAL DAMAGE TO BIRCH

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A RELATIVELY FEW animal species are responsible for most of the reported damage to the birches. White-tailed deer, yellow-bellied sapsuckers, porcupines, moose, and hares are the major animals involved. We will review reports of damage, discuss the underlying causes, and describe possible methods of control.

For example, heavy deer browsing that eliminates birch regeneration can be especially damaging, regardless of how well birch is managed. Here the immediate action may well be direct control of the deer population; but the basic long-term need is for action through a better understanding of deer and plant ecology.

WHITE-TAILED DEER (*Odocoileus virginianus*)

Yellow and paper birch are important browse species for deer (Hosley 1956, Stiteler and Shaw 1966). Yellow birch is a preferred food of deer in northern forests; paper birch in these forests is a second-choice deer food, but it is much used by deer in some sections (Hosley 1956). Browsing of yellow birch by deer in the United States and Canada often results in the mortality or reduced height of seedlings, both natural regeneration and plantations (Christ 1959, Curtis and Rushmore 1958, Drinkwater 1957, Eyre and Zillgitt 1953, Jacobs 1965, Jarvis 1957, Stoeckeler et al. 1957, von Althen 1964, Wang 1968). The effects of deer browsing on populations of yellow birch seedlings may be so severe as to prevent regeneration (Graham 1954). Paper birch apparently is affected similarly by heavy browsing (Bjorkbom 1967 and 1968, Graham 1958, Stoeckeler 1955), but less information is available on the subject of deer damage to this species.

Yellow birch is more resistant to the effects of deer browsing than paper birch, and both species are less resistant than red maple (Gill 1957). Browse-clipping studies of individual seedlings indicate that if paper birch is to be managed for timber, only light deer browsing can be permitted (Aldous 1952). Yellow birch apparently has not been studied from this aspect, nor is there available information about the form of sapling- and pole-size yellow and paper birch that were browsed as seedlings.

Discussion

Most of the above reports are from studies made after damage to commercial tree species was observed over large areas. The gross effects of very heavy browsing by deer (hedged seedlings and browse lines) are now well known from some of these and other reports. Under such conditions, regeneration of yellow and paper birch is not likely to survive unless the deer population is controlled.

Excessive deer browsing of commercially important species occurs when there is a severe imbalance between the deer population and its food supply. Under normal conditions the deer spread their feeding over a large number of plant species, most of which are non-commercial species. The effect of slight overbrowsing on any one species is usually self-correcting under these conditions, because the deer select their food from among more abundant species.

However, when the deer population is too large, the effects of overbrowsing begin to accumulate. The incidence, and then the intensity, of browsing on noncommercial species slowly increase until heavy mortality within species occurs. In the meantime, browsing on commercial tree species increases

as some of the noncommercial browse plants become scarce. First the height of seedlings is reduced until there is a preponderance of browsed seedlings entirely within the reach of deer; the form of seedlings is often changed to produce a variety of undesirable conditions. Then the rate of mortality among seedlings increases until it exceeds the rate of replacement by new seedlings. Deer preferences among food species gradually disappear; finally, it becomes only a matter of which food species are most resistant to the effects of heavy browsing and which among the once low-preference browse species are most digestible. Under these conditions, deer can easily prevent the survival of all but a few scattered woody browse plants.

Large disturbances of the vegetation can change the order of events to produce even greater modification of this somewhat classic pattern. Fire, blowdowns, land clearing, farm abandonment, changes in deer harvest regulations, and the management of timber are examples of natural events and human activities that can change the pattern in different ways, even to the extent of reversing it. These influences probably are responsible for some of the place-to-place variation in the amount of deer damage reported. They also increase the difficulty of determining the underlying cause of deer damage.

Although an overpopulation of deer is almost always suggested as the reason for excessive damage to some particular valuable species—such as birch—this may not be the underlying problem. The problem may be a preference by deer for the particular species of interest, a high susceptibility of that species to the effects of browsing, a low density of seedlings of that species before the damage was reported, a deer range in poor condition, or some complex mixture of several of these factors.

Thus the term "overpopulation of deer" is a relative one. Damage to seedlings of a single commercial tree species, to those of several commercial species, or to all woody browse species may each be attributed to an overpopulation of deer, yet each might represent a deer population of different size. It depends upon where the primary interest lies.

Influence of Timber Management

Timber-management activities sometimes lead to deer damage of commercial tree

species. Clearcutting in patches for birch regeneration, for example, produces islands of new and concentrated food supplies, and deer are invariably attracted to them by the browse from felled trees and later by the new growth of plants. Our own general observations of deer use of clearcut patches in the northern hardwood type lead us to believe that the patches virtually funnel deer to this new food supply. The patches seemed to constitute naturally baited areas for deer because the variety and concentration of plants provide an excellent source of browse that can be obtained with minimum effort.

We suggest that the successful establishment of yellow and paper birch in clearcut patches may depend largely on two factors: (1) the level of deer damage in the general area of the patches immediately before cutting, and (2) the density and stocking rate of woody browse plants, including yellow and paper birch, in the clearcut patches two or three growing seasons after cutting.

Unless deer damage before cutting is at a very low level, the density of woody browse stems in the patches may have to be very high (at least 200,000 stems per acre?). Even if damage before cutting is at a low level, a density of at least 100,000 stems per acre might be necessary because deer browsing is still likely to be concentrated in the clearcut patches. If deer damage is at a low level before cutting and the area density of browse stems in the patches is also low, the effects of concentrated browsing may prevent or at the very least delay the regeneration of yellow and paper birch.

Deer Damage Control

The best control of deer damage to yellow and paper birch is damage prevention. This requires knowledge of: the density of the deer population; the condition of the deer; the condition of the deer food resource (incidence of browsing and area density of important deer forage species); and the density per acre and intensity of browsing of reproduction of commercial tree species.

Browse information may be collected by the use of a trend survey such as currently used on the National Forests of the Northeast (*Shaw and Stiteler 1962*). A count of deer pellet groups on plots since the last leaf fall (*Krefting and Shiue 1960*) will yield an index to the deer population in the areas of

interest. And the condition of deer may be determined from the examinations of deer made by game department biologists during the annual hunting season. Evaluation of this information is necessarily subjective, but a little experience will permit reasonably accurate evaluations of the need for preventive action.

Prevention of damage to yellow and paper birch reproduction may be accomplished in one of the following ways: (1) increase the deer hunting pressure within existing deer harvest regulations, (2) utilize special habitat practices to increase the yield of deer foods, (3) increase the reduction in the level of the winter deer population, (4) fence to exclude deer from regeneration areas, and (5) develop systems of deer-habitat management.

Measures to increase hunting pressure.—Hunting pressures can be increased by: providing good access roads; using signs to designate the areas and to identify all interior access roads and trails; providing hunters with scale maps of the areas, showing roads, parking areas, trails, cutover stands, permanent openings, waterways, and all other significant features to facilitate travel and orientation within the areas; and publicizing the availability of the area for deer hunting.

Special habitat practices.—There are several special practices that may reduce the damage hazard to reproduction. Clearcutting buffer areas in stands near the regeneration cuttings may dilute the impact of deer browsing. Also, timber-stand-improvement browse cuttings may be made in poletimber stands (Jordan *et al.* 1965). In this practice all stems except the future crop trees are felled in winter to produce a new source of browse in the tops of felled trees and later in the stump sprouts and new growth of understory vegetation.

Almost any practice that will increase the yield of deer food may reduce the damage hazard. However, an increase in food production may also lead to an increase in deer production; thus the deer population must be held stable through adequate deer harvests.

Reduction in the winter deer population.—If the cause of deer damage is obviously an overpopulation of deer, there is also likely to be evidence of widespread damage and a history of overbrowsing of commercial and non-commercial plant species alike. The best

available immediate solution is a heavy reduction in the winter deer herd. If this can be accomplished, there is likely to be a dramatic improvement in the condition of the deer (Hesseltun *et al.* 1965), but probably a much slower recovery of the range. There may also be some relief from damage to regeneration after clearcutting. And use of special habitat practices may hasten range recovery.

Damage that occurs in the vicinity of winter deer yards is a special case. Here the primary interest is in the survival of the deer rather than in reducing their numbers. Cutting practices to increase the production of hardwood deer browse within and adjacent to yarding areas has been described (Laramie 1968). The solution of deer food problems in and adjacent to yarding areas probably would also reduce damage to timber regeneration in the vicinity of such areas.

Fencing to exclude deer.—This is a direct action that can be taken to prevent or to control deer damage to yellow and paper birch. Fencing would seem to have an application only in special cases: for example, areas under artificial regeneration.

There is no evidence that fencing has yet been used in the management of yellow and paper birch. However, the use of fencing to prevent deer damage to timber regeneration in European countries is well known, and different kinds of fencing have been tested experimentally in the United States for their effectiveness in excluding deer (Blaisdell and Hubbard 1956, Jones and Longhurst 1958, Longhurst *et al.* 1962). Fences have also been used to protect research study plots (Grisez 1959a and 1959b, Jordan and Sharp 1967, Krefting 1951).

Fences are generally of two kinds: high fence (6 to 8 feet), and low fence (about 4.5 feet) to which an outrigger is attached at an angle of 45° or less. Wooden or steel posts, or trees, may be used to support the fence. The total direct cost per linear foot of fencing will depend on the strength and durability of the materials used and the labor costs to erect and maintain the fence.

It may be assumed that the cost of fencing today is at least as high as 33 cents per linear foot. At this rate the cost of fencing a 10-acre clearcut would be \$871 or \$87 per acre; the cost of fencing a 100-acre clearcut

would be \$2,761 or \$28 per acre. Thus, because of its high cost, fencing in timber management should be considered as a last resort. Moreover, fencing may even add to the problem by reducing the acreage available for deer browsing.

Systems of deer habitat management.—Fencing, emergency feeding of deer, or heavy reduction in the winter deer population all fail to correct the cause of overbrowsing. Such alternatives are sometimes the only practical ones available where deer damage is a serious matter, though none of them offers a real solution to the problem of coordinating the production of timber and the production of deer. Any long-term solution of this problem is likely to require that any expedient action to control deer damage be accompanied by concerted efforts to contain the problem, if at all possible, through both improved silvicultural methods and the development of systems of deer habitat management. Admittedly, the knowledge needed to develop complete systems of deer-habitat management is not yet available, but planned management of the deer population through habitat manipulation will be required to achieve a permanent solution to the browsing problem in timber management.

YELLOW-BELLIED SAPSUCKER **(*Sphyrapicus varius varius* L.)**

Sapsucker damage occurs when the birds drill holes in the bark of living trees to feed upon sap and bark tissues. On severely damaged trees the drilling forms a pattern of rows and columns of closely spaced holes, forming a band that extends partly or completely around the bole (*Kilham 1964, Shigo 1963*). In the severest cases, the many individual wounds apparently combine to girdle the tree. Other damaging effects of drilling are decay, formation of cavities, stain, curly grain, adventitious branching, reduction in tree vigor (*McAtee 1911, Rushmore 1969*), and rinkshake (*Jorgensen and Lecznar 1964, Shigo 1963*).

This sapsucker is the only one of four subspecies that occurs in eastern North America (*Howell 1952, McAtee 1911*). Its summer range extends from the East Coast nearly to the West Coast, from about 40° to 50° N. latitude in the East and about 52°

to 63° N. in the West, as well as along the Appalachian Mountains south to about 35° N. Approximately two-thirds of the summer range in eastern North America lies within the northern forested regions. Sapsuckers are here from about mid-April until late September or early October.

Damage to Yellow and Paper Birch

Sapsucker damage to orchard, shade, and forest trees has been recognized for more than a century. But it was not until the early 1900's that the scope and importance of the damage to forest trees became generally known (*McAtee 1911*). At that time it was estimated that sapsuckers damaged at least 10 percent of the trees within their range, and that in some areas more than 90 percent of the trees sustained damage.

Paper, yellow, and gray birch are the favorite food species of the sapsucker on the Penobscot Experimental Forest in Maine (*Rushmore 1969*). A similar preference for these species was observed in New Hampshire (*Kilham 1964*). Paper birch appeared to be the most preferred among all species on the Penobscot Forest. Of 102 paper birch trees that sapsuckers had already damaged by 1964, 52 had died or were near death. It was expected that additional mortality will occur among the survivors in succeeding years. Intensive feeding occurred on paper birch trees ranging from 4 to 16 inches d.b.h.

Sapsuckers commonly fed on the same birch trees in successive years (*Rushmore 1969*). When a tree was killed, the birds transferred their intensive feeding to other trees. Sapsuckers are reported to be attracted to trees that have been wounded by other agents (*Kilham 1964*), but this is not an essential condition in their selection of trees (*Rushmore 1969*). Many birch trees were tapped in the process of selecting favorite trees, in casual feeding, and while members of a family group waited for an adult bird to leave a favorite tree.

Sapsuckers were found to be highly territorial, and to do severe damage to birches within their territories. A study of 23 territories on the Penobscot Forest showed that they averaged 7.6 acres in size. The same family of sapsuckers occupied a territory throughout the summer. And the same terri-

tories were used year after year. A survey of the Forest in 1966 indicated that sapsuckers used about 47 percent of the area.

In general, sapsuckers exhibited a seasonal pattern of feeding on the Penobscot Forest. Beginning in early spring, they fed on hemlock, spruce, and aspen for several weeks. From May to at least mid-June, red maple was heavily used. By late May the birches had become increasingly important and heavy use of these continued throughout the summer. In dry years, sapsuckers turned back to feeding on hemlocks, but later returned to the birches. The birds commonly drilled into branches of birch trees when the trunk no longer yielded sap. At times, sapsuckers removed the bark from between vertical columns of drill holes, enlarging the holes to form strips about 0.5 to 1.25 inches wide and several inches long.

The rate of mortality among trees damaged by sapsuckers was much higher among hardwood species, presumably because these were used over a longer period of time. Mortality rates among damaged trees in a sample of nesting territories was as follows: gray birch 67 percent; paper birch 51 percent; red maple 40 percent; red spruce 3 percent; and hemlock 1 percent.

Discussion

The impact of sapsucker damage on timber-management objectives for yellow and paper birch has not been determined. We do know that sapsuckers are common summer residents in northern forested areas, that birch species apparently are a preferred source of food, and that damage is common. Thus mortality, reduced growth, and reduction in log grade probably constitute a real loss in the yield and quality of these species.

Information about the extent of sapsucker damage and sapsucker-induced mortality is being collected as part of the current forest survey of Maine. When completed, this survey will permit estimates of the extent of sapsucker damage in Maine, and may show whether or not remedial action is necessary.

Sapsucker Damage Control

No sapsucker control efforts have been attempted in northern forests, nor has much research been devoted to the development of control methods. If control proves desirable,

the possibilities of silvicultural control need to be investigated.

For example, even-aged management tends to reduce the amount of hemlock; since hemlock is heavily used by sapsuckers in the spring when they are establishing their territories, sapsucker damage may be reduced under even-aged management or in stands low in proportion of hemlock. Even-aged stands may also have fewer trees suitable for the construction of nest holes, and thus may be less subject to damage. And we need to know whether the removal of heavily damaged favorite trees in a TSI or thinning operation will result in damage to new trees in that stand or in the relocation of sapsuckers to other stands.

Manipulation of sapsucker habitat through silvicultural techniques will almost certainly be more effective than any type of direct control and much more acceptable to non-timber users of our forest lands.

OTHER ANIMAL SPECIES

The total damage to yellow and paper birch by other species may ultimately prove to be greater than that caused by deer and sapsuckers. But published reports of damage by other species are mostly about local occurrences; there are relatively few of them for each species; and they usually describe the kind of damage that is highly visible, such as evidence of overbrowsing, girdling, or bark stripping. What is generally lacking are reports on surveys of the incidence and effects of damage to forest stands over large areas, including the kinds of damage that are less visible and less easily identified—such as the loss of small seedlings and seeds as a direct result of animal feeding. This kind of damage is not often reported, yet it may be important.

The following animal species are either known to cause damage to yellow and paper birch, or they may be a potential cause of damage because of their feeding habits.

PORCUPINE (*Erethizon dorsatum*)

Damage to hardwood trees of any size—from sapling to sawtimber—occurs when porcupines debark portions of the stem or main branches to feed on the cambium. Debarking occurs mostly in winter and often results in

lowering the quality of timber and in reducing growth and merchantable height. In some instances the trees are killed. Damaged trees may be weakened or deformed and made susceptible to breakage and to insect and disease attacks (*Hepting and Jemison 1958, Krefting et al. 1962*).

From a study of porcupine damage in a second-growth northern hardwood-hemlock stand in Wisconsin, it was found that yellow birch was among the three species that sustained the greatest economic loss (*Krefting et al. 1962*). The three species comprised about 84 percent of the total number of trees in the stand. The damage to yellow birch was heaviest in trees of small sawtimber size. Paper birch was not damaged. In the same report it was estimated that, on National Forests in the Lake States, 534,000 acres sustained heavy and medium porcupine damage in 1960.

Evidence of feeding over a period of years has been found (*Brander and Stearns 1963*), indicating that porcupines tend to return to the same trees. It was concluded that, with a stable population of porcupines, only a small number of previously unused trees would be gnawed in any single winter. However, populations larger than 1 porcupine per 10 acres may result in serious damage to northern hardwood timber (*Stoeckeler 1950*).

Organized hunting (*Krefting et al. 1962*) and use of sodium arsenite implanted in apples (*Dodge 1959*) have both been reported as successful temporary measures to control porcupine damage. But biological methods of control would seem to be preferable.

The fisher (*Martes pennanti*), restocked on the Nicolet and Ottawa National Forests in Wisconsin and Michigan, apparently is becoming effective in controlling porcupines there (*Olson 1966*). The same author reported that the number of porcupines had declined in those areas of the Adirondacks in New York where the fisher had made a comeback, but that porcupines were still abundant in the Catskill Mountains where the fisher did not occur. And porcupines of the Superior National Forest in Minnesota were reported no longer to be a problem after the fisher made a natural recovery.

A long-term study of the fisher in Maine led to an observation that in places where they were abundant for 10 or 12 years, the

porcupine was scarce (*Coulter 1959*). However, the author also cautioned against restocking fishers in any area without thorough evaluation of objectives, land uses, attitudes, and prospects for control by fur trappers (*Coulter 1966*).

MOOSE (*Alces alces*)

Birch species are important in the diet of moose. In Newfoundland, paper birch is a favorite browse species (*Bergerud 1968, Dodds 1960, Pimlott 1965*). It was overbrowsed where the moose population was high and its growth was severely retarded in cutover areas. In Michigan, the effects of heavy browsing by moose threatened to eliminate paper birch from a timber stand (*Aldous 1947*). In Ontario, severe moose and deer browsing occurred on yellow birch (*Wang 1968*).

It seems likely that, as in the case of deer, high populations of moose will adversely affect the growth and establishment of seedling stands of birch. A density of 6 moose per square mile was tentatively considered to be satisfactory in good moose range in central Newfoundland (*Bergerud 1968*).

SNOWSHOE HARE (*Lepus americanus*)

Hares may damage seedlings by clipping the twigs, terminal shoot, or stem, or by gnawing the bark so that the stem is partially or completely girdled. In Newfoundland, paper birch was a preferred species in the diet of hares (*Dodds 1960*). It was found that hares and moose competed for the same plants, and that serious competition between the two species probably occurs only in cutover areas where fir and birch are dominants. There was evidence, too, that a reduction in coniferous cover in cutover areas discouraged their use by hares in winter.

In general, hare damage to birch species may be presumed to be a rather common occurrence, but only because of the rather voluminous reports of hare damage to coniferous species that often grow in close association with the birches, and because there are reports of hare damage to planted birch (*Jarvis 1957, Stoeckeler 1955, von Althen 1964*) and to natural regeneration on research plots (*Wang 1968*).

Small Mammals and Birds

Relatively little is known about the influence of small-animal feeding on yellow and paper birch. Reports of damage to tree seedlings and losses of seeds through the feeding activities of mice refer mostly to coniferous species, possibly because of greater past interest in problems of natural and artificial regeneration of these species. However, it may be indicative of the growing interest in regeneration of birch species that plantings of paper birch were reported to be damaged by the meadow vole *Microtus pennsylvanicus* (Bjorkbom 1968, Stoeckeler 1955). Because these voles are widely distributed in the grassy field type, birch may be damaged when planted in this type. *Peromyscus* spp. very likely also feed on birch seeds, because they have a versatile diet and they also utilize the seeds of several hardwood species that grow in close association with the birches (Hamilton 1939, Martin et al. 1951).

Red squirrels *Tamiasciurus hudsonicus* were found to inflict severe damage on paper birch in Alaska by girdling the trees (Lutz 1956). And in New York they were reported to utilize yellow and paper birch seeds (Hatt 1929). The junior author observed red squirrels collecting and storing the matured strobiles of yellow birch and also gnawing the bark of saplings of this species to obtain sap.

Studies and observations of feeding birds show that at least 8 species of songbirds eat the seeds of birch (Curtis and Rushmore 1958, Gabrielson 1924, Martin et al. 1951, Saunders 1929, Silloway 1923). Grouse and rose-breasted grosbeaks feed on the buds (Crichton 1963, Martin et al. 1951, McAtee 1908).

THE QUESTION OF CONTROL

The purpose of controlling animal damage is primarily to control economic damage. For

example, if the stocking rate of birch seedlings is thought to be satisfactory despite losses of seedlings from mice, hare, and deer feeding, then economic damage has not occurred, so control is not necessary. If the effect of sapsucker and porcupine feeding in a sapling stand does not later reduce what is thought to be a satisfactory stocking rate, then technically, at least, there has been no damage. However, if porcupines later debark future crop trees, this is very clearly animal damage, and control may be warranted.

The point of this is that there may be a continuum of animal feeding on birch species—in this example, from mice to porcupines. But damage cannot be recognized as such until it is clear that the effect of an animal's feeding has lowered the yield or quality of wood in future crop trees. This may be determined easily after the crop trees have been selected, but it may be very difficult to determine in seedling stands.

The common practice in animal-damage control is to take direct action against the animal regardless of kind of damage or the stage of tree growth. It is direct action against the direct cause. And by the time damage has occurred it may well be the only practical alternative available for immediate damage control. But it is also rather short-sighted. It is analogous to fighting forest fires to prevent them. It bypasses all of the causal relationships in nature that led to the damage.

Only when the ecology or causal relationships that precede damage are better understood and controlled are we likely to achieve permanent and effective control. Such control should be possible through a planned program of habitat manipulation that maintains a balance between vegetation and animal populations, to permit coordinated production of both timber and wildlife.

LITERATURE CITED

- Aldous, Shaler E.
1947. SOME FOREST-WILDLIFE PROBLEMS IN THE LAKE STATES. USDA Forest Serv. Lake States For. Exp. Sta. Sta. Paper 6, 11 pp. St. Paul, Minn.
- Aldous, Shaler E.
1952. DEER BROWSE CLIPPING STUDY IN THE LAKE STATES REGION. J. Wildlife Manage. 16: 401-409.
- Bergerud, Arthur T.
1968. MOOSE DAMAGE TO BALSAM FIR-WHITE BIRCH FORESTS IN CENTRAL NEWFOUNDLAND. J. Wildlife Manage. 32: 729-746.
- Bjorkbom, John C.
1967. SEEDBED-PREPARATION METHODS FOR PAPER BIRCH. USDA Forest Serv. Res. Paper NE-79, 15 pp., illus. NE Forest Exp. Sta., Upper Darby, Pa.
- Bjorkbom, John C.
1968. PLANTING PAPER BIRCH IN OLD FIELDS IN MAINE. USDA Forest Serv. Res. Paper NE-103, 12 pp. NE. Forest Exp. Sta., Upper Darby, Pa.
- Blaisdell, James A., and Richard C. Hubbard.
1956. AN "OUTRIGGER" TYPE DEER FENCE. USDA Forest Serv. Calif. Forest and Range Exp. Sta. Forest Res. Note 108. 3 pp., illus.
- Brander, Robert, and Forest W. Stearns.
1963. PORCUPINE WINTER FEEDING ACTIVITY IN MERCHANTABLE STANDS OF NORTHERN HARDWOOD-HEMLOCK. USDA Forest Serv. Res. Note LS-16, 2 pp. Lake States Forest Exp. Sta. St. Paul, Minn.
- Crichton, V.
1963. AUTUMN AND WINTER FOODS OF THE SPRUCE GROUSE IN CENTRAL ONTARIO. J. Wildlife Manage. 27(4): 597.
- Christ, John C.
1959. A STUDY OF YELLOW BIRCH (*Betula lutea*) IN THE BOGS OF ITASCA PARK, MINNESOTA. Amer. Midland Naturalist 61(2): 480-484.
- Coulter, Malcolm W.
1959. WANDERER OF THE WOODLAND. Maine Fish and Game 1(2): 9-11.
- Coulter, Malcolm W.
1966. ECOLOGY AND MANAGEMENT OF FISHERS IN MAINE. Ph.D. thesis, 196 pp. Syracuse Univ. (Dissertation Abstr. 27(9B), 1967.)
- Curtis, Robert O., and F. M. Rushmore.
1958. SOME EFFECTS OF STAND DENSITY AND DEER BROWSING ON REPRODUCTION IN AN ADIRONDACK HARDWOOD STAND. J. Forestry 56(2): 116-121.
- Dodds, Donald G.
1960. FOOD COMPETITION AND RANGE RELATIONSHIP OF MOOSE AND SNOWSHOE HARES IN NEWFOUNDLAND. J. Wildlife Manage. 24(1): 52-60.
- Dodge, Wendell E.
1959. AN EFFECTIVE POISON AND REPELLANT FOR PORCUPINE CONTROL. J. Forestry 57(5): 350-352.
- Drinkwater, M. H.
1957. THE TOLERANT HARDWOOD FORESTS OF NORTHERN NOVA SCOTIA. Canada Dep. Forestry, Forest Res. Div. Tech. Note 57. 25 pp.
- Eyre, F. H., and W. M. Zillgitt.
1953. PARTIAL CUTTINGS IN NORTHERN HARDWOODS OF THE LAKE STATES. U.S. Dep. Agr. Tech. Bull. 1076. 124 pp., illus.
- Gabrielson, Ira N.
1924. FOOD HABITS OF SOME WINTER BIRD VISITANTS. U.S. Dep. Agr. Bull. 1249. 32 pp.
- Gill, John D.
1957. REVIEW OF DEER YARD MANAGEMENT. Game Div. Bull. No. 5, 61 pp., illus. Maine Dep. Inland Fisheries and Game.
- Graham, Samuel A.
1954. CHANGES IN NORTHERN MICHIGAN FORESTS FROM BROWSING BY DEER. N. Amer. Wildlife Conf. Trans. 19: 526-533.
- Graham, Samuel A.
1958. RESULTS OF DEER EXCLOSURE EXPERIMENTS IN THE OTTAWA NATIONAL FOREST. N. Amer. Wildlife Conf. Trans. 23: 478-490.
- Grisez, Ted J.
1959a. A LOW-COST DEER FENCE. J. Forestry 57(1): 42-43, illus.
- Grisez, Ted J.
1959b. THE HICKORY RUN DEER EXCLOSURE. USDA Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 87, 4 pp., illus. Upper Darby, Pa.
- Hamilton, W. J., Jr.
1939. AMERICAN MAMMALS, THEIR LIVES, HABITS, AND ECONOMIC RELATIONS. 434 pp., illus. McGraw-Hill Book Co., Inc., New York.
- Hatt, Robert T.
1929. THE RED SQUIRREL: ITS LIFE HISTORY AND HABITS, WITH SPECIAL REFERENCE TO THE ADIRONDACKS OF NEW YORK AND THE HARVARD FOREST. Roosevelt Wildlife Ann. 2(1): 146 pp., illus. Roosevelt Wildlife Forest Exp. Sta., Syracuse Univ.
- Hepting, George H., and George M. Jemison.
1958. FOREST PROTECTION. In TIMBER RESOURCES FOR AMERICA'S FUTURE. U.S. Dep. Agr. Forest Serv., Forest Resource Rep. 14: 185-220.
- Hesselton, William T., C. W. Severinghaus, and John E. Tanck.
1965. POPULATION DYNAMICS OF DEER AT THE SENECA ARMY DEPOT. N.Y. Fish and Game J. 12(1): 17-30.
- Hosley, Neil.
1956. MANAGEMENT OF THE WHITE-TAILED DEER IN ITS ENVIRONMENT. In THE DEER OF NORTH AMERICA. Walter P. Taylor, (ed.), pp. 187-259, illus. The Stackpole Co., Harrisburg, Pa., and The Wildlife Management Institute, Washington, D.C.
- Howell, Thomas R.
1952. NATURAL HISTORY AND DIFFERENTIATION IN THE YELLOW-BELLIED SAPSUCKER. Condor 54: 237-282.
- Jacobs, Rodney D.
1965. SEASONAL HEIGHT GROWTH PATTERNS OF SUGAR MAPLE, YELLOW BIRCH, AND RED MAPLE SEEDLINGS IN UPPER MICHIGAN. USDA Forest Serv. Res. Note LS-57. 4 pp. Lake States Forest Exp. Sta., St. Paul, Minn.
- Jarvis, J. M.
1957. CUTTING AND SEEDBED PREPARATION TO REGENERATE YELLOW BIRCH. Canada Dep. Forestry, Forest Res. Div. Tech. Note 53. 17 pp.
- Jones, Milton B., and William M. Longhurst.
1958. OVERHANGING DEER FENCES. J. Wildlife Manage. 22(1): 325-326.

- Jordan, J. S., D. Hagar, and W. M. Stiteler, Jr.
1965. DEER-BROWSE PRODUCTION AND TIMBER-STAND IMPROVEMENT IN NORTHERN HARDWOODS. N. Amer. Wildlife and Natur. Res. Conf. Trans. 30: 296-305.
- Jordan, J. S., and Ward M. Sharp.
1967. SEEDING AND PLANTING HEMLOCK FOR RUFFED GROUSE COVER. USDA Forest Serv. Res. Paper NE-83, 17 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Jorgensen, Richard N., and Sophie L. Lecznar.
1964. ANATOMY OF RING SHAKE ASSOCIATED WITH SAPSUCKER INJURY. USDA Forest Serv. Res. Paper NE-21, 9 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Kilham, Lawrence.
1964. THE RELATIONS OF BREEDING YELLOW-BELLIED SAPSUCKERS TO WOUNDED BIRCHES AND OTHER TREES. Auk 81(4): 520-527, illus.
- Krefting, Laurits W.
1951. CONSTRUCTION OF THE LAKE STATES DEER ENCLOSURE. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 361. 2 pp., illus. St. Paul, Minn.
- Krefting, Laurits W., and C. J. Shiue.
1960. COUNTING DEER PELLET GROUPS WITH A MULTIPLE-RANDOM START SYSTEMATIC SAMPLE. Minn. Forestry Note 89, 2 pp. Univ. of Minn., St. Paul.
- Krefting, Laurits W., J. H. Stoeckeler, B. H. Bradle, and W. D. Fitzwater.
1962. PORCUPINE TIMBER RELATIONSHIPS IN THE LAKE STATES. J. Forestry 60(5): 325-330.
- Laramie, Henry A., Jr.
1968. DEER MANAGEMENT AND RECOMMENDATIONS IN NEW HAMPSHIRE. pp. 204-215. In THE WHITE-TAILED DEER OF NEW HAMPSHIRE. Hilbert R. Siegler, (ed.), N. H. Fish and Game Dep. Survey Rep. No. 10.
- Longhurst, W. M., M. B. Jones, R. R. Parks, L. W. Neubauer, and M. W. Cummings.
1962. FENCES FOR CONTROLLING DEER DAMAGE. Calif. Agr. Exp. Sta. Ext. Serv. Cir. 514, 19 pp., illus. Univ. of Calif.
- Lutz, H. J.
1956. DAMAGE TO PAPER BIRCH BY RED SQUIRRELS IN ALASKA. J. Forestry 54(1): 31-33.
- Martin, A. C., H. S. Zim, and A. L. Nelson.
1951. AMERICAN WILDLIFE AND PLANTS. 500 pp., illus. McGraw-Hill Book Co., Inc., New York.
- McAtee, W. L.
1908. FOOD HABITS OF THE GROSBEAKS. U.S. Dep. Agr. Bur. Biol. Survey Bull. 32, 92 pp., illus.
- McAtee, H. L.
1911. WOODPECKERS IN RELATION TO TREES AND WOOD PRODUCTS. U.S. Dep. Agr. Bur. Biol. Survey Bull. 39, 99 pp., illus.
- Olson, Herman F.
1966. RETURN OF A NATIVE. Wis. Conservationist Bull. 31(3): 22-23.
- Pimlott, D. H.
1965. INFLUENCE OF DEER AND MOOSE ON BOREAL FOREST VEGETATION IN TWO AREAS OF EASTERN CANADA. Congr. Internatl. Union Game Biol. Trans. 6: 105-116.
- Rushmore, Frances M.
1969. SAPSUCKER DAMAGE VARIES WITH TREE SPECIES AND SEASONS. USDA Forest Serv. Res. Paper NE-136, 19 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Saunders, Aretas A.
1929. THE SUMMER BIRDS OF THE NORTHERN ADIRONDACK MOUNTAINS. Roosevelt Wildlife Bull. 5(3): 319-499, illus. Roosevelt Wildlife Forest Exp. Sta., Syracuse, N.Y.
- Shaw, S. P., and W. M. Stiteler.
1962. WILDLIFE MANAGEMENT FIELD GUIDE. 10 pp. plus appendix. USDA Forest Serv., Upper Darby, Pa.
- Shigo, Alex L.
1963. RING SHAKE ASSOCIATED WITH SAPSUCKER INJURY. USDA Forest Serv. Res. Paper NE-8, 10 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
- Silloway, Perley M.
1923. RELATION OF SUMMER BIRDS TO THE WESTERN ADIRONDACK FOREST. Roosevelt Wildlife Bull. 1(4): 397-486, illus. Roosevelt Wildlife Forest Exp. Sta., Syracuse Univ.
- Stiteler, William M., Jr., and Samuel P. Shaw.
1966. USE OF WOODY BROWSE BY WHITETAIL DEER IN HEAVILY FORESTED AREAS OF NORTHEASTERN UNITED STATES. N. Amer. Wildlife and Natur. Res. Conf. Trans. 31: 205-212.
- Stoeckeler, J. H.
1950. PORCUPINE DAMAGE IN A NORTHERN HARDWOOD-HEMLOCK FOREST OF NORTHEASTERN WISCONSIN. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note 326, 1 p. St. Paul, Minn.
- Stoeckeler, J. H.
1955. DEER, MICE, AND HARES DAMAGE YOUNG ASPEN AND PAPER BIRCH PLANTINGS IN NORTHEASTERN WISCONSIN. USDA Forest Serv. Lake States Forest Exp. Sta. Tech. Note, 1 p. St. Paul, Minn.
- Stoeckeler, J. H., R. O. Strothman, and L. W. Krefting.
1957. EFFECT OF DEER BROWSING ON REPRODUCTION IN THE NORTHERN HARDWOOD-HEMLOCK TYPE OF NORTHEASTERN WISCONSIN. J. Wildlife Manage. 21(1): 75-80.
- von Althen, F. W.
1964. HARDWOOD PLANTING PROBLEMS AND POSSIBILITIES IN EASTERN CANADA. Canada Dep. Forestry, Forest Res. Br. Pub. 1043. 40 pp.
- Wang, B. S. P.
1968. THE DEVELOPMENT OF YELLOW BIRCH REGENERATION ON SCARIFIED SITES. Canada Dep. Forestry and Rural Develop. Forestry Br. Dep. Pub. 1210. 14 pp.

BIRCH MANAGEMENT ON THE WHITE MOUNTAIN NATIONAL FOREST

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THERE ARE 605,000 acres of commercial forest land on the White Mountain National Forest (based on a 1960 timber inventory). Of this, 258,000 acres are classed as northern hardwood timber type. In general, this would include some 27 percent yellow birch, 16 percent sugar maple, and 31 percent beech in trees that are 6 inches and larger.

Timber operations are now highly mechanized, and a small crew can produce relatively large volumes in a short time. Rubber-tired skidders have replaced horses and tractors in skidding, and this has greatly reduced the mileage of truck roads required in the woods. In the mountainous sections, this has done much to reduce erosion and the resultant siltation of streams. Portable chippers and stationary chippers are now producing much of the wood required by pulp mills; a Nicholson Utilizer has been producing such chips on the Forest in appreciable volumes.

Volume and value of timber cut on the White Mountain National Forest for industrial use continues to increase in spite of labor shortages and uncertain markets. In fiscal-year 1968 the cut was nearly 10 million board feet of sawlogs and about 56,000 cords of pulpwood and millwood. Total value of stumpage sold was over \$400,000. Both volume and value were the highest ever attained on the Forest.

Much less timber would be cut now if there were no market for hardwood pulpwood. Our average cut of logs last year was about 1,000 board feet per acre. By cutting pulpwood, we are able in many areas to salvage scattered sawlog trees that would otherwise be inoperable.

This increase in cut follows our ten-year plan for the period 1962-72 quite satisfactorily. Planned and actual volumes cut were:

<i>Fiscal-year</i>	<i>Planned cut¹ (million board feet)</i>	<i>Volume cut</i>
1963	22.2	21.2
1964	23.8	31.1
1965	25.5	32.4
1966	27.2	22.4
1967	28.7	30.5
1968	30.3	37.9
Total	157.7	175.5

¹ As planned in 1962.

In addition to the above commercial volumes, we have removed considerable volumes in unmerchantable trees as part of our timberstand-improvement program. Planned and actual acreages treated were:

<i>Year</i>	<i>Planned (acres)</i>	<i>Accomplished (acres)</i>
1963	7,600	12,146
1964	7,600	15,708
1965	7,600	12,669
1966	7,600	13,190
1967	7,600	8,789
1968	7,600	9,298
Totals	45,600	71,800

The general condition of our northern hardwood stands is poor. Frequent blow-downs, the beech-scale, birch dieback, ice storms, and past logging operations have degraded many stands of timber on the Forest to such an extent that about 70 percent of the timber of operable size is usable only as pulpwood. Clearcutting in summer with heavy equipment that will scarify the soil and prepare a seedbed is the best silvicultural practice for such stands. Last year, about 1/2 percent of the total Forest area (3,401 acres) was clearcut—most in hardwood stands. However, several factors influence management and cutting practices of all our stands. Among them are: tolerance, multiple use, insects and disease, and logging methods.

Influence of Tolerance

Paper birch is the most valuable species because of stumpage price and rate of growth. Balsam fir would rate second, but it is not a component of the hardwood timber type. At present, yellow birch is probably third and white ash fourth. These birches and white ash require sunlight for regeneration and growth.

Beech and hemlock will prosper with little light, and sugar maple requires relatively little. Of these three, beech and hemlock have long been relatively undesirable as sawlogs, and prices are low.

So it can be said that, on the White Mountain National Forest, if you want to increase the amount of birch and ash, you cut hard; and if you want to do the same for hemlock and beech, you cut lightly. Perpetual uneven-aged stands will have increasing volumes of beech and hemlock. Beech is extremely aggressive and really does not need a forester's help to seize new acreage. Many high, dry mountain slopes are occupied by stands of low-quality beech. The species reproduces prolifically from root sprouts as well as by all other ordinary methods, and under shade it is always present and ready to grow. Hemlock is usually defective, and even good hemlock is relatively hard to sell.

Influence of Multiple Use

Habitat management in hardwood stands on the Forest usually means clearcutting to produce browse for deer and cover for smaller game. There is no limit to the acreage of browse cuttings desired for this. The increasing timber cut over the past 6 or 7 years has helped us to break up stands of old-growth timber to supply browse for deer and small game. Often timber operations are purposely located near deer yards where winter browse is needed.

In recreation zones — such as road and stream sides, and in potential as well as developed recreation sites — single-tree selection is the planned cutting practice. The objective is to maintain or develop an attractive forest setting with an all-aged stand of healthy, well-formed trees. Fortunately beech and hemlock are very desirable in this respect if we are not too demanding in regard to health of the trees. Single-tree selection will perpetuate these species.

There are also some 13,000 acres of commercial forest in scenic areas and wilderness

areas where no cutting is done because of aesthetics. And there is considerably more area where trails, roads, and streams are so close together that cutting is impractical.

Some 20 percent of the present commercial forest is in municipal watersheds. Yarding with animals has often been prohibited, and this affects thinning efforts. Siltation of streams is by far the greatest logging problem on the Forest. For that reason logging in some watersheds and on some occasions has been limited to periods when the ground is frozen. This minimizes scarification and is probably about the poorest possible silviculture in our hardwood stands.

Influence of Insects and Disease

Unfortunately beech has not only been less desirable on the market over the years, but for the past 30 years a lot of it has been killed and most of the remainder degraded to pulpwood by the beech scale-nectria complex. As a result of this, death of birch from the dieback, high-grading of stands when they were cut in past years, and a lot of winter logging, most of our stands have only about 70 square feet of basal area in trees 6 inches d.b.h. and larger; and desirable crop trees in pole-size stands are often hard to find. Between 1940 and 1960, probably 70 percent of all sawlog yellow birch and 85 percent of the sawlog size beech were killed or degraded to pulpwood. Birch dieback ceased some 10 to 15 years ago, but the loss of beech continues. Degrading the beech is worse than killing it, for the trees prevent regeneration or growth of others.

Between 1940 and 1960, the two influences just mentioned removed from the sawlog market 30 to 60 percent of the volume on practically every acre of northern hardwood timber on the Forest. Since yellow birch is the species most in demand by industry, the value loss was greater.

Influence of Logging Methods

The first sale of timber from the Forest was in 1916; and from then until 2 or 3 years ago, so-called horse-logging was the common practice—yarding or skidding of logs was done with a single horse. Most hardwood logs had to be cut relatively short, for otherwise they were too heavy for the horse to drag. Hardwood pole stands could be thinned by

this method with relatively little damage to the residual trees.

As recently as 3 years ago, probably 80 percent of our cut of timber was horse-logged. Now there is practically none. Everybody has rubber-tired skidders, and competition urges them to skid fast and recklessly. They can and do haul several of our biggest trees in tree lengths at one time; weight of the log is not a limitation. A good operator can still thin our pole hardwoods and haul from the stump with little damage to the residual stand, but such operators are not common and we are now planning a lot less of such thinning than we were 2 years ago. We think we will be doing less commercial thinning than would have been done with horse skidding. More of it will probably be noncommercial. In total, much less will probably be done.

However, the big skidders are by far the best machines ever used on the Forest for clearcutting. We try to do the maximum amount of such cutting in summer and to encourage tree-length logging. In this way we get scarification. Summer logging in the mountains is more practical with skidders than with horses.

The rubber-tired skidder and other mechanical harvesters are probably here to stay, and silviculture must be adapted to them. Operators are being forced to minimize the amount of labor required to harvest timber, and this will probably mean even more mechanization in the woods.

Relatively few truck roads are needed with skidders, and this is a great improvement over the horse-bulldozer system that it replaced. When all of your land is tilted from 10 to 70 percent and you skid with horses, the timber-sale administrator does well if he keeps truck roads 400 feet apart. The pattern of these parallel roads along the slopes, as they were first used by drag sleds and later by trucks, can be seen from the air or on aerial photos over much of the Forest. They are a horror to water-management people. Main rubber-tired skidder roads can be kept 1,000 feet apart. This by no means eliminates the erosion problem, but it helps.

Summary

All of the preceding discussion points up the desirability of silvicultural clearcuttings in many of our present hardwood stands; that

is, cutting every tree over 2 inches except for scattered seed trees. Regeneration is no problem; great numbers of birch, ash, and maple reproduce in these clearcut areas. And scarification increases the amount of birch and ash. There is no silvicultural limit on the size of clearcutting if there are seed trees.

We are fortunate in having the Northeastern Forest Experiment Station's northern hardwood experimental forest on the National Forest, with evidence there of birch and ash regeneration after heavy clearcuttings 35 years ago. They are carrying on research on regeneration of birch on the experimental forest and on a 1½ million board-foot timber sale on the White Mountain Forest. In that sale, we are cutting everything over 2 inches d.b.h. from strips that are 50 feet wide. There are three sets of strips, one to be cut every 2 years. Variations of this method are applied on some other sales up to 4 or 5 million board feet in volume. The technique is adaptable to skidder logging and can hardly fail to regenerate intolerant hardwoods under our conditions. Strip cutting also lends itself to areas where broad-scale clearcuttings might be considered unsightly. If put in on slopes at right angles to the line of sight from highways, the strip cut may be quite concealed.

At the other extreme from clearcutting or strip cutting, single tree selection cutting produces hemlock, beech, and some maple. Aesthetically, these may be among the most desirable species. Spruce is also favored by relatively light cuttings since it is almost always present as advance growth and less of it is damaged by a light cutting. Selection cuttings are most useful in scenic and recreation areas.

From 1916—when the first cuttings were made on the White Mountain National Forest—until about 1936, small volumes of timber per acre, fear of wind damage, and lack of markets resulted in the practice of commercial clearcutting *for sawlogs only* in our hardwood stands. Such cuttings often amounted to single-tree selection cuts, and many pulpwood-quality trees were left to form a residual stand. Income per acre was low and no attempt was made to accomplish a complete silvicultural timber-stand-improvement job since it could not be financed. From 1939 until recent years, single-tree selection cuttings were the planned cutting practice.

Thus, from 1916 until recently, in one way or another, we made light partial cuttings and encouraged the regeneration of beech, hemlock, and maple. During the mid 1950's, we decided that we should be cutting heavier to promote regeneration of birch. The development of a hardwood pulpwood market at about the same time made it possible to do this. We were able to remove a lot more low-quality trees and to open up the stands to encourage intolerant species. During the past 3 years we have been able to require silvicultural clearcutting on our sales. The big skidders have also helped by tearing up the ground (seedbed scarification) and eliminating unwanted trees. Thus, we feel that we are now getting the type of regeneration we want on most of our cutover areas.

As markets improve, we should be able to do more clearcutting. Of course, in the end, we are setting up a big thinning job for the future, but markets and operating methods may change several times before then.

We try to do our clearcutting in summer, with rubber-tired skidders and tree-length logging to insure reproduction. And we want to do our thinning in the winter, skidding short logs (20 feet or less) to minimize damage to residual trees. During the year ending 30 June, 1968, we regenerated 3,401 acres on sales, and had 2,920 acres thinned.

Our increased use of clearcutting and even-aged management is not as complete a change as some seem to think. Although the harvest-regeneration cuttings under even-aged and uneven-aged management are quite different, there really is not any great difference in the woods between the two systems most of the time. One involves a series of two or three thinnings leading up to a reproduction cut while the other is a perpetual series of thinnings. I think the extreme differences we often ascribe to the two systems are largely in the minds of people who speak in very general terms.



BIRCH MANAGEMENT ON NEW HAMPSHIRE STATE LANDS

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Paper Birch

PAPER BIRCH occurs on New Hampshire's state forests in association with almost all other upland species. The quality wood is found as far south as the Sunapee Range and the Lake Winnepesaukee area. In this northern zone, there is a ready market that recognizes grade and makes paper birch management worthwhile. In the white pine area in the southeastern part of the State, paper birch wood is generally of poorer quality and is apt to bring but little better price than the cheaper hardwoods.

State land management of paper birch begins, when funds are available, with the sapling stands. Weeding (or cleaning) with herbicides kills competitive undesirable species as well as poorly formed birch. It is seldom necessary to make a choice between well-formed stems of paper birch and other desirable species simply because of low stocking of the better stems.

Very little hardwood pruning has been done to date, but current plans call for this practice on some of the better sites. It would seem that pruning of white birch would be an even better investment than pruning of other hardwoods because of the fast growth, short rotation, and quality recognition by the market even in the smaller diameters.

Commercial thinnings are seldom required because paper birch stocking is usually low and volumes available do not justify a cutting.

Since there are very few pure paper birch stands, our harvest of this species is usually done as part of an intermediate cutting in a system of uneven-aged management for the mixed stand. Marking is done on a single-tree and group selection basis, depending upon the distribution of the species within the stand. The paper birch component in these mixedwood stands tends to be even-aged, so

it is seldom possible to leave many stems for a later cut. The smaller trees are usually of low vigor and are apt to deteriorate rapidly when the stand is opened up. Intermediate cuts in mixed stands are usually desirable to assure maximum growth on the desirable stems, but this type of cut often produces so much low-grade wood that it is not economically feasible unless there is a good market for these grades. The paper birch component provides an added volume of readily marketable wood that could make the intermediate cut in a mixed stand practical and profitable.

The condition of the paper birch is often the determining factor in the timing of the intermediate cut. Early maturity, decadence, dieback, and crown breakage due to ice storms, combined with the rapid rate of deterioration of paper birch wood, make prompt salvage cuts necessary. To detect these conditions, regular periodic inspections should be made of stands with appreciable paper birch volumes, especially those at the higher elevations and on exposed sites.

Decisions concerning the type of harvest cuts in our stands containing paper birch have been dictated by considerations other than reproduction of this species. Public use of these relatively small and accessible tracts precludes clearcutting in many instances. The high costs of a true silvicultural clearcut and early weedings are investments that will probably not pay off in less than a rotation. When reproduction of other desirable species seems assured, increased costs can be justified only by greatly increased returns at the end of the rotation. Thirty-five years ago, we were girdling yellow birch to release spruce. Hindsight tells us now that this was often a poor investment. What will the market be 80 years from now? Will improvement in wood-processing techniques and changes in consumer

tastes make other species competitive with birch?

Even though our harvest cuts are not specifically designed for maximum reproduction of this species, they usually do provide conditions favorable to reproduction of intolerants over much of the acreage. Group-selection cuttings in pine, mixed hardwoods and old-pasture spruce stands, strip cuttings in spruce and fir, and occasional clearcuts in the salvage of overmature stands all result in openings favorable to birch reproduction. Hardwood sprout control is one of our standard TSI practices in cutover areas where seedling growth of desirable species will benefit from this practice. The removal of the sprout overstory in this early stage of the development of the new stand is especially beneficial to the intolerant species. So we expect that our overall paper birch stocking will be maintained or increased with these management practices.

The value of paper birch to the economy of New Hampshire is much greater than its portion of our total wood volume would indicate. It is a wood that provides more employment for local labor per thousand board feet than most species, because both primary and secondary processing take place in several communities around the State. It is also an important scenic asset, and we should attempt to insure its place in future stands.

Yellow Birch

Yellow birch attains its greatest commercial importance in New Hampshire in the general area of the White Mountains and north to Quebec. It occurs further south at the higher elevations but does not reach its maximum development in these areas. On State lands it occurs in the usual association with beech and sugar maple as well as with white ash, red maple, paper birch, and red spruce. Precommercial management practices do not differ from these followed with paper birch. As soon as we begin commercial cuts, the similarity ceases.

Because of past agricultural use and a pattern of small ownerships, our State-owned stands containing yellow birch tend to be less uniform than those on larger, more remote tracts. Our stands frequently contain areas of mature northern hardwoods mixed in with areas of pole and small sawtimber stands. This mixture of size classes is one factor that seems

to dictate uneven-aged management. We must work with what we have on the site. In marking these irregular stands, we try to include the entire sale acreage wherever there is enough volume to be cut to make an operation feasible. If we were to separate the mature areas from the pole or small sawtimber areas, there would not be enough high-grade volume to make a commercial improvement cut in the pole or small sawtimber areas. So we try to get improvement cutting done by lumping these areas with more mature areas in a single sale.

However, this approach still has its problems. What do we do with cull and low-grade wood in the mature stands? And how do we handle the younger stands to insure the best chance of satisfactory development? Where a good market for pulpwood and pallet-type logs exists, we have no problem in removing this component from the stands. But we do not generally have such markets. In a recent sale, we avoided marking pulpwood because of the lack of a market, but we did mark some low-grade hardwood logs. The successful bidder bid nothing at all on this low-grade wood.

If we are to avoid simply high grading these areas, these lower-value trees must be removed. And it must be done soon after the sale if we expect reproduction of intolerant species. If reproduction of intolerants is not desired, removal of the low-value trees can be delayed and mortality will take care of part of the problem; but eventually the remaining stems must be removed. To date we have handled most of these areas by killing these residual stems after the slash has rotted down enough to facilitate access.

A system that makes the removal of these stems the buyer's responsibility would be the best answer. However, most of our buyers do not have satisfactory markets for the low-grade wood, and they are able to meet their wood requirements without depending on areas where they must undertake TSI work.

In our improvement cuts in the small sawtimber stands, we attempt to remove all the low-grade wood that the market will take, the high risk stems in the better grades, and the less desirable species. There are, of course, several exceptions to these general rules. Stems that will serve as trainers and protect crop trees, especially yellow birch,

from exposure (which could result in decadence and epicormic branching) are left standing. Trees of the less desirable species are left uncut in situations where their removal would reduce the residual basal area below approximately 70 square feet per acre. If the potential volume to be removed in a given small sawtimber stand is considered marginal in value, we stay out of the area because logging damage may exceed the benefits of the improved cut.

No practices specifically designed to favor

yellow birch reproduction have been initiated. Success in obtaining yellow birch reproduction is apparently a problem of seedbed preparation and of control of the residual overstory. Bare-ground logging, as opposed to winter operations, will improve seedbed conditions to a certain extent. The removal of the large crowns typical of mature northern hardwoods invariably leaves some openings large enough to reproduce yellow birch. As with proper birch, we feel that our management practices will maintain present proportions of this species.



BIRCH MANAGEMENT ON INDUSTRY LANDS

by KENDALL S. NORCOTT, *Chief Forester, Brown Company,
Berlin, N.H.*

I HAVE NO revolutionary ideas to offer concerning the management of white and yellow birch. The most I can hope to accomplish is to acquaint you with Brown Company's current and past operating procedures in northern hardwoods, and to relate some of my observations of the results we are getting from harvesting substantial volumes of birch and other commercial species from nearly 800,000 acres of timberland in northern Maine, New Hampshire, and Vermont.

First, let me make it clear that, in my opinion, none of us here needs to apologize for past hardwood management practices. In fact, I think we all can agree that we did the best we could with what little knowledge was available, and operating within the economic framework of the times. Of course we might do some things differently if we were to do them over. It is the age-old story of foresight vs. hindsight.

Let me go back a few years to set the stage. One of our earliest efforts to do any cultural work on our holdings—around 1948—was a program of girdling and poisoning hardwoods. This was done to encourage the establishment and growth of softwoods, but obviously it did nothing to promote birch. Many a first-class hardwood tree was ruined in carrying out this practice.

Economics of the times played an important role in this decision. I should point out that during the past 15 years or so, yellow birch has become the most valuable species on our lands. Its presence and quantity on a job has an important influence on the financial success of the operation. The fact that we were girdling birch as little as 20 years ago indicates just how short a time we have had an interest in the propagation of this important species.

GOOD DISASTER

Well into the 1950's the Brown Company was taking part in clearcutting extensive areas of old-growth timber. Since our mills utilize all species of hardwood and softwood (except cedar), this cutting practice was relatively simple. This technique is commonly referred to as a "regeneration cut"; and in my opinion it has done more to re-establish thrifty stands of northern hardwoods and softwoods on our lands than any other silvicultural method devised. Clearcuttings are still taking place in some areas, mostly on the lands of others and quite often at the recommendation of qualified foresters. This method, under certain conditions and on certain sites, is proper; and the results, silviculturally, are gratifying.

This might be a good place to point out that one of the largest and purest well-stocked stands of high-quality white birch on our holdings came about as a result of what must have been an extremely heavy cutting of softwood over a large area around 1900. This cutting was followed closely by a severe burn. As a result of what would normally be considered a disaster, we now have several square miles of pure white birch of valuable boltwood quality. This area was thinned recently by Maine Dowel Company of Farmington, under the supervision of Ray Mitchell. I am not sure whom we can give credit to for the establishment of the fine stand of birch, but I rather suspect that whoever it was may have got himself fired if he was in any way connected with the blaze. Incidentally, I might add here that we have other areas on which this same unplanned technique for some reason did not work out so well.

When we take visitors through areas where clearcuttings have taken place, some of our guests are obviously shocked at what, on the surface, appears to be extensive areas of devastation. Those bushy looking, leafy jungles,

with a dead stub sticking out here and there, are anything but attractive to the untrained eye. But once the visitors have had a closer look, they begin to understand that these lands are far from being idle.

Careful remeasurements of permanent growth plots tells a rather exciting story. We find there is generally an adequate stocking of birch in mixture with other important commercial species. This birch appears to be competing satisfactorily with other, more tolerant species.

Although birch is the species we currently favor, we have no high hopes nor even interest in regenerating pure birch stands. Pure stands of yellow birch are not too common anywhere in our region today. Birch in mixture with other species, including softwoods, has been satisfactory. Birch found in mixture often develops more trees of superior quality. We recognize, but are not interested in tackling, the problems that are associated with pure stands of any species.

We have recorded proof that some of our 1930 clearcut hardwood lands are putting on commercial growth as rapidly as some of our better softwood types. Birch, unfortunately, is not always a leading component; its percentage varies from one location to another. Some of the answers and theories about why this is so are being brought out at this meeting.

A BLAZE OF ORANGE

Should we have cut these lands differently? I recall that, back in 1958, I had a discussion with John Bork, who was then the Brown Company's general logging superintendent, about how we should cut our old-growth hardwood types in the vast Swift Diamond drainage. Our interest was not so much in birch regeneration as it was to leave the stand in the best possible condition to insure the earliest or the greatest return on the owners' investment. Birch did interest us, however, because we owned a birch sawmill and veneer mill; but we also had a pulpmill that could utilize hardwood of any species.

With these markets on hand, we were in the best possible position to do the thing that should leave this property in top shape. We decided to see what marking our cut would do for us. Armed with paint guns, we set out to mark a sample. Obviously we

wanted to take off the large mature timber. This was the initial reason for our being there. While we were there, we decided that we might just as well cut the overmature trees, for we doubted that they would last long after the cutting in their weakened state. We could at least salvage some pulpwood from them if we took them now. Then we considered the deformed intermediates. They were as old as the mature dormants and could not contribute much to the residual stand if left. They, like the overmature trees, did not give the appearance of being seed-orchard material. We found a number of individual spruce and fir trees that were hardly noticeable when we first started. To open the stand up, as planned, was to bid them goodbye. Since they were fairly large, we marked them for cutting. The few smaller suppressed trees found on this tract were so deformed and weak looking that we marked them for pulpwood.

By this time, the forest was a blaze of orange paint. So that ended this experiment in our old-growth hardwood timber types, and we proceeded to cut all the commercial-size wood. If opening up the stand and permitting the light to come through was good for the regeneration of birch, then that appeared to be the thing to do with this timber. We agreed that second-growth hardwood stands represented something else again, and should be given special consideration and quite likely different treatment.

Forest Service people first drew our attention to a comparison between some company property that had been clearcut years ago and some adjacent Government land where a partial cutting had taken place at about the same time. You guessed it. After 20 years, we had a fine young pole-size stand with a high percentage of thrifty yellow birch, while across the line there is a pretty fair stand of pulpwood-quality maple. I wish I could say that this always happens. Let's just say that all systems were "Go" for yellow birch, and we just couldn't miss.

CUTTING TODAY

By contrast, Brown Company's operations today, like most everyone else's, are geared to the use of rubber-tired skidders and other mechanical equipment. Economics in the use of this type of equipment dictates that we concentrate on larger wood, leaving smaller

trees that normally might have been cut when we were using horses. For hardwood, we generally stick to a 14-inch d.b.h. class and up. This means that in mature stands containing old-growth and second-growth timber in mixture, we are now cutting roughly 6 to 8 cords of all species per acre, depending on the stand's past treatment. This generally leaves a stand that supports an average of 8 to 10 cords of pulpwood-size wood per acre. The species composition of our residual stands varies, again depending to a great extent on previous treatment.

What this all amounts to is that we are currently operating wood to a diameter limit. Exceptions to this rule are when stand conditions dictate either a clearcutting or an individual tree-selection method. Factors entering into the choice of cutting method are age, stand stability, health, aesthetics, accessibility, wildlife requirements, recreation, etc.

Because of the good demand for birch veneer and sawlogs, we have profited from cutting old-growth stands that are heavily stocked with birch. As we cut the old-growth birch, we generally pick up all other species in the larger diameter classes for both logs and pulpwood. A large share of the old-growth hardwood and mixedwood forests found on our lands contain high percentages of yellow birch (often 40 to 50 percent of the hardwood content has been birch). For the many reasons discussed at this meeting, all too often after these partial cuts, yellow birch has become a minor component of our residual or second-growth stands. The only exceptions have been when an overall stand is heavily populated with 2- to 3-acre bunches of old-growth hardwood. These bunches are generally clearcut because of their large diameter, often leaving a site condition suitable for the establishment of birch or other intolerant species.

CATCH OF BIRCH

Regardless of what method of cutting we decide on, it appears that, to make yellow birch an important component of our future stands, we must consider in our planning:

1. Intensity and selectivity of the last cut.
2. Intensity and selectivity of our planned operation.
3. Advanced reproduction.

4. Season of operation.
5. Method of logging.
6. Seed source and wind direction.
7. Soils and site quality.
8. Site preparation.
9. Moisture.
10. Vegetation and wildlife competition.
11. Weather and temperature.

If we are fortunate and we find ourselves with a good catch of birch, then we must be prepared—IF NECESSARY—to:

1. Weed and thin and carry on other cultural work . . . or bide our time for the long haul and hope for the best.
2. Adjust to changing markets brought about by changing public demands.
3. Protect from fire, insects, disease, poachers, etc.
4. Adapt to changes in logging and utilization technology.
5. Continue to control against destructive competition—wildlife, etc.

In addition to the above, we must defend our timber lands from:

1. Human competition.
2. Single use advocates.
3. Adverse legislation.

Lastly, we must brace ourselves against rising tax costs and be prepared to pay our bills.

In the 70 to 80 years it takes to grow an average quality, medium-size birch tree, any one of the above factors could contribute to the failure of a tree to get started, to reach maturity, or to be harvested. It would almost appear that we are dealing with a very sensitive, high-risk product. Is it any wonder that we may be a little skeptical about spending large sums of money on the intensive management of birch, with all its potential value?

SUMMARY

Clearcutting

1. Clearcutting will increase our chances of establishing fair stands of thrifty young hardwood, which often will contain reasonably high percentages of birch.
2. It may be necessary to limit the size of our clearcut areas to insure establishment of hardwood seedlings as opposed to sprout

growth, and at the same time to offer the new crop limited protection from the elements.

3. We can expect rapid growth rates (in all species) in noncommercial size stems (on reasonable sites) for at least the first 30 years.
4. In general, we will not get severe competition for any length of time from noncommercial woody species. (No apparent need for treatment.)
5. Commercial volumes will be too limited in size for operation for some time unless harvesting and utilization standards change radically.
6. In the long run, regeneration cuts will require more acres to sustain the kind of production of the commercial size trees we require today.
7. We should establish additional growth plots sampling a variety of locations, age classes, and other conditions so as to better measure and understand the results of our efforts and their effect on the establishment and growth of birch and other associated species.

Partial Cutting

It is generally felt that our chances of regenerating high-quality hardwoods, especially intolerant birch, are not too great with partial cuts. Chances are that we will reduce the quality of our residual stand by logging damages. We will encourage maple and other tolerant species. However, we are prepared to accept these calculated risks in exchange for the following anticipated gains:

1. An acceleration in growth of commercial-size residual trees as a result of the removal of old-growth timber.
2. An early return to the area for a harvest of sizable wood.
3. For our mills, a more continuous supply of raw materials from fewer acres.
4. An opportunity to manage all areas more intensively.
5. Less fiber loss to disease, insects, and other risks.
6. Greater mechanical and manpower production as a result of operating fair-size timber.
7. Less public pressure from the standpoint of aesthetics.

Last fall I attended a Hardwood Training Session in Bartlett, N.H. Almost everyone involved in any form of hardwood management was present; and many of the leaders of that session are here today. We attended lectures and field trips that dealt primarily with hardwood stands, and not with individual species. We found the subject involved and challenging, and we found differences of opinion. One thing we all came to realize was that we had hardly scratched the surface of this complex subject. The variables from one area or site to the next were almost overwhelming.

The same holds true today, where we are concentrating on one species. Even after we have learned all the idiosyncrasies that go with the establishment and cultivation of birch, we still must develop practical harvesting methods that will insure the propagation of this important forest species. I'm not discouraged: I simply hope I can attend the next symposium, when we can again summarize the results of our efforts.



MANAGEMENT OF BIRCH FOR OTHER USES

by OLIVER P. WALLACE, Associate Professor, School of Forest Resources, University of New Hampshire, Durham, N.H.

Who Pays for Costs of Other Uses?

THE MANAGEMENT of any species for wood implies that there is a market, or confidence that there will be a market, for the wood. Certainly public programs to encourage forest owners to grow wood are based on the premise that markets exist and will continue to exist. Although the growing and cultivating of birches for wildlife and aesthetic quality also has direct costs, it has no clear market, no selling price. Thus the cost of managing forests for these uses must be borne by the public whenever the desired results incur costs over and above those that are a part of management for wood production. Or, if we assume that environmental quality (including recreation opportunities) is a public responsibility of those who own forests or who are charged with their management, then we have to demand that these owners and managers produce wildlife, water, and aesthetics in the public interest. The cost of producing these amenities would then become part of the costs of wood production and thus would be paid for by the buyers of wood—eventually the general public.

We are probably closer to this situation than most people realize. State, federal, and wood-industry forest lands are already being managed to include these amenities in management planning. The forest industries have to include these costs in their product prices. Government organizations are tax-supported; thus the general public pays either way.

For nonindustrial private woodlands, there is no clear picture. Some landowners are spending money on these other forest uses, some are not. Perhaps landowners whose forests are visible to the traveling public or whose lands are within urban sprawl areas will be forced to produce the social amenities desired by the American public. The responsibilities of land ownership would then be said to include maintenance of aesthetic quality.

If wood products must absorb the costs of producing environmental quality for Americans, then there is some danger of pricing wood out of competition with other materials. However, other industries will also have increasing costs as public pressures for pollution control force them to use more expensive and more effective control techniques. These costs will also cause increases in the price of competitive materials.

Wood producers and users can also help to keep wood competitive, in the face of increased costs of other management activities, by improving the efficiency of their management, utilization, and marketing practices. We have already heard some of the things that can be done to improve management and utilization of the birches. I would like to describe some marketing practices that could increase returns and therefore permit us to provide more in the way of management for other uses.

Birch Marketing

Both paper birch and yellow birch have brought top prices in the Northeast since 1960. A study of stumpage prices shows that yellow birch has consistently brought the highest price. From the New Hampshire Forest Market Reports, ratios were calculated to rank sawlog stumpage prices of the various species. Yellow birch ranked first, then white pine, hard maple and paper birch, spruce, and all other species, in that order. Thus yellow birch offers the top opportunity for returns to management efforts.

A similar study of sawlog delivered prices shows that yellow birch ranks first again, but paper birch is second, hard maple third, spruce fourth, and white pine fifth. A further study of the ratio of delivered price to the operating costs plus stumpage shows yellow birch and paper birch ranking first and second.

Because the ratio of delivered price to all operating costs plus stumpage is greater for

birch, landowners should consider selling their logs at the millyard rather than as stumpage. This differential also indicates that wood-using industries would find it more profitable to operate their own lands than to buy other people's logs. This may also be a reason to purchase additional lands that are suited to paper birch and yellow birches. Since 1962, this difference between all costs and delivered price has increased. Regardless of the reasons for the difference—such as scarcity of the species—selling sawlogs at the millyard is more profitable for a landowner than selling his trees as stumpage.

A comparison of ratios between delivered price and operating costs plus stumpage for various birch products shows that birch should not be sold for pulpwood unless it in no way qualified for boltwood, sawlogs, or veneer (table 1). Thus a landowner can increase his level of management practices if he sells at the point where he gets the highest return—the millyard. Conversely, wood industries should look to intensified management of their own lands as these ratios increase.

All our large wood industries today consider market conditions for various species, and how possible changes in these conditions may affect their management programs. However, many of our wood industries do not relate markets to management opportunities, nor do they study future aspects to guide management practice levels. The decline of both quality and quantity in our birch empire is a clear example. Hardwood-using companies in the Adirondack region of New York were definitely on a cut-out and get-out schedule

in the 1950's. Today they are no longer operating, despite increased market opportunities. They made no attempt to foresee the future of our wood markets, nor to invest in forest management.

The birches may contribute to the pulpwood supply at present, but price trends and market opportunities indicate that future calculations of wood supplies available for pulp should be reduced by the volume of the birches. To sell these species as pulpwood will be poor marketing practice.

Favorable marketing practices that allow intensified management for birch timber will also improve the other forest-land benefits. Insofar as paper and yellow birch areas are increased by timber management, the aesthetic and scenic qualities of our woodlands will also be increased. But more important, higher prices for wood will allow specific management for those other amenities that our population increasingly demands.

Table 1.—Ratios of delivered price to operating costs plus stumpage for white and yellow birch, 1968¹

Product	Yellow Birch	Paper Birch
Veneer	3.19	2.47
Sawlog	1.80	1.32
Boltwood	1.29	1.08
Pulpwood	.82	.82

¹ New Hampshire Forest Market Report. Univ. N.H. Cooperative Ext. Serv., Durham, N.H. 1968.

MANAGEMENT OF BIRCH FOR AESTHETICS AND RECREATION

by JOHN H. NOYES, *Professor of Forestry, Department of Forestry
and Wildlife Management, University of Massachusetts, Amherst, Mass.*

WHEN PAPER BIRCH and yellow birch are managed for aesthetic and recreation purposes, timber values become secondary, although in some instances compatibility exists among the several objectives. At times, timber and wood-products production is excluded entirely in the interests of aesthetics and recreation.

In keying forest-management practices to the appearance characteristics of trees, it is appropriate to examine in some detail the tree qualities that relate to appearance.

All tree species have recognizable characteristics that set them apart from each other. For some species, these various characteristics are readily apparent, easy to identify—some from a considerable distance, others only from a much closer vantage point. Visually, it is possible to identify and classify trees as to (1) color—foliage, flowers, bark; (2) shape—outline of crown and branching habit; (3) texture—size and shape of leaves and density of foliage in the crown, and by smooth, ridged, or plated bark; (4) size—height and diameter; and (5) growth habit—single or multiple stems, clumps.

Trees are viewed singly or in mass—as individual trees, groups of trees of the same species, or groups of trees consisting of a variety of species, shapes, and sizes. They may be in pure stands or mixed stands, even or uneven aged. They can be manipulated in arrangement through silvicultural treatments to fit certain design criteria.

Aesthetically, both yellow and paper birch are easy to identify. Both of these species have many attractive qualities that add contrast and variety to the landscape—so important in relieving monotony and stimulating viewer interest.

One of Our Most Beautiful Trees

The outstanding characteristic of paper birch that has established it as one of the

most beautiful trees of North America is its gleaming white bark. On very young trees, the bark is of brown or bronze color; on older trees it develops its whiteness, peeling in thin horizontal strips that tend to curl at their outer extremities.

Paper birch has a distinctive form with its fine, feathery twigs tending to droop at their tips, hanging in graceful fashion. In Britain, the counterpart of this tree (European white birch) has earned the title "Lady of the Woods" (*Edlin 1966*). Foliage colors are attractive in spring, summer, and fall. In growth habit, paper birch frequently has multiple stems, a characteristic that adds to its popularity for ornamental uses.

Yellow birch has many of the fine qualities of paper birch that make it a desirable tree of high aesthetic interest. Its bark is of yellowish to bronze color, peeling horizontally in very thin, narrow curling strips. On older trees, the bark develops into fairly thick yellowish-brown plates. Its foliage is attractive throughout the growing season. Yellow birch is more likely to grow as a single-stemmed tree than paper birch.

Associated species of paper and yellow birch play an important role in the aesthetics of these two trees. The species composition of natural stands in which these two birches occur includes such trees as balsam fir, white and red spruce, hemlock, white pine, white ash, red oak, basswood, red and sugar maple. All of these associated species are attractive and may combine with or add desirable contrast to stands containing birch.

Both birch species have many characteristics that fit them for uses other than for commercial timber. The range of uses is broad. It includes a combination of aesthetic and functional values: single trees for specimens; groups of trees for utility purposes in parks or in greenbelts or along roadsides to satisfy

needs for shade, screening, air purification, ameliorating air temperatures, and beautification. Both species are fine subjects for nature study.

The wood of paper birch, aside from its traditional value for timber, is used for wood carving and turning. Its bark is collected by youngsters (and some adults) for a variety of uses—not in the best interests of aesthetics, for a discolored scar is left as permanent evidence that bark has been removed. Bark was used extensively by Indians and early settlers for canoes. The oily bark of yellow birch has often been a boon to campers and hunters in the north woods: even when wet, it can be used to start cooking or warming fires.

Managing for Aesthetics

The birches are moderately resistant to damage in high-use recreation areas. In a study of recreation use, Ripley (1962) rated native trees and shrubs for their ability to withstand the impacts of recreation use as gaged by disease infection, insect infestation, and decline. Differences in the ability of species to withstand the impacts of recreation use were consistently large. Of the twenty-two hardwoods reported, yellow birch ranked eleventh. Trees able to withstand a higher degree of use according to the measurement factors employed included hickories, white ash, beech, dogwood, and black gum.

Silvical requirements for paper birch and yellow birch are an important consideration in managing them for aesthetics and recreation purposes. Paper birch often grows on drier sites than yellow birch. Yellow birch generally grows better on northern and eastern slopes; paper birch grows well on all site aspects, which may influence its use over a wider range of recreation site locations (*USDA Forest Service 1965*)

Both paper birch and yellow birch grow on glacial soils in many locations where stone and sand content is relatively high. Such soils are not readily compacted. This fact may be important in planning location of recreation areas where heavy use and accompanying compaction would otherwise result in poor tree survival.

Some modification or adjustment in cultural practices are usually needed to assure perpetuation of paper birch and yellow birch in

areas especially devoted to aesthetics or recreation.

More frequent weedings, thinnings and improvement cuttings may be required to maintain desirable levels of birch stocking. Scarification of seedbed may be necessary to assure adequate regeneration of both species. The use of small burned patches may also be effective for paper birch regeneration. Direct seeding or planting may be necessary as a supplement to natural seeding in some places. Advantage should be taken of the ability of paper birch to develop from stump sprouts and produce multiple stems, so desirable aesthetically.

In the interests of aesthetics, systems of harvesting that involve large clearcut areas should be avoided. To obtain maximum reproduction of paper birch, clearcut strips or patches $\frac{2}{3}$ to 1 acre in size are suggested. The shelterwood system, resulting in approximately 50 percent full sunlight below overhead canopy, may also be used to advantage (*Horsley 1968*).^{*} Yellow birch is somewhat more tolerant than paper birch and can be reproduced after harvesting by the group-selection system.

Unforgettable Vistas

Paper birch and yellow birch look good anywhere—singly, in clumps, in pure stands, or in mixture. It is difficult to improve on their appearance—but it may be necessary to employ special measures to keep them growing in a healthy condition. Since they are intolerant or intermediate in character, judicious thinning or release—especially at young age—is a necessary practice to assure survival. Very cautious cutting—just enough to permit and maintain dominance—is important. Otherwise, decline, dieback, and other maladies may develop when a stand is opened up too much.

An important feature of managing trees for aesthetics and recreation relates to the development of vistas. With trees as striking and beautiful as paper and yellow birch they, in themselves, can be made focal points for vistas with avenues or lines of sight cut to

^{*} Horsley, S. B. DIRECT SEEDING OF PAPER BIRCH IN STRIP CLEARCUTTINGS. Unpublished Master's thesis, Department of Forestry and Wildlife Management, University of Massachusetts, 116 pp., 1968.

them from vantage points along a path or highway. Also, these trees can frame the view for a vista when other trees and shrubs of lesser aesthetic interest are thinned out (Noyes 1969), such as the famous view of Mt. Chocorua from Route 16 in New Hampshire.

Cutting operations in the interest of aesthetics and recreation (Noyes 1968) should be concerned particularly with:

- Utilizing all material possible from harvesting operations.
- Performing light harvest cutting operations whenever possible so as to leave the forest intact.
- Enhancing aesthetic qualities of the landscape by developing vistas and emphasizing desirable topographic features of the area by either creating or utilizing existing openings in the forest.
- Protecting woodlands from uncontrolled fires.
- Protecting uncut trees, seedlings, and shrubs by careful felling, skidding, and hauling practices.

- Replacing cut trees, if needed, by providing for adequate regeneration, planting seedlings, utilizing natural seedlings, or releasing desirable understory stems already established.

- Protecting the site against erosion by proper cutting operations, including well-planned skid and haul road layout and adequate water-drainage facilities.

- Cleaning up afterwards of such unsightly things as refuse and discarded equipment and parts.

- Cutting up logging slash and severely damaged trees, so they lie close to the ground, after a harvesting operation.

Many of the activities relating to aesthetic and recreation management practices for birch could be applied also to other species. The inherent appearance qualities of these two species, however, should stimulate management in their behalf wherever they exist and should encourage their introduction elsewhere on sites suited to them.

Literature Cited

- Edlin, H. L.
1966. TREES, WOODS AND MAN. 272 pp. Collins, London.
- Noyes, J. H.
1968. TIMBER HARVESTING AND FOREST AESTHETICS. Univ. Mass. Coll. Agr. Coop. Ext. Pub. 440. 19 pp., illus.
- Noyes, J. H.
1969. WOODLANDS, HIGHWAYS AND PEOPLE.

- Univ. Mass. Coop. Ext. Serv. Pub. 33. 21 pp., illus.
- Ripley, T. H.
1962. TREE AND SHRUB RESPONSE TO RECREATION USE. USDA Forest Serv. SE. Forest Exp. Sta. Res. Note 171. 2 pp.
- United States Forest Service.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. U.S. Dep. Agr. Agr. Handb. 271. 762 pp., illus.

MANAGEMENT OF BIRCH FOR WILDLIFE HABITAT

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THE LIST of wildlife species known to prefer paper birch and yellow birch as food is a long one. To mention a few: beavers and porcupines chew on the bark and wood; sapsuckers feed on the sap; other songbirds—notably the redpoll, pine siskin, and chickadee—relish the seeds; ruffed grouse eat the catkins, buds, and seeds (in northern Maine and Canada this bird is often called the “birch partridge”); and snowshoe hare, moose, and whitetail deer browse on the twigs. At least 24 different kinds of animals are known to feed on birches (*Martin et al. 1951*).

Our whitetail deer in the Northeast exhibit a clear preference for the birches. This information comes from deer-browse surveys conducted on National Forests in the Northeast in the early 1960's. In systematically located transects on each Ranger District, all twigs between 1 and 5 feet from the ground that showed 1 inch or more of current annual growth were counted by species and recorded as browsed or unbrowsed.

Deer browsing on birch twigs (predominantly yellow birch but some paper birch) was consistently greater than would have occurred by random feeding. For example, on the White Mountain National Forest in New Hampshire, birch twigs comprised 7 percent of the total twigs produced and available to deer; yet 28 percent of all twigs browsed were birch. This indicates that birch is browsed four times as heavily as would be expected by random chance. This is called a browse index of 4. An index of 1 would indicate browsing in direct proportion to availability. The four National Forests where birch twigs were produced in significant amounts are listed below, along with the browse index of each (*Stiteler and Shaw 1966*). There can be little doubt that deer browse birch by preference.

National Forest	State	Browse index for birches
Allegheny	Pennsylvania	4.8
White Mountain	Maine & New Hampshire	4.1
Monongahela	West Virginia	2.7
Green Mountain	Vermont	2.6

Two of the general findings from the browse survey are relevant to discussions here. First, on five of the six forests surveyed, an average of 85 percent of all browsing occurred on twigs of noncommercial species—berry bushes, mountain maple, and other weed species. Second, twigs of sprout origin were preferred better than 2 to 1 over twigs of seedling origin. Low-growing nontimber plants such as *Cornus*, *Rubus*, and *Vaccinium* (all preferred by deer) are particularly abundant in areas regenerated by clearcuttings, and so are stump sprouts.

From this it can be deduced that: (1) clearcutting for birch regeneration, with certain precautions mentioned later, will enhance wildlife habitat, and (2) there will be a better chance for survival of seedlings desired for timber management in clearcuttings because of the buffering effect of nontimber plants and sprouts that are preferred by deer, provided of course that the weed species are not appreciably reduced under the guise of a silvicultural practice. Maybe the deer will help to do the weeding job for the forester if the right kind and amount of nontimber plants are present.

The key to planning an overall timber-management system to produce optimum wildlife habitat is to strive for good distribution of forest stands representing different age groups over the entire home range of the wildlife species for which you wish to manage. Consider the following:

Young Stands

Young (seedling-sapling) stands established by clearcutting, seed-tree cutting, or two-cut shelterwood methods provide a surge of lush vegetation. The invasion of forbs, grasses, berry bushes, seedlings, and sprouts offer wildlife a complete high-protein diet for about 10 years after cutting. If saplings are weeded, the wildlife values of these superfood areas may even be extended to the time small pulpwood sticks can be cut as part of a thinning operation.

It is best for wildlife if regeneration areas are between 2 and 20 acres. Long narrow cuttings are better than square or circular cuttings because they create more edge (*Allison 1966*). If more than 20 acres are involved, strive to keep the short dimension to an average of 5 to 10 chains. The following guidelines by Roach and Gingrich (1962) should also be followed:

Space areas chosen for regeneration cuts far enough apart to permit creating one or more additional openings between them during some future cut. . . . Openings should total no more than 10 to 15 percent of the area of any working unit during a cutting interval in order to provide for sustained production.

Although written as a timber management guide, this sustained-production concept applies to both timber and wildlife habitat. The more these openings are dispersed throughout the working unit (home range of the wildlife species), the more benefit there will be for wildlife.

Poletimber Stands

As forest stands proceed from young to middle age, the wildlife food zone is gradually transferred from the ground to the tree canopies where seeds, nuts, and fleshy fruits are produced. Most untreated pole stands are relatively unproductive as wildlife habitat because their tight canopies prevent undergrowth development; and tree crowns are too small and crowded to produce much

mast. To maintain wildlife values, improvement cuts are essential. The released crowns will put out more fruit and seeds, and the sunlight reaching the ground will result in temporary but significant increases in ground plants and low-growing woody material. For example, the number of woody twigs available to deer will more than double if the basal area is reduced from 110 to 80 square feet (*Shaw and Ripley 1965*). The good effects will remain on the plus side for nearly 10 years, so intermediate cuts at 10-year intervals are desirable.

Sawtimber Stands

Sawtimber stands produce the lion's share of the acorns, beechnuts, hickory nuts, and other tree fruits that drop to the ground and are so eagerly sought by squirrels, deer, bear, grouse, and turkey. Improvement cuts in sawtimber stands of less than rotation age have the same beneficial effects as in pole stands, perhaps more so because thinning the high irregular crowns of older stands permits more sunlight to reach the forest floor.

For wildlife purposes, an ideal distribution of stand size classes to aim for is 25 percent seedling-sapling (2-5 inches d.b.h.), 25 percent poletimber (6-10 inches d.b.h.), and 50 percent sawtimber (11 inches d.b.h. and over) (*Shaw 1967*). In the northern hardwood type where paper and yellow birch are favored in the forest management system, this 25-25-50 stand-size distribution can be reached rather easily in a few cutting cycles if an 80- to 100-year rotation age is set as a goal. In fact, it is about what you would expect under a sustained-yield plan with timber production as the only objective.

If the few precautions mentioned earlier relative to regeneration areas—size, distribution, and extent—are heeded, forest management for birch production is completely compatible with forest management for wildlife production. Any of the silvicultural systems and cultural work mentioned during this symposium can be made to serve both purposes.

Literature Cited

- Allison, Donald G.
1966. IMPROVING YOUR LAND FOR RUFFED GROUSE. 18 pp. N.H. Fish and Game Dep., Concord, N.H.
- Martin, Alexander C. Herbert S. Zim, and Arnold L. Nelson.
1951. AMERICAN WILDLIFE AND PLANTS. pp. 304-305. McGraw-Hill Book Co., New York.
- Roach, Benjamin A., and Samuel F. Gingrich.
1962. TIMBER MANAGEMENT GUIDE FOR UPLAND CENTRAL HARDWOODS. USDA Forest Serv. Cent. States Forest Exp. Sta. and N. Cent. Region. 33 pp.
- Shaw, Samuel P.
1967. WOODLOTS, WILDLIFE AND TIMBER MANAGEMENT. N. Amer. Wildlife and Nat. Res. Conf. Wildlife Manage. Inst. Trans. 32.: 238-246. Washington, D.C.
- Shaw, Samuel P., and Thomas H. Ripley.
1965. MANAGING THE FOREST FOR SUSTAINED YIELD OF WOODY BROWSE FOR DEER. Soc. Amer. Foresters Proc.: 229-233. Detroit, Mich.
- Stiteler, W. M., and S. P. Shaw.
1966. USE OF WOODY BROWSE BY WHITETAIL DEER IN HEAVILY FORESTED AREAS OF NORTH-EASTERN UNITED STATES. N. Amer. Wildlife and Nat. Res. Conf. Wildlife Manage. Inst. Trans. 31: 205-212. Washington, D.C.
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