

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.

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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

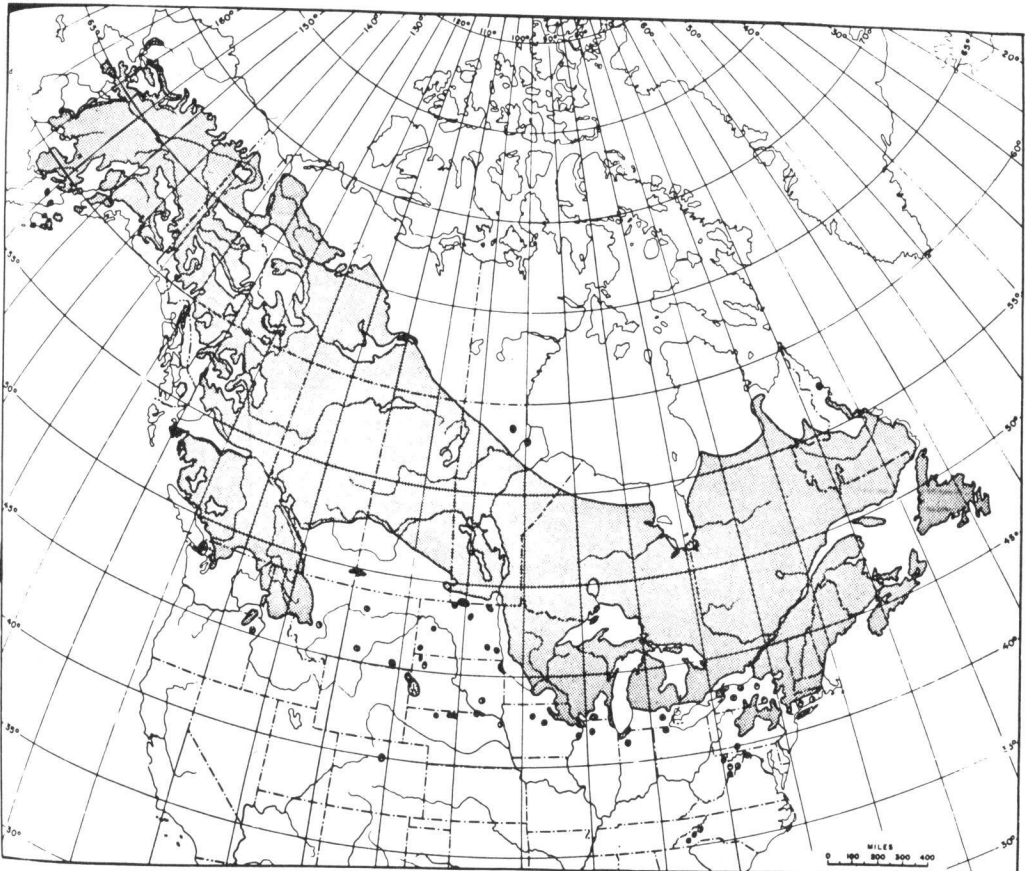


Figure 1.—The range of paper birch (From Fowells 1965.)

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

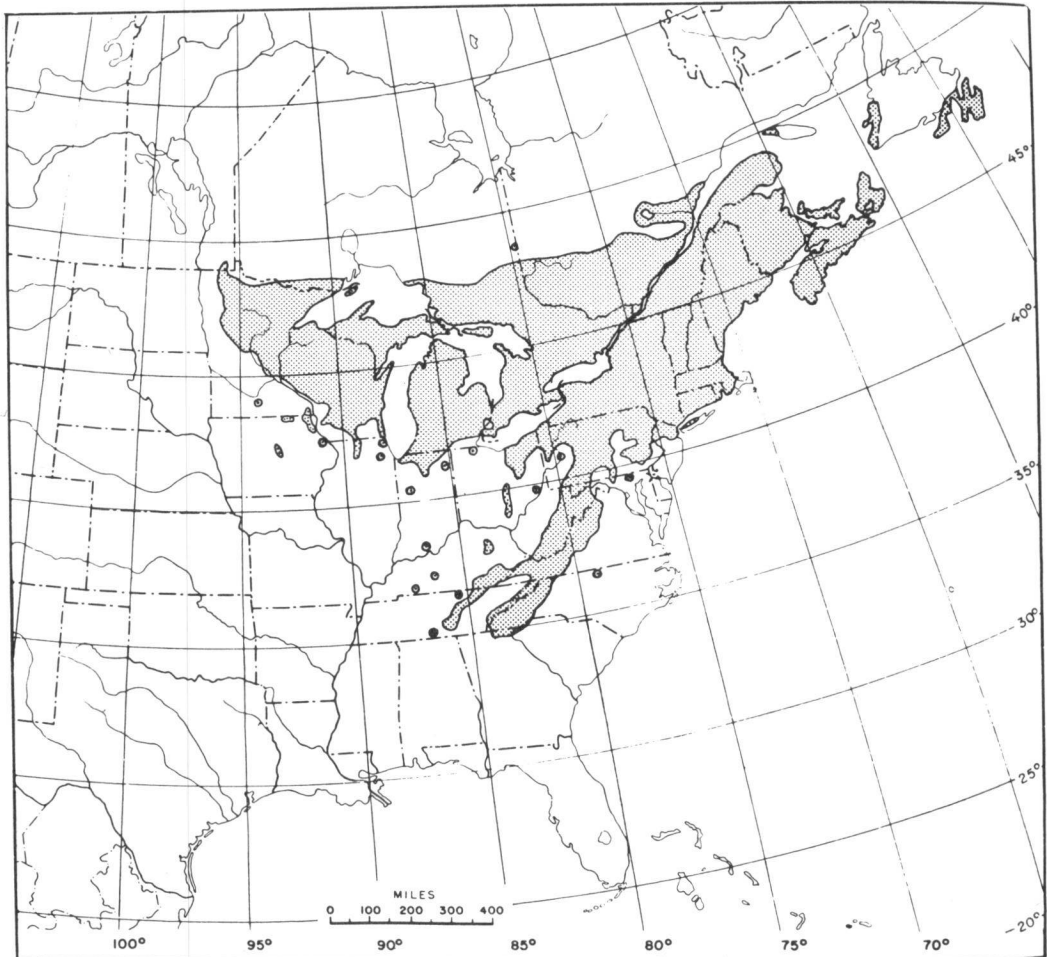


Figure 2.—The range of yellow birch (From Fowells 1965.)

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.

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