Growth of
Yellow Birch
in a Podzol Soil

by Merrill C. Hoyle

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The Author--

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Introduction

YELLOW BIRCH (*Betula alleghaniensis* Britton) has been described as a very sensitive tree that adapts poorly to changes in environment (Gilbert 1960). In New Hampshire, old-growth yellow birch stands have displayed high mortality and low production (Filip *et al* 1960). And in second-growth stands, the percentage of yellow birch has been found to decline under all levels of stocking examined. Furthermore, this species had the highest mortality and made only poor to fair ingrowth in studies conducted over a 25-year period on the Bartlett Experimental Forest in New Hampshire (Leak 1961). Besides making poor growth, yellow birch has been beset by several maladies, especially post-logging decadence (Hall 1933) and dieback (Hawboldt 1947).

Little is known about the causes of this characteristically poor performance of yellow birch. Several aspects of the problem have been examined in the past, but more recently forest soils have been studied for possible clues. Of particular interest is the effect of rooting depth on the development of birch (Pomerleau and Lortie 1962).

Yellow birch generally develops a shallow root system on forest soils in the Northeast. This is understandable where hardpans, bedrock, or water tables are found close to the surface; but in deeper and well-drained soils the superficial rooting is more difficult to explain.

Redmond (1954) observed, after excavating yellow birch roots, ". . . that they develop in an area or fail to do so because of isolated edaphic peculiarities in their immediate vicinity . . ." In subsequent pot experiments, he discovered that yellow birch seedlings developed extensive roots in loam but not in sand. He felt that higher nutrient content of the loam was responsible.

Tubbs (1963) and Winget *et al* (1963) obtained similar results for yellow birch seedlings variously planted in humus and mineral soils collected under hemlock-hardwood stands in the Lake States. Seedlings developed well in humus, but only slightly or not at all in mineral soil. Tubbs tried unsuccessfully to induce rooting in the mineral soil by adding a commercial fertilizer solution (7-6-19). And I experienced similar difficulties in attempts to grow yellow birch seedlings in mineral soils for purposes of soil-fertility evaluation.

Therefore it was decided to examine the effects of soil physical properties on the growth of yellow birch before pursuing the nutrition studies any farther. The purpose was twofold: first, to better understand the influence of physical properties themselves; and second, to be able to make some allowance for physical effects when evaluating the effects of chemical and micro-organism factors.

Forest soils consist of several distinct layers or horizons that have developed as a result of weathering processes and the influence of vegetation. These horizons are generally recognizable by color differences. Though birch roots are concentrated in the upper horizons, a few roots are found in the lower horizons. Therefore all mineral horizons were considered in this study.

Horizon differences and soil physical properties were tested. Specifically, the objectives were to discover which horizons of a well-drained podzol soil were most favorable to growth of yellow birch and what treatment or combination of treatments to modify bulk density and aeration would permit the best growth in each horizon.

The Soil

The Hermon soil used in the study was collected beneath a northern hardwood stand on the Northeastern Forest Experiment Station's experimental forest at Bartlett, New Hampshire. The Hermon series is a well-drained deep podzol developed on loose late Wisconsin glacial till derived from granite and gneiss. Hermon soils are characteristically stony and are generally found on gently rolling morainic uplands in Maine, New Hampshire, Vermont, western Massachusetts, and northeastern New York.

A description of the study soil is given in table 1. By the American system, this soil would be called a loamy sand; but because it averages about 70 percent sand and 30 percent silt

Table 1.—*A descriptive illustration of the Hermon soil profile used in this study*

Horizon thickness (inches)	Horizon label	Horizon description
½ to 1	L	The litter layer consists of recently deposited leaves, twigs, and bark of birch, beech, and maple.
¼ to ½	F	The fermented layer consists of partially decomposed litter.
1¼ to 1½	H	The humus layer consists of completely decomposed litter and is a black, amorphous material.
1½ to 2	A_2	The A_2 horizon is light to dark gray as a result of severe leaching of soluble salts, iron, aluminum, and clay.
3 to 4	B_{22}	The B_{22} horizon is the zone of maximum accumulation of iron, aluminum, organic matter, and clay removed from the A. Color is dark reddish-brown.
9 to 10	B_{23}	The B_{23} horizon is similar to the B_{22}, but has a lower amount of deposited materials and a yellowish-brown color.
6 to 7	B_3	The B_3 horizon is transitional to the C horizon below and has a light yellow color.
12 +	C	The C horizon is the slightly weathered parent material, from which the overlying A and B horizons probably developed. Color is light olive gray.

Table 2. — *Some physical properties of the Hermon soil horizons*

Horizon	Bulk density	Pore volume	Air volume	Water volume[1]
	g/cc.	*Percent*	*Percent*	*Percent*
H	0.26	95.9	50.7	45.2
A_2	.97	63.4	17.4	46.0
B_{22}	.72	72.8	29.5	43.3
B_{23}	.96	63.7	25.6	38.1
B_3	1.20	54.7	26.4	28.3
C	1.43	46.1	21.1	25.0

[1] At 0.06 atmospheres tension.

with little or no clay content, the Canadian term "silty sand" seems more fitting.

Additional physical properties are shown in table 2. Moisture-holding capacities (last column) are generally good. Wilde (1958) reported that air volumes of forest soils supporting vigorous hardwood stands are seldom below 15 percent. Only the A_2 horizon of the Hermon soil comes close to this minimum value. Pore volumes are generally well above the 40-percent limit reported by Hidding and van den Berg (1961) to obstruct root penetration of field crops. Also, bulk densities are lower than the restrictive value of 1.75 put forth by Veihmeyer and Hendrickson (1948).

Soil chemical analyses[1] indicated that important nutrients were in low supply. Nitrogen and potassium were measured in every horizon, and greatest amounts were found in the H and A_2. Exchangeable calcium was found only in the H and A_2; and exchangeable magnesium only in the H, B_{22}, and B_{23}. Soil acidity ranged from pH 3.8 to 5.3 (H and C horizons respectively).

Procedures

Soil Treatments

Bulk soil samples of six horizons (H, A_2, B_{22}, B_{23}, B_3, and C) were collected separately in sacks and allowed to attain an air-dry condition before storage. In the laboratory, previously weighed

[1] Hoyle, M. C. VARIATIONS IN FOLIAGE COMPOSITION AND DIAMETER GROWTH OF YELLOW BIRCH WITH SEASON, SOIL, AND TREE SIZE. In press, Soil Sci. Soc. Amer. Proc.

Table 3. — *Estimated average bulk density of potted soils, by horizons and treatments*

Horizon	S[1]	SO	SF	SFO	S2F	S2FO
H	0.22	0.25	0.21	0.22	0.22	0.19
A_2	.73	.78	.48	.54	.35	.33
B_{22}	.82	.77	.49	.50	.36	.34
B_{23}	1.00	1.02	.63	.64	.42	.42
B_3	1.06	1.04	.64	.67	.45	.46
C	1.34	1.36	.78	.85	.64	.53

[1] Key to treatment symbols: S = Soil receiving distilled water. SO = Soil receiving 0.1 percent H_2O_2. SF = Soil and filler, 1:1 ratio, receiving distilled water. SFO = Soil and filler, 1:1 ratio, receiving 0.1 percent H_2O_2. S2F = Soil and filler, 1:2 ratio, receiving distilled water. S2FO = Soil and filler, 1:2 ratio, receiving 0.1 percent H_2O_2.

4.5-inch clay pots were filled with soil material. The pots were reweighed after filling to obtain estimates of soil bulk density. Commercial vermiculite (Terralite) was used as an inert[2] filler material to modify the natural soil bulk density.

Three soil bulk density treatments were developed for each horizon: 500 ml. of air-dry soil (control); 250 ml. soil plus 250 ml. filler (a 1:1 ratio by volume of soil to filler); 167 ml. of soil plus 334 ml. of filler (a 1:2 ratio of soil to filler). The potted soil bulk densities are given in table 3. Generally the 1:1 ratio reduced natural bulk densities by 30 to 40 percent and the 1:2 ratio by 50 to 60 percent. Humus bulk density was not altered by addition of filler. This offered a means of evaluating some extraneous influences of the filler, such as a fertilizer effect and the effect of reducing pot soil volume.

Supplemental oxygen was provided by watering the "0" pots with 0.1 percent hydrogen peroxide (H_2O_2) after the method of Melsted *et al* (1949).

Seeds

Seeds used in this study were all collected from one dominant yellow birch tree on the Bartlett Experimental Forest. Cones were air-dried, broken up, and sieved to separate seed from bracts. Seeds were further separated into two sizes — those that would pass a 10-mesh sieve and those that would not. The larger seeds were sown in several germination trays filled with coarse sand

[2] Ideally, such filler should be chemically inert, that is devoid of any plant nutrients. Vermiculite is nearly so, but it does contain small quantities of available bases, mostly potassium.

and vermiculite. Trays were watered daily and kept under cool white fluorescent lights.

After germination, four apparently healthy seedlings were planted in each pot. The first true leaves were just emerging at time of planting. All potted soils were kept at the field-moist condition by frequent watering from below.

Environmental Conditions

A chamber was constructed to provide favorable lighting. Two banks of four F96T12CW Slimline fluorescent lamps (Sylvania)[3] plus three 60-watt incandescent bulbs yielded light intensities of 100 to 2,000 foot-candles according to height of lamps above the pots. Light at about 300 foot-candles at pot level was maintained for the first 5 weeks, and at approximately 1,000 foot-candles for the rest of the experiment. Seedlings were grown under a 21-hour photoperiod composed of fluorescent light from 9 p.m. to 5 p.m. and incandescent light from 4 p.m. to 6 p.m. Day temperatures of 24° C., night temperatures of 21° C., and a relative humidity of 51 percent generally prevailed in the chamber. Pots were rearranged weekly to offset a slight variation in light intensities.

Measurements

Height measurements were taken periodically from the point of cotyledon attachment to the growing tip. At termination of the study, above-ground portions of the seedlings were collected, dried at 70° C., and weighed.

Experimental Design

This study was originally designed as a 6 x 3 x 2 Model I (fixed treatment effects) factorial. Specifically, the factors were: (1) horizons — six levels; (2) bulk density treatments — three levels; (3) oxygen treatments — two levels. Three replications gave a total of 108 pots.

However, because of wide differences in growth rates among horizons, all pots were not terminated at the same time. In addition, many pots yielded seedlings of such small size that meaningful weight data could not be obtained. Consequently, where permissible, these data have been subjected to Tukey's method of testing for significant differences among treatment means (Snedecor 1956). Height data are presented graphically.

[3] Mention of trade names does not imply endorsement by the U. S. Department of Agriculture.

Results and Discussion

Height Growth

The greatest differences in height growth occurred between horizons. Smaller differences that resulted from soil treatments developed within the top three horizons, but not within the lower three (table 4). Eighty days after planting, control seedlings in humus (H) were about 27 cm. taller than controls in the A horizon, while seedlings in the untreated B and C horizons remained at their initial size (fig. 1). After 122 days, seedlings in the SF and S2F treatments of the B_{22} horizon finally displayed some measurable height growth (table 4 and fig. 1). All other treatments in this horizon and all those in the lower three horizons remained unchanged.

The rates of seedling height growth in humus were rather high. Slower growing seedlings in the SF series averaged about 8.9 mm. per day in humus over a 20-day period of most rapid growth. Control seedlings (S series) attained a higher rate of 12.0 mm. per day in humus for the same period. The tallest single yellow birch seedling measured in humus at 80 days was 62 cm., which represents an average growth rate of nearly 7.8 mm. per day over the entire period. By comparison, A_2 seedlings (S and SF series) averaged only 4.1 mm. per day over their 20-day period of most rapid height growth.

In addition to total size and maximum growth rate obtained, these soil horizons affect yellow birch development by delaying establishment time. For this study, this was defined as the time elapsed between planting and initiation of the period of most rapid height growth. Establishment time for the SF series was

Table 4.—*Average heights (cm.) of yellow birch seedlings at time of last measurement, by horizon and soil treatment*

Horizon	Soil treatment						Days since planting
	S[1]	SO	SF	SFO	S2F	S2FO	
H	42.1	42.4	34.9	34.0	43.7	35.2	80
A_2	25.2	36.4	25.4	28.1	18.0	22.1	117
B_{22}	1.8	1.2	4.6	1.1	4.6	3.0	122
B_{23}	1.3	1.0	1.9	1.2	1.2	1.5	122
B_3	1.5	1.3	1.4	1.5	1.3	1.2	122
C	1.3	1.3	1.8	1.8	1.9	1.6	122

[1] Key to treatment symbols is given in table 3.

approximately 45 days in H, 65 days in A_2, and over 122 days in B_{22}. It was somewhat doubtful if yellow birch in the lower three horizons would ever become established.

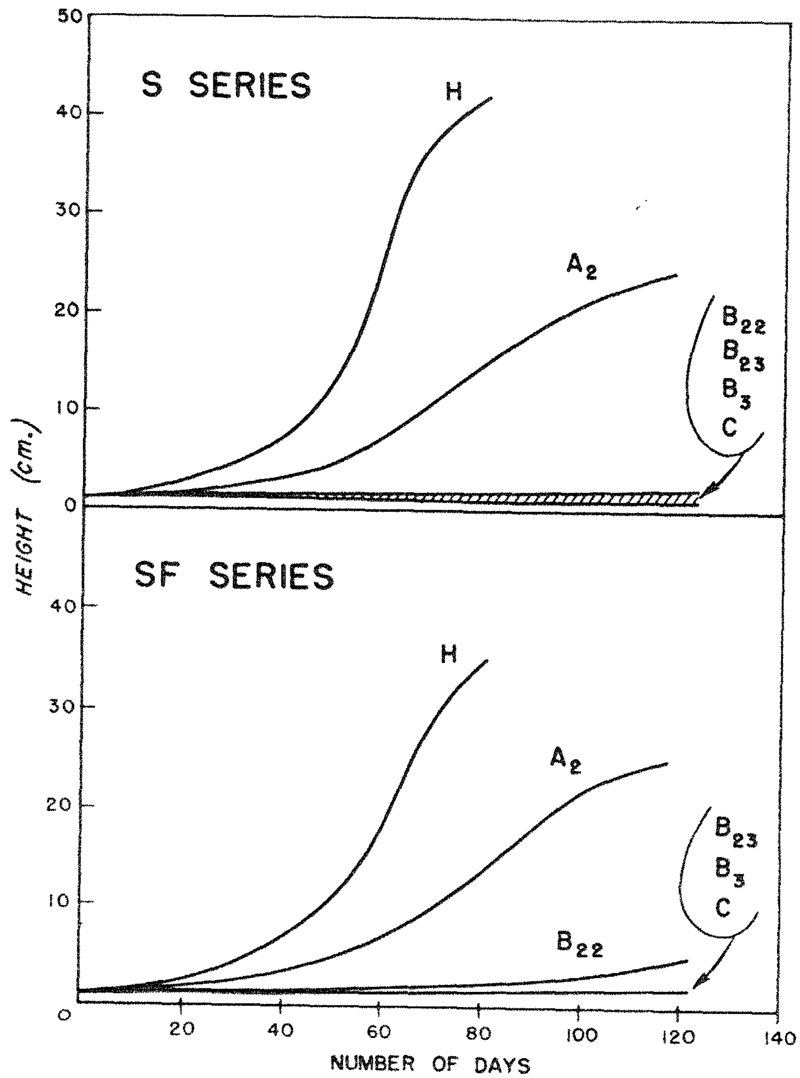

Figure 1. — Height growth curves for yellow birch seedlings growing in the various horizons of a Hermon soil. Top, S series or control; bottom, SF series, a 1:1 ratio of soil to filler by volume.

Dry-Weight Data

Dry weights (by soil treatment) of yellow birch seedlings at time of harvest are given in table 5 for the top three horizons only. After 138 days most seedlings in the subsoil horizons remained alive but had attained little or no additional growth since planting. Consequently, statistical tests for significant differences among treatment means could be determined only for the top three horizons.

Summary statements for the statistical data in table 5 are: (1) For humus, only S2F was significantly greater than S (control series); all other treatments were equal to or less than S. (2) For A_2, only SO was significantly greater than S; all others were not significantly different from S. And (3) for B_{22}, SF and S2F were significantly greater than S; all others were not significantly different from S.

In the absence of any consistent pattern of treatment effects within and among horizons, no acceptable explanation of these results can be offered. However, in view of the height and dry-weight measurements obtained from this study, it was clear that, of the three factors tested, horizons were by far the most influential (fig. 2). Improved seedling growth in the A_2 (resulting from oxygen treatment) and B_{22} (resulting from bulk density treatment) still fell far below that obtained in humus.

Table 5. — *Average dry-weight (mg.) of yellow birch seedlings at time of harvest, by horizon and soil treatment*[1]

Horizon	Soil treatments						Days since planting
	SFO	S2FO	SF	S	SO	S2F	
H	1310	1310	1330	1810	1860	2360	80
	S2F	S2FO	SF	S	SFO	SO	
A_2	590	736	875	905	993	1543	117
	SFO	SO	S	S2FO	SF	S2F	
B_{22}	15	17	30	79	131	134	138

[1] A value is not significantly different (5-percent level) from those to the right of it when connected by a solid line.

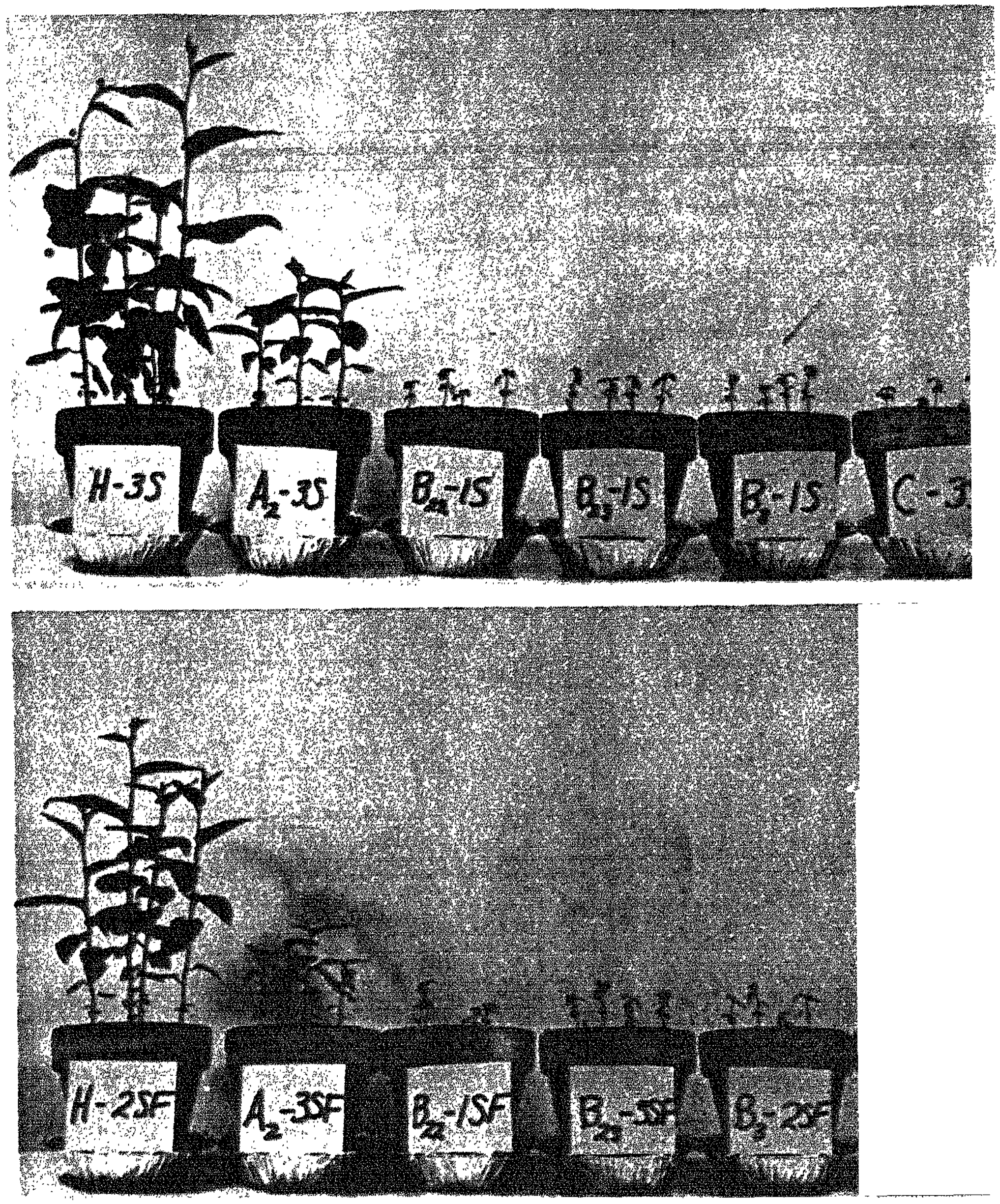

Figure 2. — Comparative growth of yellow birch seedlings at 53 days in the various horizons of a Hermon series, podzol soil. Top, S series or control; bottom, SF series, a 1:1 ratio of soil to filler by volume. (Card numbers refer to replicates.)

With respect to the lower three horizons, where seedlings failed to develop despite adequate light, temperatures, moisture, and treatments to modify soil bulk densities and soil aeration, one may conclude, by elimination, that soil fertility was the primary limiting factor. Certainly, to a lesser degree, this was also indicated for the A_2 and B_{22} horizons.

Seedling Descriptions

As shown, best growth was produced in the humus. Seedlings were large, with deep green leaves and one or several branches (fig. 3). The A_2 seedlings, though of fair size, were stunted by comparison: stems were smaller in diameter and shorter in height; the leaves were much reduced in size and chlorotic; and there was no branch development. Seedlings in the B and C

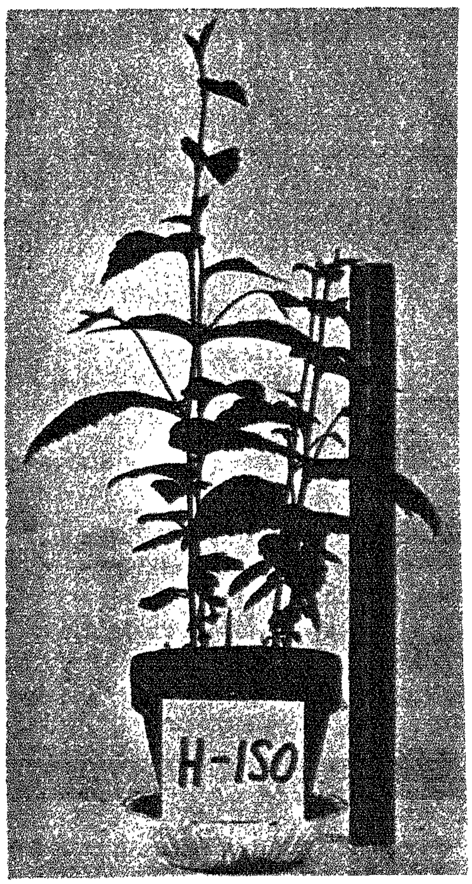

Figure 3. — Yellow birch seedlings growing in humus (SO series, receiving supplemental oxygen). Note the large leaves and good development of branches.

horizons were even poorer: they exhibited only slight development after planting, and several leaves died.

Other than reduction in overall size and general lack of growth, several symptoms appeared on the leaves that further suggested the existence of nutrient deficiencies. Leaves on seedlings in A_2 pots were generally chlorotic. Reddish-purple anthocyanin spots were noted on many leaves. Downward leaf curling was another widespread symptom. Marginal and interveinal necroses were numerous. Humus seedlings, though displaying lush growth, showed three visible leaf symptoms as the plants aged: tip, marginal, and interveinal necroses; slight curling under of the leaf margins; and puckering in the leaves, which produced a blistery surface. Apparently not even the humus provided an optimum nutrient pool for yellow birch development.

Summary and Conclusions

This study was undertaken to determine what soil horizons and treatments to modify bulk density and aeration in each horizon would permit the best growth of yellow birch seedlings. The soil was a podzol belonging to the Hermon series. And the study was conducted indoors to insure adequate light and temperature; sufficient moisture was supplied to the potted soils by frequent waterings. The results of the study are:

- Yellow birch seedling growth was good in humus (H), fair in the A_2 horizon, poor in the B_{22}, and practically nil in the remaining B and C horizons.
- Seedling-height and dry-weight data indicated that treatments to improve bulk density and aeration did not generally produce better growth than the untreated soils.
- The author concluded that soil factors other than moisture, bulk density, and aeration were more severely limiting to growth of yellow birch in the Hermon soil. Soil analyses, plus the size and appearance of birch seedlings, strongly indicated the existence of nutrient deficiencies.

Soil analyses and seedling growth in the various horizons point to humus as the principal source of nutrients in the test soil. Therefore management should certainly provide against excessive loss of humus by wildfire[4] or erosion. In addition, because

[4] It is possible that light prescribed burning would provide a temporary fertilizer effect and would be helpful in regenerating yellow birch in clearcut areas.

extensive rooting is very limited in the deeper horizons (for some still unknown reason), root competition in the surface horizons among all types of vegetation present on the site must certainly be severe.

Consequently, it seems practical to advise the use of early and frequently repeated crop-tree thinnings (Hawley and Smith 1954, pp. 387-388 and 411) in order to reduce root competition between dominant stems. Further reduction in root competition with crop trees by understory trees and woody shrubs could probably be accomplished by mechanical or chemical methods. The purpose of these treatments would be to conserve the small amount of available nutrient capital and to permit use of that capital only by the selected crop trees.

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