Fertilization Fails to Increase Diameter Growth of Selectively Managed Northern Hardwoods

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Introduction

High costs of land ownership, increasing stumpage prices, and short supplies of the better grades of veneer and sawlogs have stimulated interest in fertilizing high-quality northern hardwood crop trees. The value of these species justifies management on an individual tree basis. Previous fertilization studies in Lake States northern hardwoods have been conducted in unmanaged even-age, pole-size stands (8, 9, 10). Results of fertilizing individual sawlog-size northern hardwoods in a selectively managed all-age stand are reported here.

Stand and Site Conditions

This study was conducted in a 16.2 ha (40-acre) all-age northern hardwood stand near Amasa, in western Upper Michigan. The stand is managed for continuous production of high-quality veneer and sawlogs by single tree selection on a 12-year cutting cycle. The site is on a nearly level plain of glacial till with a 0-2% westerly slope. Soils are of the Stambough-Goodman complex, a moderately well-drained Alfic Haplorthod (coarse, loamy, mixed, frigid) developed from a 76-152 cm (30-60 in.) silt cap over gravelly, loamy sands, Internal drainage is impeded somewhat by the textual discontinuity of the underlying material and an accumulation of clay materials (B_t horizon) in the lower profile. The textural discontinuity and the argillic horizon result in a temporary perched water table.

Site index (age 50) for sugar maple on these soils is about 21m (65 feet). In the original stand, more than 60% of the trees 51cm (20 in.) dbh and greater had merchantable heights of 2½ to 3½ 5-m (16-ft.) logs, also indicating a good site. Stand and site conditions were unusually uniform over the study area with surface soil pH 5.5, 5.0% organic matter, and 0.25% total N; available nutrients (kg/ha) were: 28 P, 165 K, 1,000 Ca, and 100 Mg (25, 147, 895 and 90 lbs/acre).

Initial timber volume on the 40 acres was 393 Mbf with 10% cull. Over 80% of the volume was sugar maple; the balance consisted of 9.2% yellow birch (*Betula alleghaniensis* Britton), 7.9% American basswood (*Tilia americana* L.), and 2.5% American elm (*Ulmus americana* L.). Basal area averaged 21 m^2/ha (91 ft. ^{2}/acre) in trees 25 cm (10 in.) dbh and larger; total basal area was 32 m^2/ha (140 ft.^{2}/acre). Diameters ranged up to 76 cm (30 in.) dbh and merchantable heights to 3½ 5-m (16 ft.) logs. The initial cut in 1936 removed 10.6 m^2/ha (46 ft.^{2}/acre) of sawlog basal area and 66% of the net volume.

An improvement cut in 1964 left a residual basal area of 11.5 m^2/ha (50 ft.^{2}/acre) in trees 25 cm (10 in.) dbh and larger; total basal area averaged 18m^2/ha (78 ft.^{2}/acre). Thus, when the stand as treated in 1970, midway through the cutting cycle, residual stocking was near optimum for stand development and growth of high-value logs (1). The improvement cut reduced cull volume to 1.2%. Net volume was 6.3 Mbf/acre: 88% maple, 7% yellow birch, 3% elm and 2% basswood. Volume

TABLE 1. *Species distribution of selected crop trees (number).*

Treatment	American Basswood	Yellow Birch	American Elm	Sugar Maple	Total[1]
Control	9	12	12	472	505
Fertilized	8	9	15	468	500
Total	17	21	27	940	1,005

[1]Living trees at conclusion of study.

distribution between small 25-37 cm (10-14 in.), medium 38-49 cm (15-19 in.), and large 50-65 cm (20-25 in.) sawlogs was 21, 54, and 26% respectively.

Methods

The stand was divided into five 3.24 ha (8-acre) blocks; each was split into two plots. On each plot, approximately 100 (93 to 110) vigorous crop trees 25 to 65 cm (10 to 25 in.) dbh were selected, measured, and numbered. All sample trees were dominant or strong codominants with well-developed crowns; each contained at least one potential grade #1 5-m (16-ft.) sawlog. Crop trees on randomly selected plots were treated with 2.61 kg (5.75 lbs.) per tree of 20-20-20- N-P-K fertilizer, approximately 700 kg/ha N, 300 P, and 600 K. Fertilizer was surface broadcast over an approximately 1.0 m (3.3 ft.) wide band around the base of treated trees on 10 June 1970. A total of 502 trees were fertilized; there were 506 controls (Table 1). Diameter at breast height (dbh) of crop trees was measured in the fall after three and after six growing seasons following fertilization. Differences in dbh growth of sample trees on the five pairs of plots were evaluated by paired t-tests at the 0.05 probability level.

Forty core samples of the surface 30 cm (12 in.) of soil on each plot were composited, air-dried, and passed through a 2 mm sieve. Sub-samples of each composite sample were analyzed for N, P, K, Ca, Mg, pH, and organic matter content. Total N was determined by Kjeldahl analysis (2); Bray P_1 extractable P was measured colorimetrically. Exchangeable K, Ca, and Mg were determined by atomic absorption after extraction with neutral normal NH_4OAc, organic matter by loss-on-ignition, and pH with a glass electrode in a 1:1 soil-water suspension.

Results and Discussion

Species distribution on control and fertilized areas was nearly identical; the number of maples differed by only four trees and the minor species by three or less (Table 1). Three maples died over the 6-year period; two of them had been fertilized. Mean annual diameter growth of minor species was slightly greater than that of maple, but there were not enough for valid comparisons and their presence did not change the overall mean (Table 2).

TABLE 2. *Mean annual diameter growth (cm) of sawlog-size northern hardwoods 6 years following fertilization (number of trees in parenthesis).*

Treatment	Sugar Maple	Other Species	All Species
Control	0.41	0.51	0.41
	(472)	(33)	(505)
Fertilized	0.41	0.48	0.41
	(468)	(32)	(500)

TABLE 3. *Periodic and total dbh growth (cm) of northern hardwood species by initial diameter.*

Initial	1970-72		1973-75		6 Yr. Total	
dbh	Control	Fertilized	Control	Fertilized	Control	Fertilized
25-37	1.14	1.17	1.19	1.24	2.34	2.39
38-49	1.17	1.17	1.30	1.35	2.46	2.54
50-65	1.17	1.19	1.32	1.32	2.51	2.51
All	1.17	1.17	1.27	1.30	2.44	2.49
Mean Annual Growth	0.38	0.38	0.43	0.43	0.41	0.41

Crop trees in all three diameter classes grew at essentially the same rate; medium and large sawlogs grew slightly more than smaller ones but the differences were minor (Table 3). Diameter growth of trees in all classes was slightly greater the second 3-year period than the first. Fertilization did not significantly increase dbh growth of crop trees in any of the three size classes during either measurement period, nor the 6-year total. Likewise, there were no significant differences in basal area growth. Six-year growth of crop trees averaged 1.65 m^2 (17.76 $ft.^2$) on control, and 1.63 m^2 (17.50 $ft.^2$) on fertilized plots. Mean annual growth per tree was 27.2 cm^2 (0.176 $ft.^2$) for control, and 27.1 cm^2 (0.175 $ft.^2$) for fertilized trees.

Mean annual dbh growth of both fertilized and control trees averaged 0.41 cm (0.16 in.), nearly 2.54 cm (1.0 in.) over the 6-year period. Diameter growth of dominant and codominant northern hardwoods in unmanaged stands on similar sites normally averages about 2.54 cm (1.0 in.) per decade. The greater growth observed in this study is typical of these species grown in selectively managed stands on good sites. Slightly greater growth of the minor species (Table 2) reflects the presence of basswood and elm, which generally grow somewhat faster than birch and maple.

The absence of a significant growth response following fertilization (Tables 2 and 3) was not unexpected. We have found similar results in pole-size stands of both birch and maple growing on comparable sites (8). The nearly equal growth of crop trees in each of the three diameter classes (Table 3) indicates that periodic cuttings will maintain superior growth of crop trees until they reach large sawlog sizes (3). Fertilization did not stimulate growth of one size class at the expense of another, as frequently occurs following fertilization of even-age stands (9). It can be inferred that there was no significant relation between treatment response and tree age because in managed stands, age and size are closely related (12). Tree vigor, as indicated by growth rate, did not influence treatment response; nearly

TABLE 4. *Number of trees that grew 2.5 cm or more in dbh during the 6 years following fertilization.*

Initial	Treatment	
dbh	Control	Fertilized
25-37	73	78
38-49	117	119
50-65	53	45
Total	243	242
Percent	48.1	48.4

half of the study trees grew 2.54 cm (1.0 in.) or more during the 6-year period, and fertilization did not change this proportion (Table 4).

The minor increase in growth of both control and fertilized trees during the second measurement period (Table 3) apparently was due to more available soil water. May through August precipitation averaged 35.4 cm (13.9 in.) during each of the first three growing seasons and 38.5 cm (15.2 in.) each of the second three.

Reasons for the lack of a fertilization response are not readily obvious. Site conditions determine: (a) the natural nutrient-element resources; (b) biological and chemical reactions that regulate nutrient availability; and (c) nutrient cycling processes (6). Available nutrients were similar to those of a previous study in which fertilization significantly increased foliar concentrations of applied nutrients but failed to stimulate radial growth of pole-size maple growing on a similar site (10). Although foliar analyses were not performed in the present study, adequate natural levels of soil nutrients and absence of a growth response (Table 3) suggest luxury consumption of added nutrients.

Nutrient uptake by competing vegetation was negligible since few seedlings or saplings were present adjacent to fertilized trees and nearby grasses and herbaceous vegetation were killed by the fertilizer treatment. The absorbing roots of forest-grown trees generally are concentrated within an area approximated by the crown periphery (4, 5), although individual maple roots may extend considerably further (11). The method of fertilizer application concentrated nutrients in a small portion of the rooting area. Death of grasses and herbaceous vegetation around fertilized trees suggest roolet mortality due to salt toxicity as a partial explanation for the absence of a growth response. In future studies, fertilizers should be applied over a larger area, more representative of the root distribution.

In the upper Lake States, northern hardwood species are the climax vegetation on the better forest sites, i.e. well-drained, medium and finer textured soils with high native nutrient levels. Rapid decomposition of logging slash (3), a thin litter layer, and favorable soil reaction (pH 5.5) indicate active nutrient cycling. Rapid growth and absence of a fertilization response (Table 3) indicate that nutrient availability is not a major factor limiting diameter growth. Previous studies in pole-size stands growing on similar sites have indicated that diameter growth was not limited by nutrient availability (8). Thus, efficient nutrient cycling and natural nutrient levels in the better northern hardwood soils appear adequate for rapid growth of these species in managed stands. The large sample size and uniform experiemental material (Table 1) lend credence to the results.

Management Implications

This stand is representative of large areas of managed northern hardwoods in the upper Lake States. Management by single tree selection results in a good proportion of large, high-value trees (13) and is the recommended silvicultural system for sustained yields of high-quality veneer and sawlogs (1). Stand density influences nutrient availability through root competition (7). Periodic cuttings maintain superior growth rates and are conducive to efficient nutrient cycling. Fertilization can be used in intensive forest management; the greatest responses have occurred with coniferous species growing on marginal or nutrient-deficient sites. However, fertilization is not likely to increase growth of managed northern hardwoods on medium and better sites.

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