Fertilization Fails to Increase Diameter Growth of Sawlog-size Northern Hardwoods in Upper Michigan

by

Douglas M. Stone¹, Stephen G. Shetron² and James Peryam³

Abstract

Five hundred individual, sawlog-size crop trees in a selectively managed northern hardwood stand were fertilized with 2.61 kg (5.75 lbs) of N-P-K fertilizer per tree in June 1970. The stand is predominantly sugar maple (*Acer saccharum* Marsh.) growing on a deep silt loam soil of good site quality. Three- and six-year diameter at breast height (dbh) and basal area growth were analyzed by treatment and diameter class. Fertilization did not increase dbh or basal area growth during either measurement period. Mean annual dbh growth of both fertilized and control trees was 0.41 cm (0.16 in.); trees in all diameter classes grew at essentially the same rate. Nearly 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. Natural supplies of nutrients in good hardwood soils appear adequate for rapid growth of these species. Periodic cuttings maintain superior growth rates and contributes to efficient nutrient cycling. Fertilization is not recommended on sites like this because growth responses are not likely to justify costs.

Résumé

Cinq cents tiges individuelles de dimensions sciage, choisies dans un peuplement de feuillus nordiques, ont été traitées à l'engrais N-P-K à raison de 2.61 kg (5.75 lbs) en juin 1970. L'essence dominante, l'érable à sucre (*Acer saccharum* Marsh.) croît sur un sol profond, un loam argileux de bonne qualité. Trois et six années de croissance au DHP et la croissance en surface terrière ont été analysées par traitement et par classe de diamètre. La fertilisation n'a pas augmenté la croissance en diamètre ou en surface terrière durant la période d'observation. L'accroissement annuel moyen au DHP des arbres témoins et traités fut de 0.41 cm (0.16 po). Les arbres dans toutes les classes de diamètre se sont accrus au même taux. Près de la moitié des arbres étudiés ont fait 2.54 cm (1 po) en six ans et la fertilisation n'a pas affecté cette proportion. L'apport naturel d'éléments nutritifs dans de bons sols à feuillus semble satisfaisant pour la croissance rapide des espèces en présence. Les coupes périodiques maintiennent le taux de croissance à un niveau supérieur et contribuent à un cyclage adéquat des éléments nutritifs. La fertilisation n'est pas recommandée sur de tels sites, où les réponses de croissance ne justifient pas les coûts.

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 (Stone and Christenson 1974, Stone 1977, 1980). 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 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- to 152-cm (30- to 60-in.) silt cap over gravelly, loamy sands (Humo-Ferric Podzol subgroup of the Canadian classification system). Internal drainage is impeded somewhat by the textural discontinuity of the underlying material and an accumulation of clay materials (B₁ 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 21 m (65 ft). In the original stand, more than 60% of the trees 51 cm (20 in.) dbh and larger had merchantable heights of 12.5 to 17.5 m (40-56 ft), also indicating a good site. Analyses of composite samples of the surface 30 cm (12 in.) of soil showed pH 5.5, 5.0% organic matter, and 0.25% Kjeldahl N. Available nutrients (kg/ha) were: 28 P, 165 K, 1000 Ca, and 100 Mg (25, 147, 895, and 90 lbs/acre).

In 1936, timber volume on the 40 acres was 393 Mbf (Scribner) with 10 % cull. More than 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 m²/ha (91 ft²/acre) in trees 25 cm (10 in.) dbh and larger; total basal area was 32 m²/ha (140 ft²/acre). Diameters ranged up to 76 cm (30 in.) dbh and merchantable heights ranged up to 3-1/2 5-m (16-ft) logs. The initial cut in 1936 removed 10.6 m²/ha (46 ft²/acre) of sawlog basal area and 66% of the net volume.

An improvement cut in 1964 left a residual basal area of 11.5 m²/ha (50 ft²/acre) in trees 25 cm (10 in.) dbh and larger; total basal area averaged 18 m²/ha (78 ft²/acre). Thus, when the stand was fertilized in 1970, midway through the cutting cycle, residual stocking was near optimum for stand development and growth of high-value logs (Arbogast 1957). The improvement cut reduced cull volume to 1.2%; net volume was 6.3 Mbf per acre. Species composition was approximately 88% maple, 7% yellow birch, 3% elm and 2% basswood. Volume distribution between small 25-37 cm

¹Silviculturist, North Central Forest Experiment Station Bedford, Indiana.

²Associate Professor, Ford Forestry Center, Michigan Technological University, L'Anse, Michigan.

³Area Superintendent, Lake States Woodlands Division, American Can Company, Amasa, Michigan.

⁴This article was written and prepared by U.S. Government employees on official time; it is therefore in the public domain.

(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, about 100 vigorous crop trees 25 to 64 cm (10 to 25 in.) dbh were selected, measured, and numbered. All sample trees were dominants 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 fertilized with 2.61 kg (5.75 lbs) per tree of 20-20-20 N-P-K fertilizer on 10 June 1970. Fertilizer was surface broadcast over an approximately 1.0 m (3.3 ft) wide band around the base of treated trees. In total, 502 trees were fertilized; there were 506 controls (Table 1). Diameter at breast height of crop trees was measured in the fall after three and after six growing seasons following fertilization. Differences in dbh and basal area 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. Subsamples of each composite sample were analyzed for N, P, K, Ca, Mg, pH, and organic matter content. Total N was determined by Kjeldahl analysis (Bremner 1965); Bray P₁ extractable P was measured colorimetrically. Exchangeable K, Ca, and Mg were determined by atomic absorption after extraction with neutral normal NH₄OAc. Organic matter was determined by loss-on-ignition, and pH was determined by using a glass electrode in a 1:1 soil-water suspension.

Results and Discussion

Fertilization did not significantly increase dbh growth of crop trees in any of the three size classes during either measurement period. Likewise, there were no significant differences in basal area growth. Six-year growth of crop trees averaged 1.65 m² (17.76 ft²) on control, and 1.63 m² (17.50 ft²) on fertilized plots. Mean annual growth per tree was 27.2 cm² (0.176 ft²) for control, and 27.1 cm² (0.175 ft²) for fertilized trees.

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 2). Diameter growth of trees in all classes was slightly greater during the second 3-year period than the first.

Species distribution on control and fertilized areas was nearly identical (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 too few trees were present for valid comparisons and their presence did not change the overall mean (Table 3).

Mean annual dbh growth of both fertilized and control trees averaged 0.41 cm (0.16 in.) or 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 (Eyre and Zillgitt 1953, Jacobs 1968). The greater growth observed in this study (Table 3) is typical of these

Table 2. Periodic and total dbh growth (cm) of northern hardwood species by initial diameter.

Initial dbh	1970-72		1973-75		6 yr total	
	Control	Fertilized	Control	Fertilized	Control	Fertilized
24.4-36.8	1.14	1.17	1.19	1.24	2.34	2.39
37.1-49.5	1.17	1.17	1.30	1.35	2.46	2.54
49.8-63.5	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

Table 3. Mean annual diameter growth (cm) of saw log-size northern hardwoods 6 years after fertilization (number of trees in parenthesis).

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

species grown in selectively managed stands on good sites. Slightly greater growth of the minor species 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. Ellis (1979) found that sugar maple in four 35- to 85-year-old stands in southern Ontario responded well to release but not to fertilization with ureaform at 295 and 590, and triple superphosphate at 227 and 454 kg/ha. Likewise, pole-, and small sawlog-size stands of both birch and maple growing on a variety of site conditions in Upper Michigan consistently responded to release but none have shown a significant fertilization response (Stone 1977). The nearly equal growth of trees in each of the three diameter classes (Table 2) indicates that periodic cuttings will maintain superior growth of crop trees until they reach large sawlog sizes (Eyre and Zillgitt 1953). Fertilization did not stimulate growth of one size class at the expense of another, as frequently occurs following fertilization of even-age stands (Stone 1980). 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 (Tubbs 1977).

Tree vigor, as indicated by growth rate, did not influence treatment response; nearly 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:

Initial dbh	Control	Fertilized
24.4 - 36.8	73	78
37.1 - 49.5	117	119
49.8 - 63.5	53	45
Total	243	242
Percent	48.1	48.4

The minor increase in growth of both control and fertilized trees during the second measurement period (Table 2) 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.) during each of the second three.

Reasons for the lack of a fertilization response are not readily obvious. Site conditions determine: (1) the natural

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

¹Living trees at conclusion of study.

nutrient-element resource; (2) biological and chemical reactions that regulate nutrient availability; and (3) nutrient cycling processes (Leonard *et al.* 1972). 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 (Stone and Christenson 1975). Ellis (1979) also found that fertilization of sugar maple with N and P significantly increased foliar concentrations of both elements but did not increase diameter growth. Although foliage was not analyzed in the present study, adequate natural levels of soil nutrients, absence of a growth response (Table 2), and previous work (Stone and Christenson 1975, Ellis 1979) suggest luxury consumption of added nutrients.

Nutrient uptake by competing vegetation was negligible because 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 (Kramer and Kozlowski 1960, Fayle 1965), although individual maple roots may extend considerably further (Stout 1956). 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 rootlet 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.

The largest and most consistent forest fertilization responses have occurred with coniferous species growing on marginal or nutrient deficient sites. In the northeastern United States, sugar maple and other northern hardwood species have been reported to respond to fertilization, generally with high rates of N or N plus P (Mitchell and Chandler 1939, Mader and Thompson 1969, Safford 1973, Lea *et al.* 1979). These stands usually occupied less productive sites with more acidic soils than those studied in Upper Michigan, northern Wisconsin (Stone 1977, 1980) and southern Ontario (Ellis 1979). Moreover significant growth responses normally have not persisted more than 2 to 3 years and cost effectiveness has not been demonstrated.

In 1970, when this study was begun, the prospects of increasing growth of high-value crop trees by fertilizing were economically attractive. Since then the economic outlook for forest fertilization has changed drastically. Production of N fertilizers is energy-intensive and costs have increased much more than stumpage values. Domestic phosphate supplies are dwindling and by 1990 an estimated 75% of the World's P supply will be imported from the Middle East⁴. Even higher fertilization costs are likely. Substantial increases in timber yields and/or product prices will be required to justify fertilization costs.

In the upper Lake States and southeastern Canada, northern hardwood species are the climax vegetation on the better forest sites, i.e. well-drained, medium and finer textured soils that have high native nutrient levels (Braun 1950). Rapid decomposition of logging slash (Eyre and Zillgitt 1953), a thin litter layer, and favorable soil reaction (pH 5.5) suggest active nutrient cycling. Rapid growth and absence of a fertilization response (Table 2) indicate that nutrient availability is not a major factor limiting diameter growth. Previous studies in yellow birch and sugar maple stands on similar sites have shown that radial growth was not limited by nutrient availability (Stone 1977, Ellis 1979). 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 experimental material (Table 1) lend credence to the results.

Management Implications

The stand we studied is representative of large areas of managed northern hardwoods in the upper Lake States. Management by single tree selection results in a high proportion of large, high-value trees (Tubbs and Godman 1973) and is the recommended silvicultural system for sustained yields of high-quality veneer and sawlogs (Arbogast 1957). Stand density influences nutrient availability through root competition (Mitchell and Chandler 1939). Periodic cuttings maintain superior growth rates and are conducive to efficient nutrient cycling.

The largest fertilization responses have occurred on marginal or nutrient deficient sites. Some northern hardwood species on acidic soils in the northeastern US have responded briefly to high rates of N or N plus P, but fertilization is an energy-intensive practice and costs have increased much more than stumpage values. Fertilization of managed northern hardwoods on medium and better sites in the upper Lake States is not recommended because returns on investments will, at best, be very small compared to those from regulating stocking levels by thinning even-age stands or periodic harvest cuts in all-age stands.

Acknowledgement

We gratefully acknowledge the cooperation of Donald G. Lambrecht and Russell A. Oettel, American Can Company. We also thank Loren Berndt, USDA, Soil Conservation Service, for soil classification; and manuscript reviewers, R. A. McQuilkin, North Central Forest Experiment Station; C. H. Tubbs, Northeastern Forest Station; E. H. White, and the late A. L. Leaf, State University of New York at Syracuse.

References

- Arbogast, C., Jr. 1957. Marking guides for northern hardwoods under the selection system. USDA For. Serv., Stn. Pap. 56, 20 p. Lake States For. Exp. Stn., St. Paul, MN.
- Braun, E. L. 1950. Deciduous forests of eastern North America. 596 p. Hafner Publ. Co., New York.
- Bremner, J. M. 1965. Total nitrogen. In C. A. Black (ed) Methods of soil analysis. Part 2. Chemical and microbiological properties. Am. Soc. Agron. Inc., p. 1149-1178. Madison, WI.
- Ellis, R. C. 1979. Response of crop trees of sugar maple, white ash, and black cherry to release and fertilization. Can. J. For. Res. 9:179-188.
- Eyre, F. H., and W. M. Zillgitt. 1953. Partial cuttings in northern hardwoods of the Lake States. USDA Tech. Bull. 1076, 124 p.
- Fayle, D. C. F. 1965. Rooting habits of sugar maple and yellow birch. Can. For. Branch, Dept. Publ. 1120, 31 p.
- Jacobs, R. D. 1969. Growth and yield. In Sugar Maple Conf. Proc., Aug. 20-22, 1968. p. 96-104. Michigan Tech. Univ., Houghton, Michigan.
- Kramer, P. J., and T. T. Kozlowski. 1960. Physiology of trees. MacGraw-Hill Co., New York, 642 p.
- Leonard, R. E., A. L. Leaf, and J. B. Berglund. 1972. The role of forest site in fertilizer response. USDA For. Serv., Res. Pap. NE-243, 7 p. Northeast. For. Exp. Stn., Upper Darby, PA.
- Mitchell, H. L., and R. F. Chandler. 1939. The nitrogen nutrition and growth of certain deciduous trees of northeastern United States. Black Rock. For. Bull. 11, 94 p.
- Stone, D. M. 1977. Fertilizing and thinning northern hardwoods in the Lake States. USDA For. Serv., Res. Pap. NC-141, 7 p. North Cent. For. Exp. Stn., St. Paul, MN.
- Stone, D. M. 1980. Fertilization of a pole-size maple stand: 10-year results. Can. J. For. Res. 10:158-163.
- Stone, D. M., and D. R. Christenson. 1974. Fertilizing and thinning maple poles: preliminary results. USDA For. Serv., Res. Note NC-158, 4 p. North Cent. For. Exp. Stn., St. Paul, MN.

⁴National Academy of Science. 1982. Washington, D.C.

Stout, B. B. 1956. Studies of the root systems of deciduous trees. Black Rock For. Bull. 15, 45 p.

Tubbs, C. H., and R. M. Godman. 1973. Lake States northern hardwoods. *In*. Silvicultural systems of the major forest types of the United States. USDA, Agric. Handb. 445, p. 55-58. Wash., D.C.

Honorary/Honoraire	3
Fellow/Émélite	29
Active/Actifs	2111
Affiliate/Affiliés	103
Student/Étudiant	291
Retired/Retraité	189
Temporarily Lost/ Parti temporairement	
Total	2726

Date _____	Section _____	Change of membership type from _____ to _____ e.g. Active to Retired etc.
------------	---------------	---

<div style="border: 1px solid black; width: 100px; height: 20px; margin-bottom: 5px;"></div> Identity Code (from address label)	
<div style="border: 1px solid black; width: 200px; height: 20px; margin-bottom: 5px;"></div> Surname first — no titles	
<div style="border: 1px solid black; width: 200px; height: 20px; margin-bottom: 5px;"></div>	
<div style="border: 1px solid black; width: 200px; height: 20px; margin-bottom: 5px;"></div> Street	
<div style="border: 1px solid black; width: 200px; height: 20px; margin-bottom: 5px;"></div> City and Province	
<div style="display: flex; align-items: center;"> <div style="border: 1px solid black; width: 50px; height: 20px; margin-right: 10px;"></div> <div style="border: 1px solid black; width: 50px; height: 20px;"></div> </div> Postal Code	
<div style="border: 1px solid black; width: 200px; height: 20px;"></div>	

Office use only

<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Province/Section
<div style="border: 1px solid black; width: 100px; height: 20px;"></div>	Bulk/Multiple label
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Subscription type/copies
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Membership type/Yr. grad.
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	University/Degree
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Y.O.B./Special title
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	W.G. 1 st /2 nd Choice
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Yr. joined
<div style="border: 1px solid black; width: 50px; height: 20px;"></div>	Can. J. For. Res/