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Growth of Nitrogen-Fertilized and Thinned Quaking Aspen

(*Populus tremuloides* Michx.)

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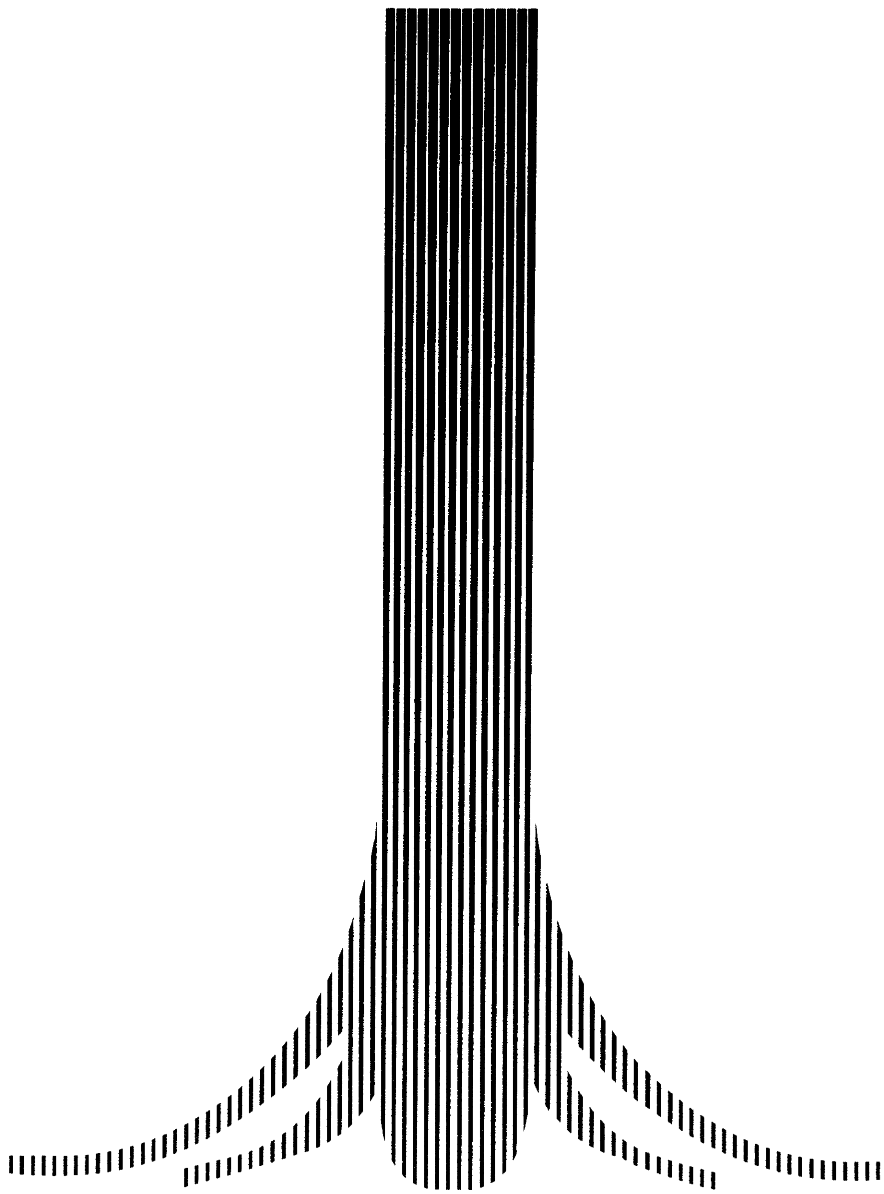

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Growth of Nitrogen-Fertilized and Thinned Quaking Aspen (*Populus tremuloides* Michx.)

Donald A. Perala and Paul R. Laidly

Crop trees of quaking aspen (*Populus tremuloides* Michx.) and its Eurasian equivalent, *P. tremula* L., grow faster after thinning. Thinning first at about age 10 to 15 years accelerates diameter growth the most (Day 1958; Steneker 1966, 1969, 1974; Perala 1978; Langhammer 1979; Schmiedel 1982; Kairyukshtis *et al.* 1985), although 5- to 7-year-old stands can also benefit (Hubbard 1972, Bella 1975). Newly initiated stands (1 to 3 years old) may need more time to express dominance (Perala 1984) before they can respond (Sorensen 1968, Bella 1975). One or two more thinnings up to age 30 prolong rapid growth (Perala 1978, Schmiedel 1982, Kairyukshtis *et al.* 1985). Stands older than 30 years respond little to thinning (Pike 1953, Schlaegel 1972, Perala 1978).

Aspen has responded little to added phosphorus, potassium, or calcium, but has grown 33 to 177 percent faster when fertilized with nitrogen (Van Cleve and Oliver 1982, Heinonen 1983, Harris *et al.* 1984, Safford and Czapowskyj 1986, Berguson and Perala 1988). Rates of 150 to 450 lbs/acre are needed, and the response lasts 3 to 10 years or more. One study reported aspen fertilized with NPK (0, 100, or 200 lbs/acre each) in factorial with thinning (unthinned, 300, or 600 trees/acre). The fertilizer increased 5-year growth by 15 to 30 percent; thinning increased it by 15 to 70 percent (Doucet and Veilleux 1982).

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The primary objective of thinning and fertilizing aspen is to produce marketable material quickly. Rotations for sawtimber can be shortened by as much as 20 years by thinning (Steneker 1974, Perala 1978, Schmiedel 1982). Wood quality is improved because decay caused by the fungus, *Phellinus tremulae* (Bond.) Bond. et Boriss, has less time to develop. The fungus enters from dead occluded branches that can be controlled by frequent entries to maintain about 70 percent stocking (Il'in 1981) and by pruning (Kostylev 1976). Total bolewood yields can be increased by 10 to 37 percent by capturing anticipated mortality in thinnings and maintaining stands at near-optimum stocking for growth (Day 1958, Steneker 1974, Perala 1978, Hocker 1982, Kairyukshtis *et al.* 1985).

We report here a study in aspen that yielded large responses to thinning, but ambiguous and smaller responses to nitrogen fertilizer.

STUDY AREA

We installed the study in aspen sapling stands near Toivola (St. Louis County) and Greaney (Koochiching County) in north-central Minnesota. The climate is humid, with warm summers and cold winters. Annual temperature and precipitation average 38.5°F and 26.6 inches, respectively.

Both stands regenerated by root suckers after the parent stands were clearcut for aspen sawtimber and pulpwood during the winters of 1966-1967 (Greaney) and 1971-1972 (Toivola). The associated tree species were paper birch (*Betula papyrifera* Marsh.), balsam fir (*Abies balsamea* (L.) Mill.), and balsam poplar (*Populus

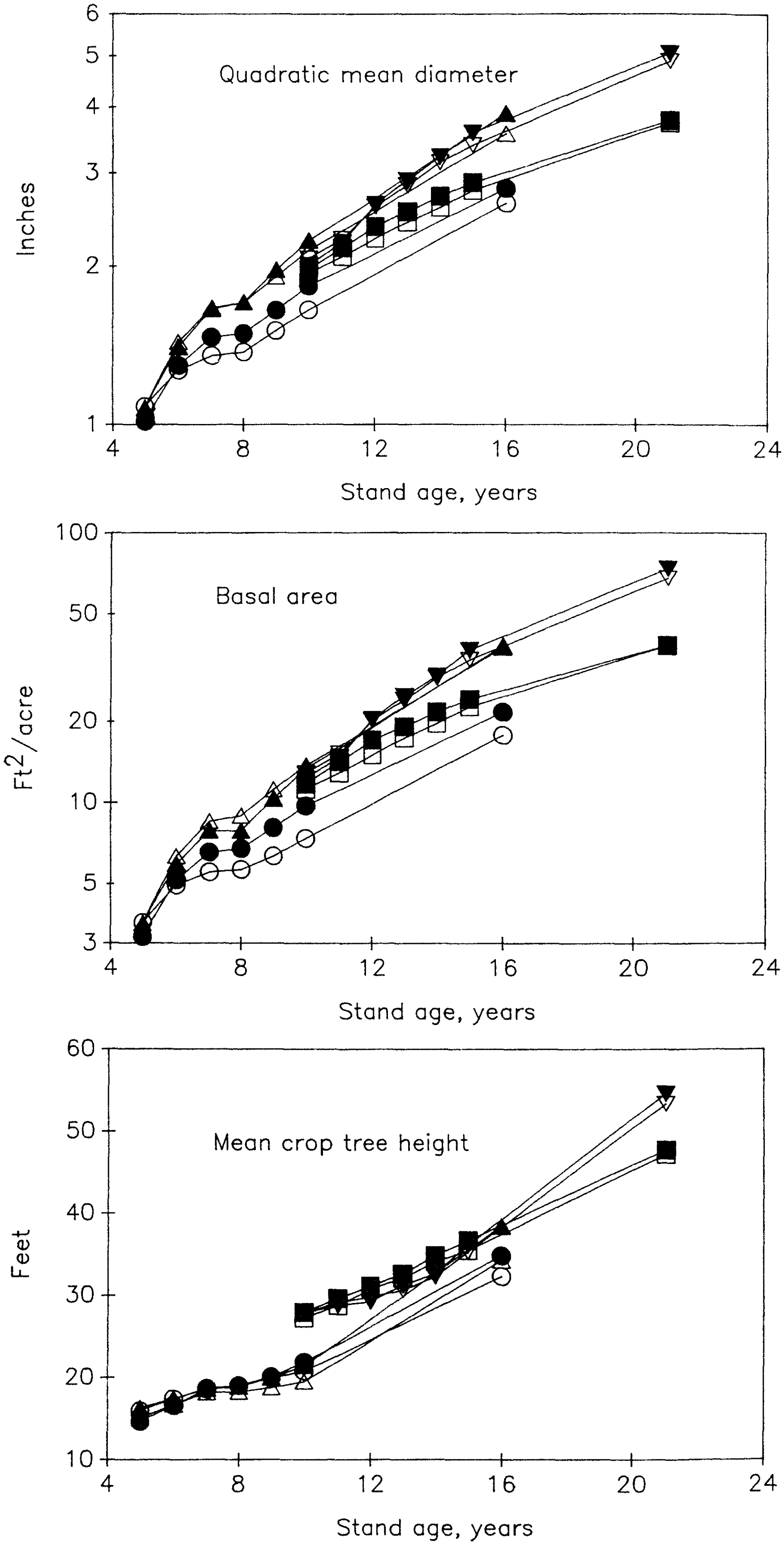
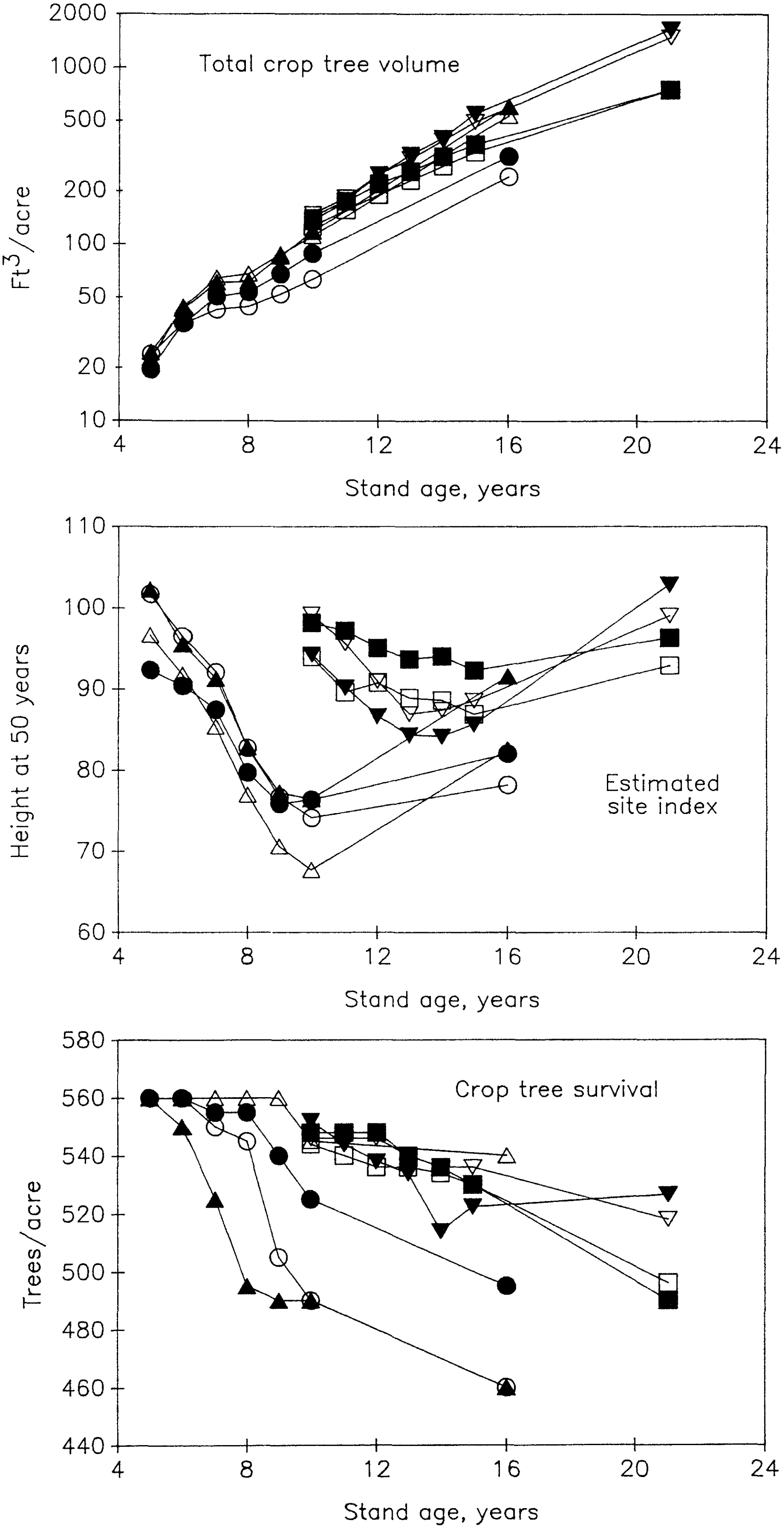


Figure 1.—*Crop tree growth at Toivola (circles and triangles) and Greaney (squares and inverted triangles). Squares and circles are unthinned; shaded symbols are fertilized. Note logarithmic scales for diameter, basal area, and volume.*


Total crop tree volume
Ft³/acre
2000
1000
500
200
100
50
20
10
4
8
12
16
20
24
Stand age, years
Estimated site index
Height at 50 years
110
100
90
80
70
60
Stand age, years
Crop tree survival
Trees/acre
580
560
540
520
500
480
460
440
Stand age, years

balsamifera L.). The soils were unnamed well-drained clay loams considered excellent for growing aspen. Water tables were about 8 feet deep.

METHODS

In early spring of 1977, we established 16 1/5-acre circular treatment plots in 5-year-old saplings (11,500±2,400 stems/acre) at Toivola and 20 plots in 10-year-olds (5,500±2,000/acre) at Greaney. Dominant and co-dominant potential crop trees (550/acre) were permanently numbered with tree marking paint on circular measurement plots (0.05 acre at Toivola; 0.1 acre at Greaney) centered on the treatment plots. Four treatments replicated four times (Toivola) or five times (Greaney) were applied in a randomized design:

1. no treatment (control),
2. fertilize with 150 lb nitrogen per acre as NH_4NO_3,
3. thin to leave the crop trees, and
4. fertilize and thin (treatments 2 and 3).

Diameter at breast height of crop trees was measured to the nearest 0.1 inch with steel diameter tapes and total height of 8 to 10 crop trees per plot was measured to the nearest 0.1 foot with a fiberglass pole in spring 1977, annually after each of the first 5 years' growth, and after 11 years. Crop tree injury and disease were also recorded. The Toivola area was defoliated by the forest tent caterpillar (*Malacosoma disstria* Hubner) in 1979. Two replications at Greaney were destroyed by beavers in 1981.

Tree measurement summaries gave plot values for trees per acre; net basal area (B) and mortality basal area, ft²/acre; and quadratic mean d.b.h. (D), inch. Mean plot height (H) was determined by regression (Appendix). Total volume under bark (V), ft³/acre, was derived from the product, BxH, according to Schlaegel (1975). Significant treatment effects were determined by ANCOVA of derived plot volume (Appendix). Plot site index was estimated (Gevorkiantz 1956, Lundgren and Dolid 1970) each year from the three tallest trees on each plot.

Table 1.—*Eleven-year net growth by study site and treatment*

Treatment	Basal area	Diameter	Height	Volume
	Ft²/ac	*In.*	*Ft*	*Ft³/ac*
		Toivola		
Control	14	1.6	16	220
N-fertilize	18	1.8	20	300
Thin	34	2.5	19	510
Thin+N	34	2.8	22	580
		Greaney		
Control	27	1.8	20	630
N-fertilize	27	1.8	20	620
Thin	55	2.8	26	1,340
Thin+N	60	3.0	27	1,500

RESULTS AND DISCUSSION

Thinning, and to a lesser extent, N-fertilizer, accelerated both diameter and height growth of aspen crop trees (table 1, fig. 1). Significantly more volume was produced by the larger crop trees, especially those thinned and fertilized at Greaney (table 2). Allowing for the covariate initial volume, thinning added 42 ft³/acre/year bolewood (+56 percent) to crop trees at Greaney and 30 ft³/acre/year (+189 percent) to crop trees at Toivola.

Table 2.—*Parameters for the equation for predicted volume, $V_p=aV_o^b$, reconstituted from unweighted least squares linear regression[1] solutions of Eq. [7] (Appendix)*

Site	Treatment	Parameter a	Parameter b
Toivola	Control	182×10^{-3}	2.243
	N-fertilize	335×10^{-1}	0.761
	Thin	292	0.193
	Thin+N	383	0.145
Greaney	Control	127×10^{-5}	2.747
	N-fertilize	503×10^{-1}	0.556
	Thin	693×10^{-1}	0.613
	Thin+N	712×10^{-1}	0.631

[1] For Toivola, n = 16, $s_{y.x}$ = 76 ft³, R^2 = 0.972.
For Greaney, n = 20, $s_{y.x}$ = 113 ft³, R^2 = 0.992.

Covariate adjusted response to N was modest, but consistent, in combination with thinning. Without thinning, response was mixed:

Site	Thinned	Unthinned
	Ft³/acre/year (percent)	
Toivola	+6 (+13)	+15 (+91)
Greaney	+16 (+14)	-17 (-22)

Growth response to thinning and N pales in comparison to the effects of just 1 year's defoliation by the forest tent caterpillar. By interpolation, growth loss in height, diameter, and volume was 72, 81, and 87 percent, respectively (fig. 1). Growth rates completely recovered the next year.

Calculated site index differed widely over the study period, especially at Toivola (fig. 1). Existing site index curves are obviously inadequate for very young stands. At age 15, estimated site index for the controls is 87 at Greaney and 77 at Toivola. These are valid relative, but not absolute, estimates of site index.

Crop tree mortality was acceptable at Greaney, but troubling at Toivola (table 3, fig. 1). *Hypoxylon mammatum* (Wahl.) Mill. was the primary agent. After 11 years, 4.5 percent of the crop trees were infected at Toivola, but only 1.2 percent at Greaney (table 4). Treatment was not a factor; the infection rate in the controls was lowest at one site but highest at the other. Clonal variation in disease resistance (Copony and Barnes 1974) may override treatment effects, but there also may be treatment, site, and age interactions that we do not yet understand.

Table 3.—*Total number and basal area of trees that died over the first 5 years by site and treatment*

	Stems		Basal area	
Treatment	Toivola	Greaney	Toivola	Greaney
	Per acre		*Ft²/acre*	
Control	70	14	0.51	0.34
N-fertilize	35	18	.22	.40
Thin	15	10	.29	.32
Thin+N	70	30	.80	1.02

Table 4.—*The infection rate of aspen crop trees by* Hypoxylon mammatum *after 11 years by site and treatment*

Treatment	Toivola	Greaney
	Percent	
Control	0.0	2.0
N-fertilize	4.0	1.7
Thin	11.0	1.2
Thin+N	3.3	0.0

CONCLUSIONS

Quaking aspen responded to thinning and N-fertilizer much as reported elsewhere. Our ambiguous site/thin/N interaction is puzzling and adds little to our understanding of how aspen responds to fertilizer. Although nutrient response is usually smaller on fertile sites than on deficient sites (Allen 1987), we cannot attribute the N-response differences to site quality because site and age are confounded and neither is replicated.

Height growth commonly increases in fertilizer studies but is seldom affected by thinning. Ralston (1954) and Dahms (1971) report two exceptions, in red pine (*Pinus resinosa* Ait.) and lodgepole pine (*P. contorta* Dougl.), where height growth improved after thinning on droughty sites. Quaking aspen is especially sensitive to water deficit (Sucoff 1982) so that improved height growth is possible through water conservation by density control.

Hypoxylon canker threatens the thinned trees at Toivola but not at Greaney. We do not know if the risk can be attributed to stand age, site quality, or clonal character. Much more work is needed to enable better selection of hypoxylon-resistant stands for thinning.

ACKNOWLEDGMENTS

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APPENDIX

Numerical Analysis

Mean plot height (H, for tree D), ft, was estimated from height:d.b.h. equations of the form,

$$H = aD^b. \qquad [1]$$

These were derived from plot-by-plot regression analyses of the linearized log-log model of Eq. [1],

$$\ln ht = a+b(\ln dbh)+e_i, \qquad [2]$$

where
ht=total tree height,
dbh=tree d.b.h.,
a,b=estimated coefficients, and
e_i=error.

Standard errors averaged about 5 percent of total tree height (table 5).

Table 5.—*Height equations ($H=aD^b$) mean accuracy by site and treatment*

Treatment	Standard error Feet	Standard error Percent	R^2
	Toivola		
Control	0.96	4.64	0.744
N-fertilize	1.07	5.42	0.610
Thin	0.97	4.71	0.726
Thin+N	0.99	4.73	0.686
	Greaney		
Control	1.53	4.40	0.433
N-fertilize	1.64	4.72	0.548
Thin	1.66	5.08	0.499
Thin+N	1.42	4.27	0.310

Standing plot volume with respect to age can be described by the model:

$$V = aA^bc^A \quad [3]$$

where

A = stand age, years, and
a,b,c = parameters to be estimated.

The value of the parameters will differ if treatment or site alters curve shape (determined by parameters b and c) or rate (a). These parameters were estimated for each plot (ignoring initial observations that were used later as covariates) from the linearized form of Eq. [3],

$$\ln V = \ln a+b(\ln A)+(\ln c)A+e_i \quad [4]$$

The fit statistics for this model were extremely good (table 6). Because parameters b and c are correlated with a, predicted present volume (V_p) for each plot, rather than the coefficients, was the variable used to test treatment effects. V_p is analogous to computed plot mean volume over years and avoids the serial correlation problem common to growth series analysis (Sullivan and Reynolds 1976, Stewart-Oaten and Murdoch 1986). V_p was an unbiased and precise estimator of present volume (table 7).

Table 6.—*Volume growth equations ($V=aA^bc^A$) mean statistics. Note that A^b was not significant at Toivola and c^A was not significant at Greaney.*

Treatment	Parameters			
	a	b	c	R^2
		Toivola		
Control	10.4	0.0	1.21	0.978
N-fertilize	10.2	0.0	1.24	.993
Thin	10.0	0.0	1.28	.991
Thin+N	8.4	0.0	1.30	.988
		Greaney		
Control	0.454	2.41	1.00	.996
N-fertilize	0.791	2.25	1.00	.996
Thin	0.077	3.23	1.00	.998
Thin+N	0.059	3.37	1.00	.996

Table 7.—*Unweighted least squares linear regression of $V=a+bV_p$ ($n=34$, $R^2=.998$, $s_{y\cdot x}=21.4$ ft^3/acre)*

Predictor	Coefficient	Student's t	Probability
a	7.600	1.1	0.28
b	1.000	132.1	0.00

The effect of treatment on V_p was determined by analysis of covariance (ANCOVA). Treatment response commonly depends on variation of the experimental unit, in this case initial plot volume. Our postulated nonlinear model is

$$V_p = aV_o^b, \quad [5]$$

where

V_o = initial value of V (covariate).

The expanded model to accommodate treatment effects is

$$V_p = aV_o^bc^Fd^T, \quad [6]$$

having dummy variables (0,1) for

F=fertilized, and
T=thinned.

Note that model (6) can be collapsed to model (5) having unique values for parameter {a} and, if treatment interacts with the covariate, parameter {b}.

ANCOVA was conducted by regression of the log-log transformation of model (6),

$$\ln V_p = \ln a+b(\ln V_o)+(\ln c)F+(\ln d)T +(\text{all interactions})+e_i. \quad [7]$$

Logarithmic transformations were used because they provided linear relations and stabilized variance. (The Toivola variance was nearly twice that of Greaney, so that a pooled analysis was not appropriate.) The best subset method using Mallow's Cp criteria determined variables retained in all final equations (Weisberg 1985).

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1989. **Growth of nitrogen-fertilized and thinned quaking aspen (*Populus tremuloides* Michx.)**. Res. Pap. NC-286. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 8 p.

Reports the results of a thinning/fertilizing experiment in juvenile aspen stands.

KEY WORDS: *Malacosoma disstria*, *Hypoxylon mammatum*, mortality, volume growth.