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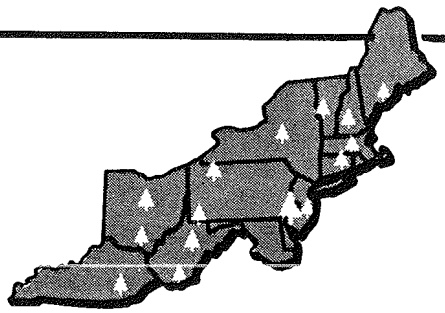

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GROWTH RESPONSE TO FERTILIZER IN A YOUNG ASPEN-BIRCH STAND

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Abstract

A thinned aspen-birch-red maple stand was fertilized with N, P, and N plus P, both with and without lime (L). Overall, treatments with N increased height growth by an average of 79 percent, and volume growth by 69 percent, over treatments without N. Lime tended to increase both average height and volume growth over each corresponding treatment without lime. The amount of growth response and the treatment that produced the greatest response differed among species. Bigtooth aspen and paper birch generally responded better than quaking aspen and red maple. Bigtooth aspen and paper birch responded strongly to N and combinations of N and P. Bigtooth aspen was the only species to respond significantly to P alone. Bigtooth aspen trees treated with NP and L grew nearly seven times as much in volume as the control trees. The volume growth of paper birch treated with NL was nearly twice that of the control. Depending on the duration of these growth responses, fertilizer treatment should substantially reduce the time required to produce merchantable size trees, particularly of bigtooth aspen and paper birch. The lesser response by quaking aspen and red maple suggests that fertilization of these species may not be practical.

INTRODUCTION

The study area is in Washington County, Maine in a young stand that originated after a fire that followed the harvest of a spruce-fir forest in 1952.

The area is gently rolling, and the soils are strongly acid Spodsols that developed from glacial till derived from granitic rocks. The soils are tentatively classified as sandy, mixed, frigid Typic Haplorthods on well-drained ridges and knolls, and as sandy, mixed, frigid Aquic Haplorthods on moderately well-drained depressions. The soils are marginal in fertility.

By 1973, the stand included a dense overstory of aspen (*Populus tremuloides* Michx. and *P. grandidentata* Michx.), paper birch (*Betula papyrifera* March.), gray birch (*B. populifolia* Marsh.), and red maple (*Acer rubrum* L.) along with an understory of widely spaced red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea* (L.) Mill.), and white pine (*Pinus strobus* L.). In the summer of 1973, the hardwood overstory was hand-thinned, which left a uniformly spaced stand of approximately 1,500 stems per ha of aspen and paper birch with an understory of spruce-fir. Stand characteristics after thinning are given in Table 1.

In 1974 we established a study to determine if the aspen-birch-red maple stand would respond to treatments with lime, nitrogen, and phosphorus applied singly and in combination. This paper reports the first 3-year growth response to the nutrient treatments.

THE STUDY

Twenty-four 20 by 20-m plots with 7-m wide isolation strips were established. Because of the nature of the landscape, some plots fell on well-drained soils, some on moderately well-drained soils, and some plots had both. Treatments were randomly assigned among plots.

The treatments were:

C = Control
L = Lime, 4,480 kg per ha; 100 percent $CaCO_3$ equivalent as ground limestone. It contained 1,749 kg Ca and 27 kg Mg per ha.
N = Nitrogen, 448 kg per ha of elemental N, as 46-0-0 urea.
P = Phosphorus, 112 kg per ha of elemental P as 0-20-0 triple superphosphate. (In addition to P, the fertilizer contained 12 percent Ca.)
And all combinations of L, N, and P for a total of eight treatments replicated three times.

Lime was broadcast by hand on the soil surface in the fall of 1974. Phosphorus and one-half of the nitrogen were broadcast in June 1975; the remaining nitrogen was added in August 1975.

Table 1. Characteristics of a 15-year old aspen-birch spruce-fir stand before fertilization (average of three replications)

Species	Stand characteristics							
	Trees/ha		Height	Dbh	Basal area/ha		Volume/ha	
	No.	%	*m*	*cm*	m^2	%	m^3	%
Bigtooth aspen	618	31	7.5	7.1	2.4	49	9.1	52
Quaking aspen	457	22	6.9	6.4	1.5	29	5.1	29
Paper birch	316	15	5.9	5.3	0.7	14	2.2	13
Red maple	121	6	6.6	5.6	0.3	6	0.9	5
Total or average	1,512	74[a]	6.7	6.4	4.9	98[a]	17.3	99[a]

[a] Balance in softwood species

Metric conversions: No./ha × .405 = No./acre; m × 3.28 = feet; cm × .394 = inches; m^2/ha × 4.4 = ft^2/acre; m^3/ha × 14.3 = ft^3/acre; m^3/ha × .2 = cord/acre

Tree measurements

All trees 1.3 cm in diameter at breast height and larger were numbered. Heights and dbh were measured and recorded for each of the species on each of the plots. The basal area and volume were calculated for each of the species on each of the plots before fertilization (1974) and annually from 1974 to 1977. Plot volume (M^3/ha) was one-half the average basal area times the average height for each species.

Statistical analyses

Height growth was analyzed as an incomplete factorial model with three factors: lime, fertilizer, and species. Even though the initial stocking varied among the species (Table 1), it was not a significant covariate with the height growth.

A preliminary analysis of volume growth showed significant effects of species, fertilizer, and fertilizer times species interaction. The species effects were due to differences in initial stocking. So initial stocking was used as a covariate with fertilizer, lime, and species as factors in an analysis of covariance, and the mean volume growth by species and treatment was adjusted to a common initial volume. The differences among adjusted mean volume growth of each treatment and the control were tested by least significant differences technique. Analysis of covariance showed that fertilizer effects and species times fertilizer interaction were highly significant.

RESULTS AND DISCUSSION

Height growth

N fertilizer significantly affected height growth. For every species except quaking aspen, height growth for at least one N treatment was significantly greater than for the control (Fig. 1). Bigtooth aspen showed the most consistent response to N. Every N treatment produced a greater response than every non-N treatment. Paper birch on plots treated with NL and NP grew more in height than it did on every non-N treated plot. The height growth response of red maple was less well defined, but the NL and NP treatments produced the greatest growth, as they did for paper birch (Fig. 1).

Height growth for all species combined followed the general pattern of the individual species, i.e., the growth of trees on N-treated plots was significantly greater than that of the trees on the non-N plots (Fig. 2). There was a consistent trend of increased height growth for each L treatment above the same non-L treatment: $\bar{L}>C$; $\bar{L}P>\bar{P}$, $\bar{N}L>\bar{N}$, etc., but the main effect for L was not significant in the analysis of variance. Because of the slow availability of lime, its effect on height growth may increase over time, which could be determined by later measurements. The tendency of species to differ in response to lime also needs closer examination. Additional data, particularly of foliar levels of Ca and Mg, may reveal species differences in the use of the surface-applied lime.

Volume growth

Analysis of variance of volume growth showed a highly significant fertilizer treatment times species interaction. This indicates that the fertilizer and lime treatments did not effect the same volume growth response for each of the species. Bigtooth aspen and paper birch responded strongly, with several treatments resulting in faster growth than the control. Quaking aspen and red maple responded less, with growth for only one treatment for each species significantly greater than the control (Fig. 3).

Bigtooth aspen responded strongly to all fertilizer treatments. Every treatment except L applied singly resulted in significantly more growth than the control. When fertilized with NP and L, this species grew almost seven times as fast as the control trees—substantially more than any other species in all treatment combinations (Fig. 3). The average volume growth for all N treatments was nearly three times the average volume growth for non-N treatments. Volume growth of bigtooth aspen treated with P and P plus L was more than two times control—the only case where P alone significantly increased growth.

Paper birch was the second most responsive species. It clearly responded to N in volume growth (Fig. 3). The average growth for all N treatments was 71 percent greater than

Figure 1.—Three-year height growth by fertilizer-lime treatments and species. Solid bars are significantly greater than the control at .05 level or greater.

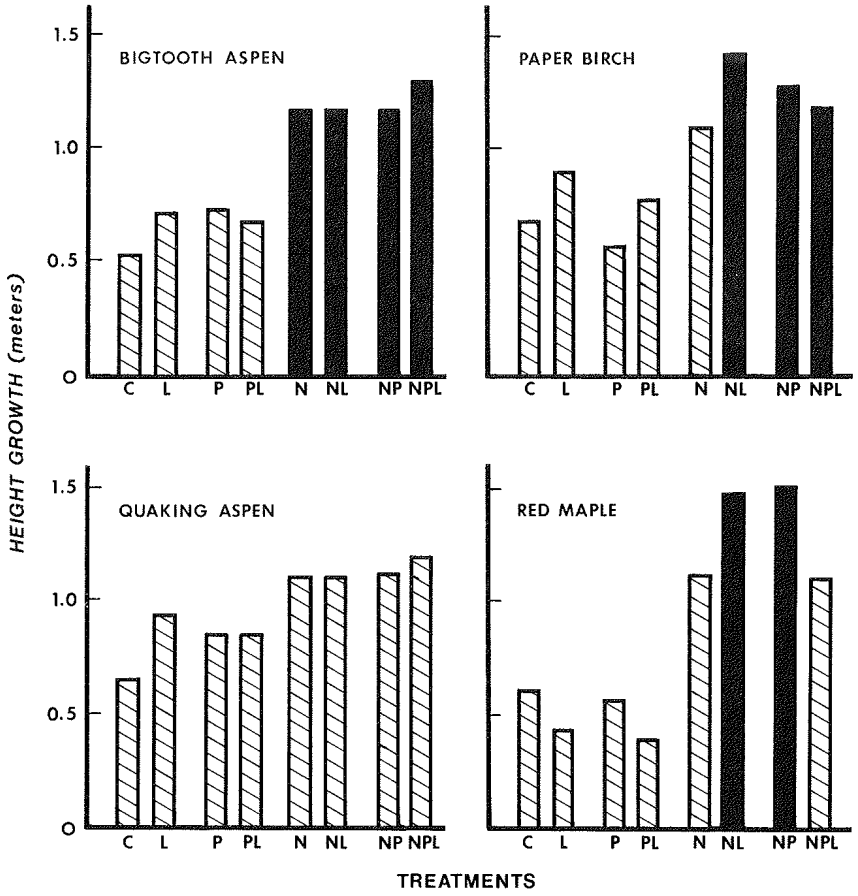
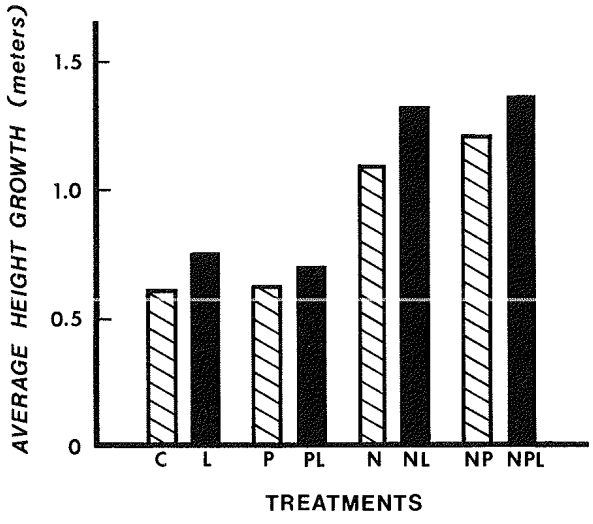


Figure 2.—Average 3-year height growth for all species, by fertilizer-lime treatments.

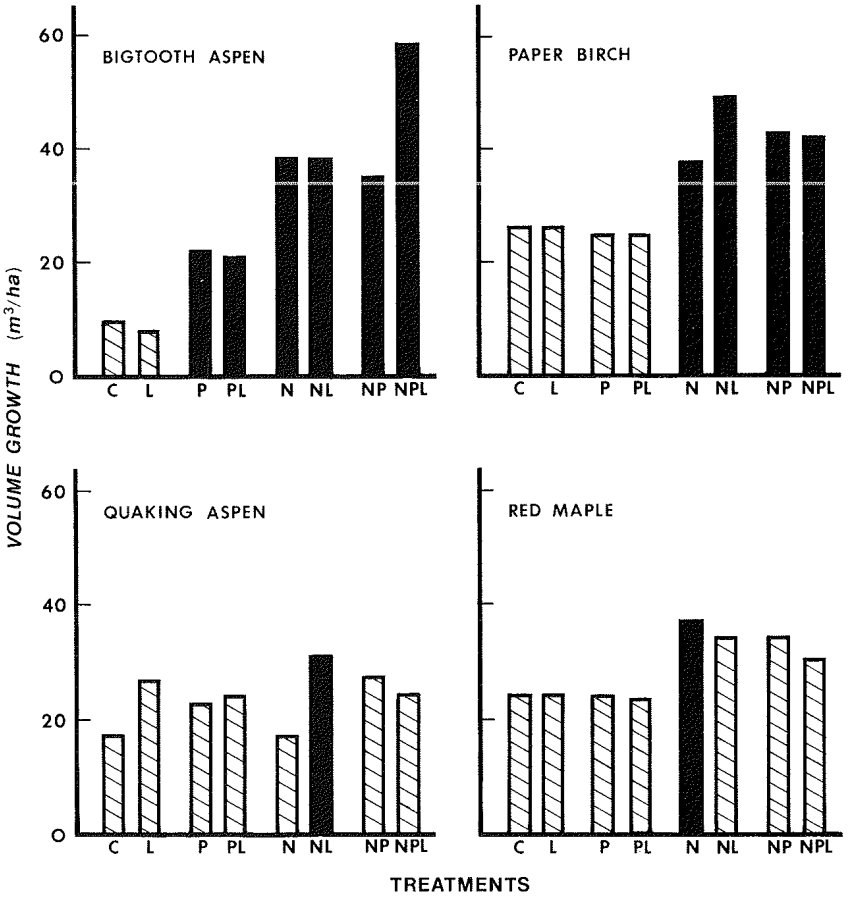


that for the non-N treatments. The best treatment, N plus L, resulted in nearly twice the growth of the control trees.

Red maple also generally responded to N rather than the non-N treatments, but L and P tended to depress growth so that the NL, NP, and NPL treatments were not significantly different from the control (Fig. 3). For this species, the lack of significant differences may result from high variation associated with the small amount of red-maple on the plots (Table 1).

Quaking aspen, which is often combined with bigtooth aspen in silvicultural considerations, responded the least consistently of any species to the fertilizer treatments (Fig. 3). The N plus L treatment was the only one that resulted in significantly greater volume

Figure 3.—Three-year volume growth by fertilizer-lime treatments and species. Solid bars are significantly greater than the control at .05 level or greater.

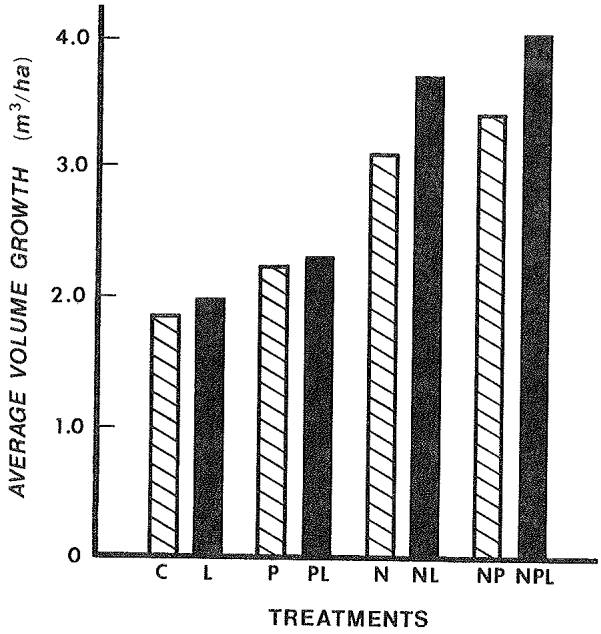


growth than the control. The average volume growth for all N treatments was only 15 percent greater than for non-N treatments—the smallest increase for any of the species. Quaking aspen did show the most consistent and greatest trend of increased volume growth in response to lime. This was the only case where L applied singly appeared to stimulate growth, and the average growth for all L treatments was 28 percent greater than the average for all non-L treatments. This result is consistent with the evidence that quaking aspen requires a high base status for good growth (Voigt et al. 1957), which might indicate that a higher base status is necessary for quaking aspen to take advantage of the supplemental N and P.

The average volume growth for all species reflected the same general trend as did height growth (Fig. 4). The main response was to N, but the response to each fertilizer treatment plus L tended to be greater than to the same treatment without L, and P>C, N>P, and NP>N. NPL, the best treatment, resulted in more than twice the volume growth of the control, which was the poorest treatment. The average volume growth for N-treated plots was 14.4 m^3/ha versus 8.5 m^3/ha for that of the non-N treatments, an increase in growth of almost 70 percent during the first 3 years after fertilization.

The apparent positive effect of lime probably results from the increased supply of bases that are critically low in these acid till soils (Hoyle 1969). Surface application does not realize the full potential of the lime, but as time passes, and as tree roots develop, the Ca and Mg from the lime will move deeper into the soil (Safford 1974). This deeper rooting and consequent increase in volume of the soil accessibly to the trees

Figure 4.—Average 3-year volume growth for all species, by fertilizer-lime treatments.



should also lead to additional supplies of moisture and nutrients.

The general response of this mixed stand to fertilizer in 3 years indicates a potential for substantially reducing rotation length by providing additional plant nutrients. Some species—bigtooth aspen and paper birch—clearly benefit from N and perhaps P and L as well. The case of quaking aspen and red maple is less well defined, but each of the species responded significantly to one of the treatments. It is obvious that we must observe the growth for a longer time to determine the duration of the growth response and whether additional effects of the surface-applied fertilizers will develop. It appears that stands of mostly quaking aspen or red maple would show less volume growth as a result of fertilization than the stands of bigtooth aspen. Fertilized stands of mostly paper birch should be intermediate in increased volume growth.

CONCLUSIONS

1. Three-year height growth of sapling northern hardwood species can be increased by N fertilizer.
2. Additional height growth may be attained with lime treatment.
3. Three-year volume growth of pioneer northern hardwoods differed among species and among fertilizer treatments within species.

ACKNOWLEDGMENT

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