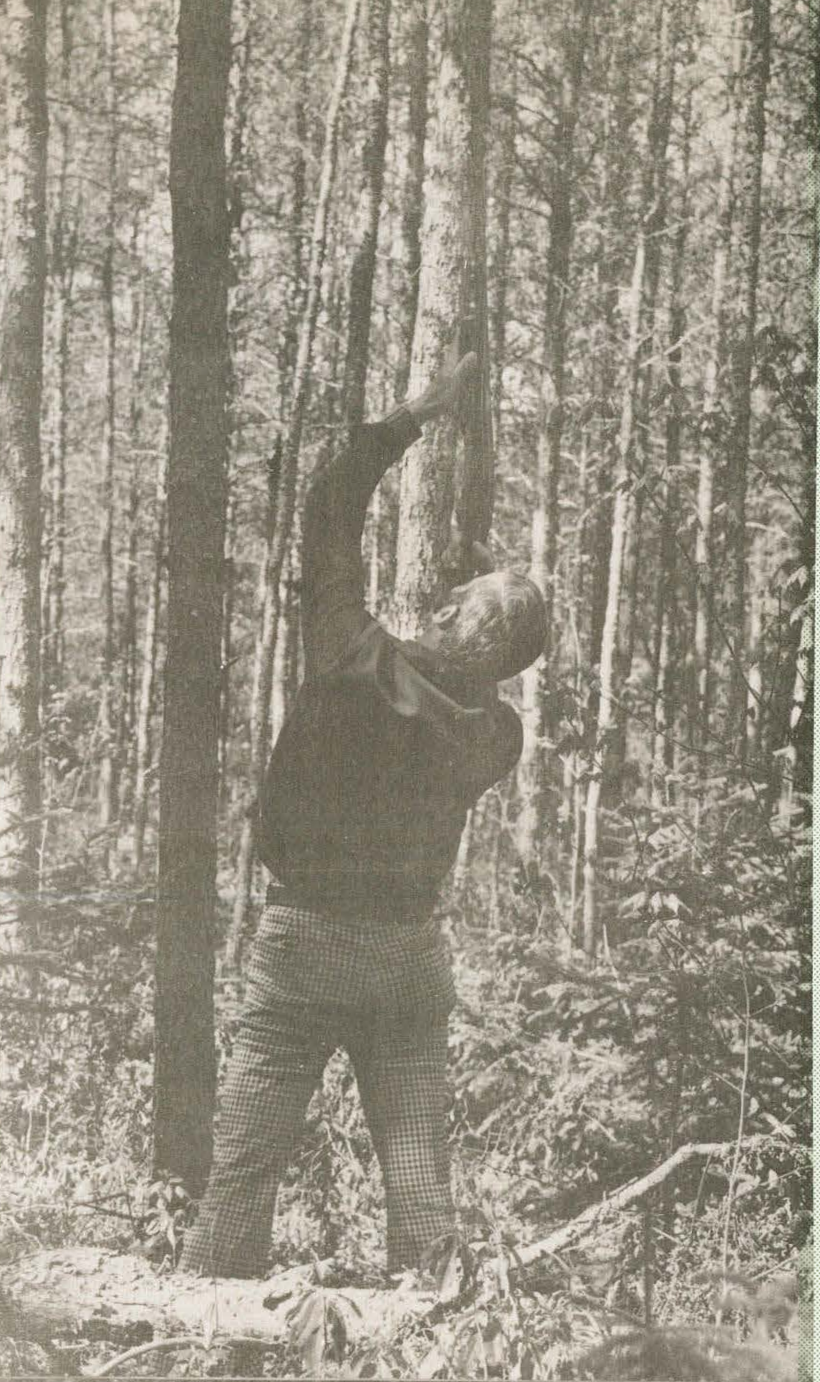

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MARITIMES

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Cover Photo:

Upper Frame — The senior author collecting foliage with a shotgun.

Lower Frame — Horizontal view of the stand. Ample sunlight reaches the ground.

ABSTRACT

A fertilization trial was initiated in 1973 in a semimature jack pine (***Pinus banksiana*** Lamb.) stand. The treatments consisted of nitrogen at a rate of 168 kg N/ha as urea applied alone and in combination with phosphorus at a rate of 168 kg P/ha as triple superphosphate. Soil and foliar nutrient levels were determined before and after fertilization. Stand responses such as mortality, dbh, and gross increases in total and merchantable volumes were periodically measured.

Concentrations of nitrogen appear to have increased only in L and F horizons due to urea fertilization. Little downward movement of added N seems to have taken place in this jack pine stand. Phosphorus levels, however, increased in both the organic and inorganic horizons in P-treated plots. Addition of N alone and in combination with P increased foliar-nitrogen levels, while P alone did not seem to affect the foliar-N levels. Application of triple superphosphate resulted in higher foliar-P levels in 1973 and 1974, but in 1975 it had declined to control levels. Treatment with N and P did not significantly affect foliar weight in either 1974 or 1975.

Mortality was consistantly higher in the control plots and decreased in the order of $N_1P_0 > N_1P_1 > N_0P_1$. Fertilization with N and NP consistantly produced higher percent basal area increase (PBAI) than the control or P treatment. Regardless of the treatment, dominant and codominant trees exhibited highest PBAI. The treatment effects on gross increases in total and merchantable volumes were similar to the effects on PBAI. In three growing seasons, the treatment with 168 Kg N/ha produced about 4 m^3/ha of merchantable wood over the control. Application of P with nitrogen yielded an additional volume of 3 m^3/ha.

RESUME

Un essai de fertilisation a été entrepris en 1973 dans un peuplement de Pin gris (***Pinus banksiana*** Lamb.) d'age moyen. Les traitements ont consisté à appliquer de l'azote à raison de 168 kg N/ha sous forme d'urée, soit seul soit combiné à du phosphore à la dose de 168 kg P/ha sous forme de superphosphate. Les concentrations de matières nutritives dans le sol et dans le feuillage ont été déterminées avant et après fertilisation. Les réactions du peuplement, telles que mortalité, dhp et accroissements en volumes total et marchand, ont été périodiquement mesurées.

Les concentrations d'azote semblent n'avoir augmenté que dans les horizons L et F, par suite de la fertilisation à l'urée. Le mouvement descendant de l'azote ajouté semble avoir été insignifiant dans ce peuplement de Pin gris. Toutefois dans les parcelles traitées au P, les concentrations de phosphore ont augmenté dans les horizons tant organiques qu'inorganiques. L'addition de N seul ou combiné avec P a augmenté les concentrations d'azote dans le feuillage, alors que celle de P n'a pas semblé affecter les concentrations de N. L'application de superphosphate s'est soldée par des concentrations accrues de P dans le feuillage en 1973 et 1974, mais en 1975 ceux-ci s'étaient abaissés aux niveaux témoins. Le traitement avec N et P n'a affecté significativement le poids du feuillage ni en 1974 ni en 1975.

Toujours plus forte dans les parcelles témoins, la mortalité diminuait dans l'ordre suivant: $N_1P_0 > N_1P_1 > N_0P_1$. La fertilisation avec N et NP a toujours produit un plus grand accroissement proportionnel de la surface terrière (APST) que le traitement témoin ou avec P. Indépendamment du traitement, les arbres dominants et codominants accusaient un meilleur APST. Les effets des traitements sur les accroissements bruts en volumes total et marchand ont été semblables aux effets sur l'APST. En trois saisons de croissance, le traitement avec 168 kg N/ha a produit environ 4 m^3/ha de bois marchand de plus que le traitement témoin. L'application de P avec de l'azote a produit un volume additionnel de 3 m^3/ha.

INTRODUCTION

Natural stands of jack pine (***Pinus banksiana*** Lamb.) in northern New Brunswick are often found on dry sites. Many of these stands are easily accessible and are a source of wood for local forest industries. MacFarlane (1973)[1] found that jack pine growth declined rapidly after the age of 35 to 40 years. This may be the result of nutrient deficiency on dry sites caused by a slow nutrient turnover and high nutrient demand at crown closure. If so, fertilization may help the trees to maintain a high growth rate at this stage.

Hoyt (1973), Krause (1973), and others (Weetman et al. 1976) reported on fertilization experiments carried out on various forest types in the Maritimes but jack pine in northern New Brunswick was not studied extensively. It was, therefore, decided to carry out a fertilization trial in a 45- to 50-year-old jack pine stand at Shaddick Lake in northeastern New Brunswick. Treatments were chosen on the basis of preliminary results of an experiment in a jack pine stand at Salmon River Road in south-central New Brunswick (Hoyt 1973). This stand showed that the growth responses were attributable to nitrogen effects and a possible first-order interaction with N and phosphorus; there was also a possible negative interaction with N and potassium.

The trial at Shaddick Lake was initiated in 1973 to determine tree and soil responses to an application of urea and triple superphosphate. Initial tree growth responses and changes in the soil nutrient regime between the time of treatment in 1973 and the first remeasurement in 1975, are reported here.

MATERIALS AND METHODS

Description of the stand

The stand is on sandy soil of glaciofluvial origin with an organic horizon ranging from 6 to 10 cm in thickness. It is located about 30 km northwest of Newcastle (47°-12'N, 65°-50'W), New Brunswick. The stand is of fire origin and was approximately 45 years old at the time of treatment. Tree heights range from 9 to 17 m. Pretreatment stand characteristics are presented in Table 1. Crown closure has occurred in this stand and yet a considerable amount of sunlight reaches the ground (see cover), as is typical for jack pine stands in this area. The ground vegetation under the stand includes extensive growth of bracken fern (***Pteridium aquilinum*** (L.) Kuhn), sparse growth of sheep laurel (***Kalmia angustifolia*** L.) and blueberry (***Vaccinium angustifolium*** Ait.), both in large patches and as individual plants, feather mosses (***Pleurozium*** sp.) and reindeer-moss (***Cladonia rangiferina*** (L.) Web.), the latter being more prevalent in open areas.

Table 1. Stand characteristics before treatment (1973)

Plot	Treatment	Stems/ha	Mean dbh (cm)	Basal area (m^2/ha)
1	N_0P_0	3527	10.20	31.23
2	N_1P_0	4050	9.48	31.15
3	N_1P_1	4030	9.90	32.63
4	N_0P_1	3408	10.09	28.95
5	N_0P_0	3269	10.47	29.90
6	N_1P_0	3121	10.32	27.99
7	N_1P_1	3507	10.42	31.81
8	N_0P_1	3220	10.03	26.82

Experimental design

Eight 0.2-ha circular plots were chosen for the study. All trees were numbered in the inner half of the plots and used for various measurements.

On the basis of results reported earlier (Hoyt 1973) four replicated treatments (N_0P_0, N_1P_0, N_0P_1, and N_1P_1) were chosen for this trial. Nitrogen was applied as urea at a rate of 168 kg N/ha and phosphorus was applied in the form of triple superphosphate at a rate of 168 kg P/ha. The plots were divided into 32 equal sections and on June 19, 1973 an equal quantity of the fertilizer material was broadcast by hand over each section of the plot. Thus, an even distribution of fertilizer was achieved.

Response variables

Stand responses DBH and foliar nutrient levels were periodically measured. Tree diameters within the inner plots were measured before treatment and after three growing seasons. Response measurements were made during early fall. In 1976, a height-diameter relationship was determined by measuring dbh and height of 30 trees in each control plot. The standard volume tables of Honer (1967) were used to compute the volume response.

Composite foliage samples were collected annually from 10 trees in each plot during the first week of

[1] Personal communication, New Brunswick Department of Natural Resources.

October by shooting small branches from the upper portions of the tree crowns. Samples were oven dried at 70°C for 24 h. Three subsamples of 100 needles from the composite sample from each plot were weighed, prior to grinding. The remainder of the sample was ground in a Wiley mill to press through a 1-mm sieve, then analyzed for total N, P, K, Ca, Mg using the methods described by MacDonald (1977).

Soil responses The nutrient status of the soil in the stand prior to fertilization was determined on the basis of samples from one soil pit. Following the first growing season, the nutrient status of a composite sample from four subsamples in each plot was examined. Organic (L, F, H) and mineral (Ae, Bf, Bc, C) horizon samples were collected separately and air dried in the laboratory. Soil physical and chemical characteristics were determined (MacDonald 1977) after oven drying.

RESULTS AND DISCUSSION

Physical and chemical characteristics of soil, prior to treatment, are presented in Table 2.

Table 2. Physical and chemical characteristics of soil from a sampling pit prior to treatment

	Soil Horizon				
Characteristic	L+F+H	Ae	Bf	Bc	C
Texture	—	ls	ls	s	s
pH	2.9	2.8	3.5	4.2	4.6
Organic matter (%)	82.3	1.9	6.7	1.7	1.0
Cation exchange capacity (meq/100 g)	85.15	6.03	8.29	0.85	0.94
Total N (%)	1.75	0.06	0.16	0.06	0.06
Extractable P (%)	.006	.005	.001	.002	.002
Exchangeable cations (meq/100 g)					
K	1.84	0.06	0.07	< 0.02	< 0.02
Ca	7.78	0.17	0.03	0.13	0.15
Mg	1.71	< 0.05	< 0.05	< 0.05	< 0.05

ls = loamy sand.
s = sand.

Application of urea and triple superphosphate altered the concentrations of N and P in the organic and mineral soil horizons (Table 3). Concentrations of nitrogen increased after urea fertilization only in the L+F horizon. Little downward movement of added N seems to have taken place in this jack pine stand. Phosphorus levels increased in each of the L+F, H, and Ae horizons after application of triple superphosphate. In the Ae horizon of the N_1P_0 plots, P was increased above control-plot levels. This is in agreement with observations made in a fertilized black spruce stand (Mahendrappa 1978). Added urea has been shown by others to increase downward movement of soil phosphorus (Beaton et al. 1969).

Table 3. Concentrations of total nitrogen and extractable phosphorus in the different horizons. Samples collected during the fall of 1973 from the experimental plots (averages of duplicate analyses)

	Nutrient concentration (%)					
	Nitrogen			Phosphorus		
Treatment	L+F	H	Ae	L+F	H	Ae
N_0P_0	1.24	1.13	0.06	0.081	0.013	0.001
N_1P_0	1.55	1.07	0.06	0.051	0.012	0.010
N_1P_1	1.41	1.02	0.04	0.098	0.053	0.021
N_0P_1	1.23	0.92	0.05	0.087	0.080	0.025

Changes in foliar nutrient levels were observed in the fertilized plots (Table 4). The increase in nitrogen concentration in both current- and 1-year-old foliage on the treated plots during the second growth season indicates that uptake was not confined to the year of application, as some workers have suggested (Morrison and Foster 1974). The samples representing N_1P_1 treatment generally contained the highest level of N. By fall 1975, foliar nitrogen levels were in decline. Effects of urea on foliar N levels in 1-year-old foliage were less pronounced. Addition of P alone did not affect N levels of the jack pine foliage.

Application of triple superphosphate influenced the concentration of P in foliage in 1973 and 1974, but by 1975, P had returned to control levels. There were no consistent trends in the concentrations of K in foliage from any of the plots. Highest concentrations of foliar K were observed in 1974 and generally the current-year foliage contained higher concentrations of K than the 1-year-old foliage.

Table 4. Concentration of nutrients in foliage (averages of duplicate analyses)

	Nutrient concentration (%)					
	Current foliage			1-year-old foliage		
Treatment	1973	1974	1975	1973	1974	1975
			Nitrogen			
N_0P_0	1.30	1.34	1.26	1.14	1.26	1.23
N_1P_0	1.24	1.45	1.36	1.24	1.40	1.28
N_1P_1	1.42	1.52	1.25	1.36	1.42	1.32
N_0P_1	1.36	1.23	1.16	1.23	1.22	1.20
			Phosphorus			
N_0P_0	0.125	0.145	0.100	0.120	0.120	0.100
N_1P_0	0.130	0.145	0.105	0.120	0.135	0.075
N_1P_1	0.140	0.165	0.115	0.135	0.145	0.100
N_0P_1	0.175	0.155	0.110	0.145	0.145	0.090
			Potassium			
N_0P_0	0.405	0.440	0.370	0.340	0.365	0.360
N_1P_0	0.435	0.475	0.370	0.330	0.440	0.280
N_1P_1	0.460	0.500	0.370	0.370	0.425	0.355
N_0P_1	0.465	0.455	0.325	0.325	0.330	0.195
			Calcium			
N_0P_0	0.170	0.160	0.115	0.230	0.250	0.195
N_1P_0	0.200	0.130	0.105	0.255	0.195	0.135
N_1P_1	0.220	0.160	0.120	0.300	0.265	0.180
N_0P_1	0.215	0.175	0.130	0.265	0.285	0.215
			Magnesium			
N_0P_0	0.105	0.115	0.080	0.085	0.090	0.075
N_1P_0	0.115	0.105	0.080	0.095	0.075	0.060
N_1P_1	0.100	0.115	0.075	0.095	0.080	0.070
N_0P_1	0.135	0.125	0.080	0.100	0.090	0.080

Concentrations of calcium in the foliage from the plots treated with triple superphosphate were generally higher than the Ca levels observed in the foliage of other plots. One-year-old foliage contained larger concentrations of Ca than the current-year foliage. This can be expected because of low recirculation of Ca within the trees and its continuous accumulation in the foliage. Foliar concentrations of Mg were higher in current foliage than in 1-year-old foliage.

Needle weights were generally higher for 1-year-old foliage than for current foliage (Table 5). Treatment with N and P did not significantly affect the needle weight in 1974 or 1975. Needle weights were not measured in 1973.

Table 5. Weights of needles (means of 6 determinations)

	Weights of 100 needles (g)			
	1974		1975	
Treatment	Current foliage	1-year-old foliage	Current foliage	1-year-old foliage
N_0P_0	1.3157	1.5399	0.8833	1.1009
N_1P_0	1.4267	1.4663	0.9339	1.1968
N_1P_1	1.4596	1.2887	0.9530	1.3666
N_0P_1	1.3117	1.4504	1.0462	1.3971

Application of fertilizer appears to have affected mortality of jack pine trees (Fig. 1). Consistently higher mortality was observed in the control plots, decreasing in the order of $N_1P_0 > N_1P_1 > N_0P_1$. Highest mortality occurred in the suppressed crown class.

The soil under this jack pine stand appears to be low in available P, and with the addition of P the suppressed trees may be able to increase their root mass and compete with larger trees for nutrients and water in the soil. This may explain the low mortality observed in P-treated plots. Since highest mortality occurred in suppressed trees, which contribute little to the merchantable volume, the economic significance of decreased mortality in the P-treated plots is questionable. This increased survival may, on the contrary, increase the nutrient and water stress in the dominant, codominant, and intermediate trees.

Lee (1974) found that the application of urea resulted in a considerable loss in basal area of douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) as a result of increased mortality. In the jack pine stand under investigation, only a slight decrease in the mortality of trees was observed in the urea-treated plots. It seems that in this stand, where considerable insolation reaches the ground, fertilization with N and P decreases the nutrient stress and thus reduces mortality of suppressed trees.

There was no significant difference in basal area between the control and treated plots before treatment (t-test). Significant increases in basal area increment

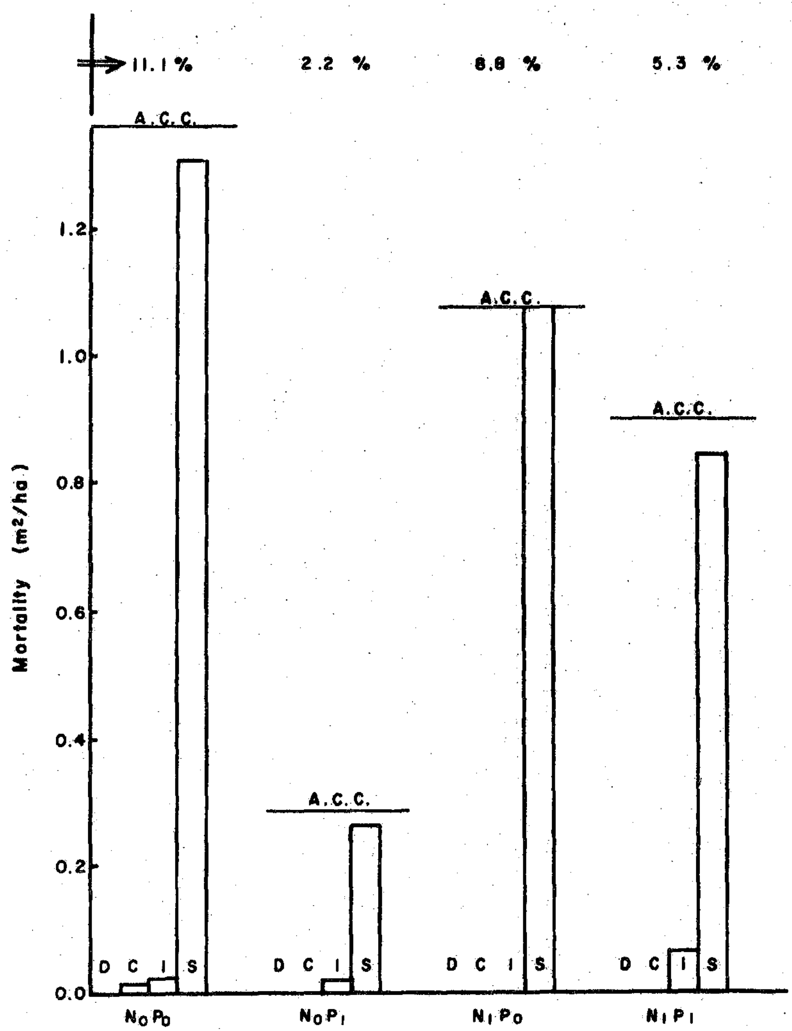

Fig. 1. Effects of fertilizer on loss of basal area by crown class (A.C.C. is loss of basal area of all crown classes; ⇒ is mortality as percent of total stems).
D, Dominant; C, Codominant; I, Intermediate; S, Suppressed.

were produced by the N_1P_0 and N_1P_1 treatments. Large basal area increases occurred in the dominant and codominant trees, followed by the intermediates (Fig. 2). Fertilization with N and NP consistently produced higher basal area increases than the control and P treatments. Application of phosphorus alone (N_0P_1) did, however, result in a considerably higher basal area increase than the control.

These results suggest that the stand is deficient in nitrogen and phosphorus. Added P may have enabled some trees to live longer. The tree response in the P-treated plots is much smaller than that in N-treated plots. Addition of N and P together has resulted in some additional basal area increase over the N (alone) treatment. Data from foliar analysis substantiate these observations since the addition of N and P together tended to maintain higher foliar P levels longer than the foliar P levels in the plots treated with phosphorus alone. Foliar N uptake appears to be greater, and increased N levels last longer, as a result of addition of N and P together. Needle weights were not significantly correlated with increases in basal area increment brought about by fertilization. This may be due partly to the method used for foliage collection. The possibility also exists that the foliar weights are not related to growth responses as measured within the first three years after fertilization.

Gross total and merchantable volume increments were significantly increased over the control by the N_1P_0 and N_1P_1 treatments but not by the N_0P_1 treatment (t-test). The treatment effects on increases in gross total and merchantable volumes (Table 6) are similar to their effects on basal area increases. The largest growth responses were observed in plots treated with N and P together, followed, in order, by responses in plots treated with N and P separately. Codominant trees responded more than intermediate and dominant trees. The trees in the suppressed crown class contributed negligible quantities to volume increments. The height diameter curve upon which the volume increments were calculated was constructed on the basis of measurements taken in the fall of 1976. This has the effect of overestimating pretreatment volumes; thus volume increment data in Table 6 are undoubtedly underestimates of the true volume responses to treatment.

Volume increments observed in different crown classes are in conformity with the treatment effects on basal area increase and foliar nutrient levels. In three growing seasons the treatment with 168 kg N/ha apparently produced an increase of about 4 m^3/ha of merchantable wood over the controls. Addition of P with N yielded a further volume increase of about 3 m^3/ha during the three growth periods. These increases in volume growth amount to 45, 28, and 11% gross merchantable volume increments over the control values, for the NP, N, and P treatments, respectively. Thus, there may be a positive interaction between N and P. These values are more or less in agreement with the series of data published by Morrison et al. (1977)

Table 6. Changes in gross total and merchantable volume increments during three growing seasons (averages of duplicate plots in which dbh of every tree was measured)

Treatment	Volume increments (m^3/ha) by treatment and crown class				
	Dominant	Codominant	Intermediate	Suppressed	Total
			Total Volume Increments		
N_0P_0	1.231	6.806	4.635	0.350	13.010
N_1P_0	1.361	8.319	6.757	0.248	16.684
N_1P_1	1.873	10.220	6.592	0.327	19.013
N_0P_1	0.695	7.218	6.372	0.339	14.624
			Merchantable Volume Increments		
N_0P_0	1.213	6.920	5.549	0.237	13.919
N_1P_0	1.347	8.467	7.753	0.071	17.637
N_1P_1	1.847	10.483	7.851	0.280	20.460
N_0P_1	0.681	7.362	7.136	0.243	15.422

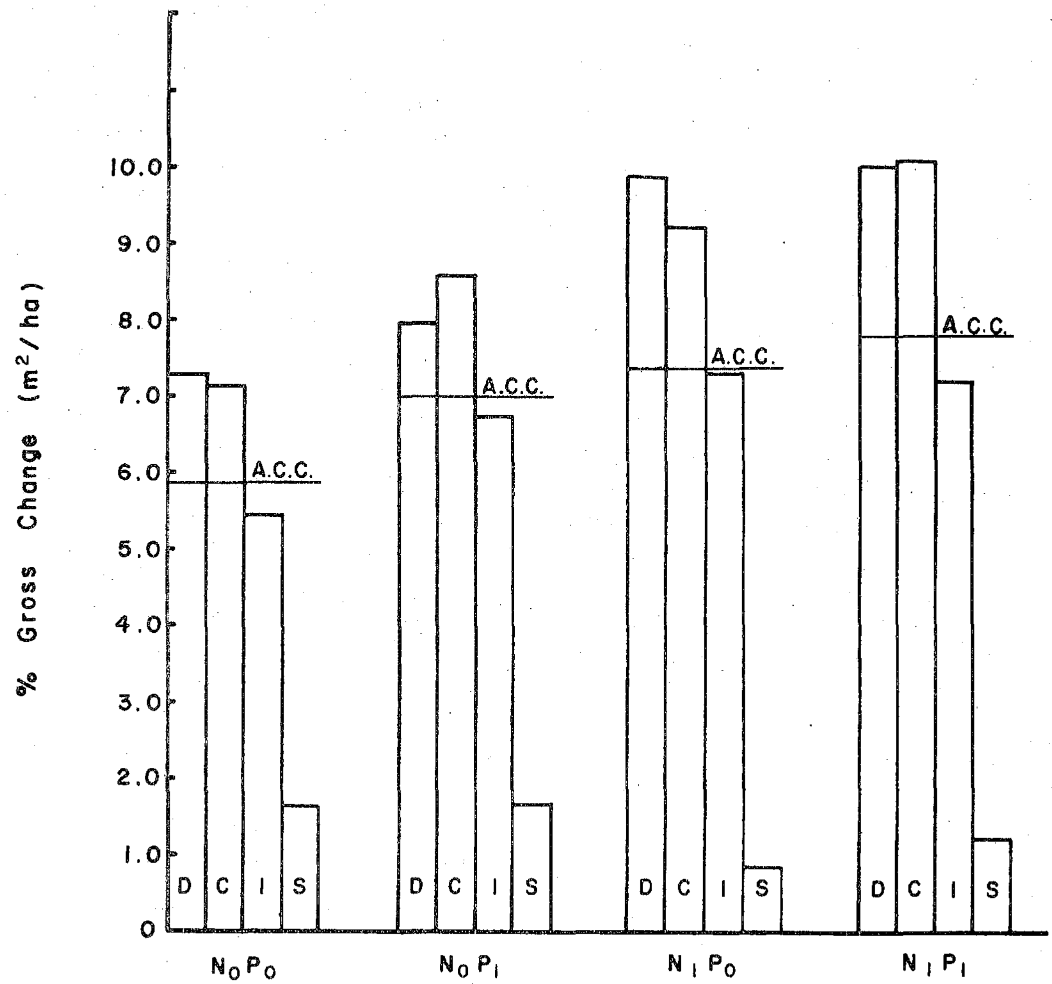

Fig. 2. Effects of fertilizer on gross change in basal area by crown class (A.C.C. is mean change in basal area of all crown classes).
D, Dominant; C, Codominant; I, Intermediate; S, Suppressed.

who found increases of 4 m^3/ha and 7 m^3/ha with N and NP, respectively, over five growth seasons in a similar stand in Ontario.

Nitrogen levels of current foliage in the plots treated with N alone remained higher than those in the control plots in 1975. Roberge (1976) suggested that organic materials treated with urea demonstrated increased microbial activity several years later. Thus, there is a possibility that treatment-induced increases in volume increments for the next three-year period may occur.

This fertilizer experiment will be remeasured every two years until the end of the tenth growing season, when a final report will be written and an evaluation of the economic feasibility of fertilizing this type of stand will be made.

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