NATURAL LODGEPOLE PINE IN WEST-CENTRAL ALBERTA
PART III: FERTILIZATION

Richard Yang

INTRODUCTION

Along with regeneration stocking control and juvenile spacing, fertilization provides a further opportunity for foresters to increase site and stand productivities. Although the actual acreage of commercial forest land fertilized in Canada is small, many research studies have been established by federal and provincial agencies as well as by industry (Rennie 1974). Little information is currently available, however, on effects of fertilization on growth and yield of lodgepole pine in Alberta.

Forest fertilization involves an investment in forest stands and sites. Information on the kind, quantity, and time of application of fertilizers needed to produce the best return is required before a sound decision can be made. This section reports preliminary analysis on the effects of N, P, and S fertilizers on a preharvest, 70-year-old lodgepole pine stand. Fertilization of preharvest stands is of great interest to forest managers since there is a possibility that investment costs plus interest can be more than recouped in a short period by increased yields.

METHODS AND MATERIALS

Study Area

Four study areas were selected in 1970 on St. Regis (Alberta) Ltd. (formerly the Northwestern Pulp and Power Company) lands near Hinton, Alberta. The study areas were located with normal density stands of two stand ages (30 and 70 years old) on Coalspur (Orthic Gray Luvisol) and Mercoal (Bisequal Gray Luvisol) soil types. Results from the 70-year-old lodgepole pine stand on the Coalspur soil type are reported here.

The study area was divided into three blocks, each of which contained twenty-four plots as required by the experimental design. The plot centers were established systematically on a square grid at about 30-m (15-chain) intervals. When a plot center fell within an abnormally open portion of the stand, the plot was omitted or moved to an adjacent fully stocked portion of the stand. Circular plots (8.0-m radius) of 1/50 hectare (1/20 acre) were used. Each plot center was marked with an aluminum post bearing the plot number, and ten unsuppressed trees closest to the plot center were tagged 15 cm above breast height. The diameter at breast height outside bark (dbhob) of all living trees in each plot and sufficient heights to form a reliable height-diameter relationship were taken in the fall of 1971.

Experimental Design

The central-composite, rotatable, second-order design (Cochran and Cox 1957) was selected for the study because the primary objective of the study has been to develop a general, predictive relationship between tree and stand responses and the incremental addition of fertilizer. Fourteen treatment combinations plus six repeating central treatments are required for three factors with five levels of fertilizer (fig. 1). Table 1 illustrates the five coded fertilizer levels being tested and the actual rates of N, P, and S on a hectare basis.

Table 2 presents the treatment combinations included in this study. In addition to the twenty composite design treatments (treatments 1-20), four combinations (treatments 21-24) were also incorporated to facilitate the analysis of an additional 2^3 factorial (-1.68 and 0 levels). The twenty-four treatments were randomly assigned to plots within a block.

Nutrient sources and their composition are listed in table 3. Nitrogen-free treatments were made using the required quantities of triple superphosphate, and elemental sulfur and phosphorus-free treatments were prepared by combining the required quantities of urea and sulfur. To minimize the contamination of the sulfur-free treatments by phosphorus ammonium phosphate was used whenever possible.

The fertilizer combination for each plot was precisely weighed out, bagged, and identified by plot number in the laboratory prior to the field application. All of the fertilizer treatments were broadcast using cyclone seeders prior to the 1972 growing season.

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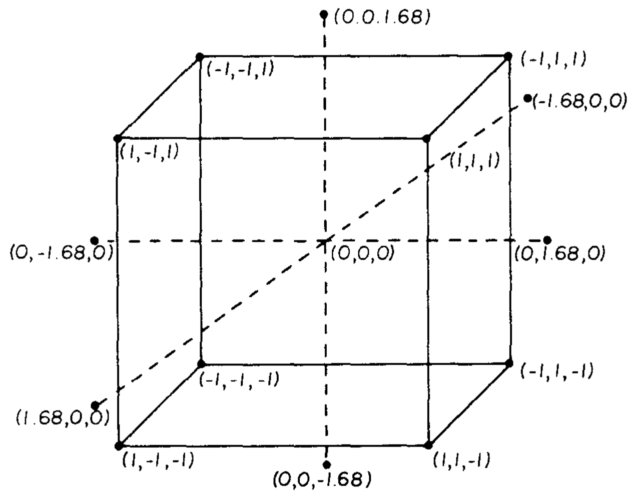

Figure 1.--Graphical representation of a 3-factor central composite rotatable design.

Table 1--Amount of N, P, and S elements applied

	Amount of elements (kg/ha)		
Code level	N	P	S
-1.68	376	188	113
1	300	150	91
0	188	94	56
- 1	76	38	23
-1.68	0	0	0

Table 2--Combinations of fertilizer treatments applied

Treatment No.	Code amount of element		
	N	P	S
1	-1	-1	-1
2	1	-1	-1
3	-1	1	-1
4	1	1	-1
5	-1	-1	1
6	1	-1	1
7	-1	1	1
8	1	1	1
9	-1.68	0	0
10	1.68	0	0
11	0	-1.68	0
12	0	1.68	0
13	0	0	-1.68
14	0	0	1.68
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	-1.68	-1.68
22	-1.68	0	-1.68
23	-1.68	-1.68	0
24	-1.68	-1.68	-1.68

Data Compilation and Analysis

After ten growing seasons, the plots were remeasured in the summer of 1981 to determine the fertilization effects on individual tree and stand growth. All living trees in each plot were identified by species and dbhob was tallied. For accurate determination of individual tree-volume increment due to various fertilizer treatments, three dominant or codominant trees in each plot were felled for stem analysis. Disks were obtained at 0.3-m stump, breast height, 3.05-m, live crown, and other height positions where a major bole shape change was taking place.

Table 3--Nutrient sources and their chemical composition

Nutrient sources	Composition	Elemental composition
Urea (46-0-0)	46% N	46% N
Ammonium	11% N	11% N
phosphate (11-55-0)	55% P_2O_5	24% P trace S
Tri. super-	45% P_2O_5	19.7% P
phosphate (0-45-0)		0.9% S
Elemental sulfur	100% S	100% S

Periodic dbh increment was determined by the diameter at breast height of the ten tagged trees with two successive measurements. Tree dbh data were excluded from the analysis whenever a tagged tree was found dead or missing in the remeasurement. Individual tree-volume increments were ascertained from volumes of the three sectioned dominant or codominant trees.

Stand-volume increments during the ten growing seasons were obtained by deriving an average diameter-height curve for trees of the study area and by using the volume equations for lodgepole pine which were described in Part II: Juvenile Spacing. Merchantable volumes, based on a 10.16-cm (4.0-in.) diameter inside bark (dib) top and a 0.30-m (1.0-ft.) stump, were calculated for all trees >11.68 cm (>4.6 in.) dbhob using Honer's (1967) merchantable conversion function for lodgepole pine. All measurements were performed in imperial units and subsequently converted into the SI system.

Efforts were made to analyze the compiled data by the central-composite, rotatable, second-order design by fitting the data to the second-degree polynomial function. The equation, however, accounted for only 30-40% of the variation in the response variables. In all cases, the lack of fit term which determines the adequacy of the equation was highly significant.

The data were subsequently analyzed by the two subfactorials incorporated in the design and randomized, complete-block arrangement of treatments. The analysis of covariance with individual tree dbh, volume, or basal area per hectare prior to fertilization as a covariate was employed.

RESULTS AND DISCUSSION

Adjusted treatment means of response variables showing 10-year periodic growth increments are summarized in table 4. The mean dbh and volume increments are respectively adjusted for average tree dbh or volume for each treatment prior to fertilization, whereas stand-response variables are adjusted for basal area per hectare of respective treatments. The analyses of covariance were justified and necessary to compare the fertilization effects of the same basis.

It was generally observed in the field that the effects of fertilizer on tree and stand growth are influenced not only by stand density but, to a certain, extent by topographical characteristics such as slope position and soil depth as well. Growth responses of the preharvest lodgepole pine are usually more pronounced for trees grown on low, concave surfaces than for those on high, concave ones. Nutrient movement and soil erosion probably explain to a large extent the variation in tree-growth responses.

Individual Tree dbh Increment

Although some fertilizer treatments produced a substantial increase in dbh growth in the 10-year period (fig. 2), the periodic increments in dbh of the ten tagged trees were not significantly different from that of the unfertilized control

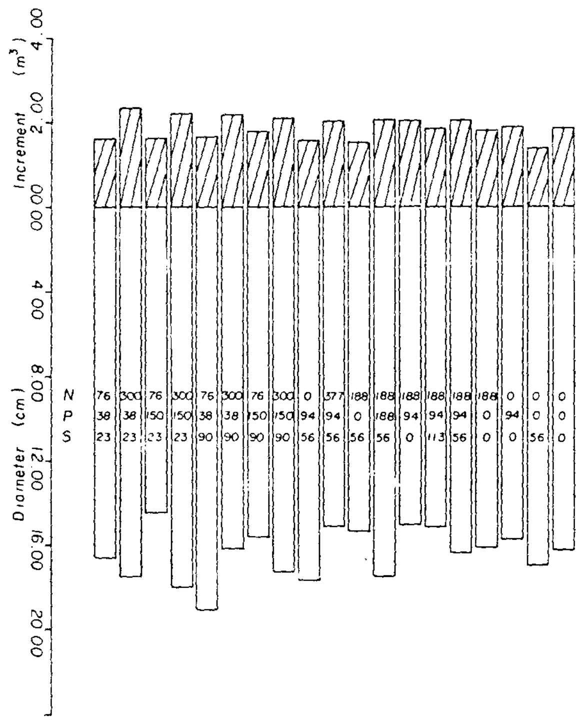

Figure 2.--Tree dbh increments in response to N, P, and S fertilization (kg/ha).

plots, due primarily to a large variation among trees within treatments. As a result of intertree competition in the preharvest, lodgepole pine stand, some of the ten tagged trees became unavoidably suppressed by the others after 10 years of dynamic development. While trees in dominating positions showed substantial increases in dbh growth in response to a fertilizer treatment, the suppressed trees produced little growth.

It is also noted that the periodic dbh increment is significantly poorer in some treatments (*e.g.*, treatments 5, 9, and 23) than that of the control. These plots were treated with medium to high rates of S (0 to 1 level) and mixed with a nil to low (-1.68 to -1) level of N. Luvisol is reportedly deficient in sulfur, nevertheless, the results seem to indicate that, in the absence of N, excessive sulfur could adversely affect the dbh growth in the preharvest lodgepole stand.

Figure 3 illustrates dbh increments in response to five incremental additions of N, P, and S. Apparently, N is required in large quantities for dbh growth because the dbh increment increased with an incremental addition of N in the range tested. The growth response showed quadratic trends to added P with a maximum growth at the 0 level of P (94 kg/ha). On the other

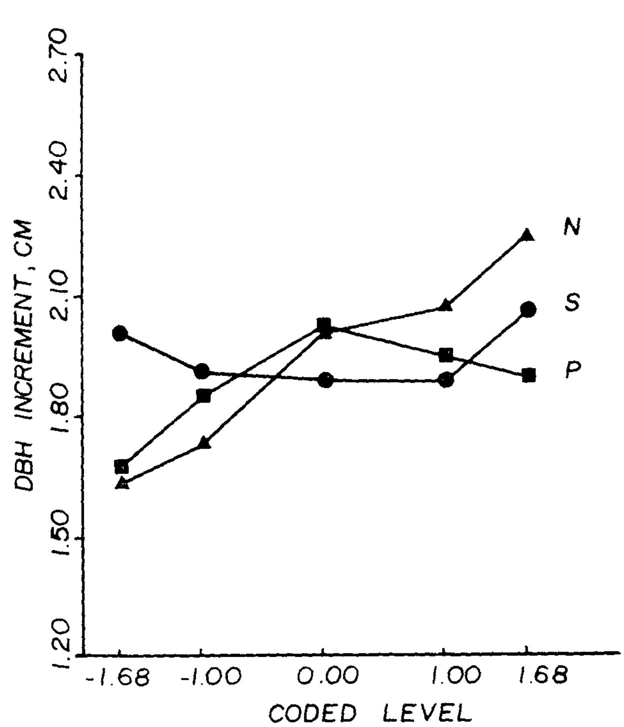

Figure 3.--Periodic dbh growth increment in response to 5 levels of N, P, and S fertilization.

hand, the dbh growth responded negatively to the addition of S to the 1 level; the reduction in dbh growth, however, is not significant.

Individual Tree-Volume Growth

Figure 4 shows the average tree-volume increments and tree volumes for treatments before the application of fertilizers. For dominant or codominant trees in the unfertilized control plots,

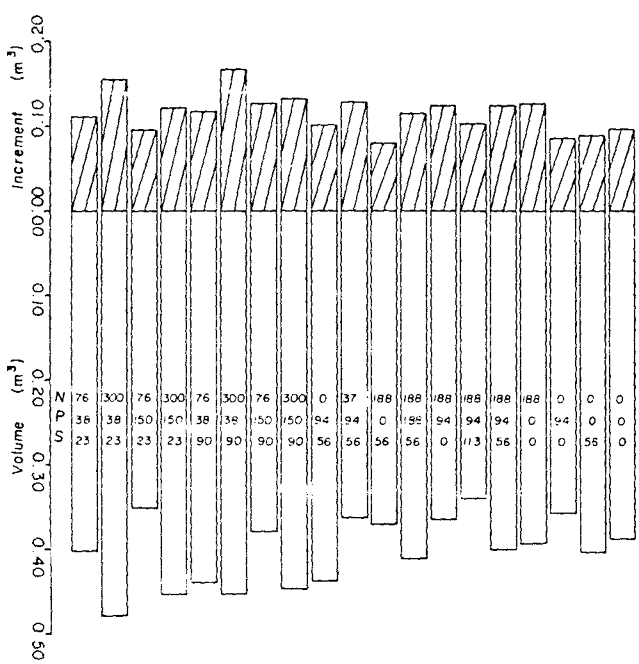

Figure 4.--Periodic tree volume growth in response to N, P, and S fertilization (kg/ha).

volume increment averaged 0.095 m^3 in the 10-year period. The volume increment was improved 28-68% by the fertilizer treatment.

Treatments which showed a considerable periodic volume increment over the control plot are, with one exception, those with an N dosage higher than the 0 level (188 kg/ha). It appears an appreciable increment in individual tree-volume growth requires a sufficient application of N. Table 1 and figure 4 suggest that an optimum gain in the periodic tree-volume growth in the preharvest lodgpole stand is obtained with N:P ratio in the range of 2-8:1 on the Luvisol.

In the absence of N supply, the tree-volume increments seem adversely affected by the addition of either P or S alone or combined. The reduction in the tree-volume growth is statistically not significant, but it indicates that P and S should not be applied to the preharvest stand without a simultaneous application of N.

The volume-increment curves in response to incremental additions of N, P, and S remain essentially similar to those of the dbh increments (fig. 5). While the responses were linear toward added N in the range tested, they were quadratic to added P and S with a maximum increment occurring at the -1 and 1 level for P and S, respectively.

Stand-Growth Increments

The effects of fertilization on stand basal area, total volume, and merchantable-volume increments per hectare are less pronounced compared to those on individual tree-volume growth because of natural variation introduced during the 10-year experiment period. Mortality and, to a lesser degree, in-growth are sources of variation; some pole-size trees were found dead of natural causes in the 10-year period. Because of the variation among plots within treatments, the power of the experiment to detect the fertilization effects on stand growth is markedly reduced.

Periodic stand basal area, total volume, and merchantable-volume increments in the control are 6.49 m^2, 66.01 m^3, and 69.92 m^3 per hectare, respectively. Three fertilizer treatments (treatments 2, 10, and 13) resulted in a significant enhancement in the periodic increments (table 4) over the control. The productivity of the preharvest stands can potentially be improved by 43-49%, 44-54%, and 45-47% for stand basal area, total volume, and merchantable volume increments, respectively, with an application of fertilizer.

The response curves for stand basal area (fig. 6), total volume (fig. 7), and merchantable-volume increments (fig. 8) per hectare are essentially identical: a linear response to added N and a quadratical response to P and S. These response curves are relatively consistent for all five response variables examined.

CONCLUSIONS

Based on the above results and discussion, it can be concluded that the site and stand productivities of preharvest lodgepole pine can be considerably improved by the application of fertilizer. In all tree- and stand-response variables investigated, the periodic increments responded linearly toward the incremental addition of N in the ranges tested and quadratically to the added P and S. An appreciable growth increment can occur only after a sufficient amount of N is applied. The results on the effects of P and S fertilization on the preharvest stand are less conclusive. Further studies of the effects of P and S and how they are interacting with N in lodgepole pine growth in preharvest stands are needed.

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Table 4--Adjusted treatment means of response variables showing 10-year growth increment

Treatment No.	Mean DBH increment a/ (cm)	Mean volume increment b/ (m^3)	Basal area increment (m^2/ha)	Total volume increment (m^3/ha)	Merchantable vol. increment (m^3/ha)
1	1.57	0.1101	5.30	57.74	59.20
2	2.15	0.1399** c/	9.70*	101.43*	101.61*
3	1.97	0.1058	7.76	79.20	81.74
4	1.93	0.1095	6.86	75.46	78.27
5	1.43*	0.1075	6.51	67.90	69.75
6	2.23	0.1608**	8.62	89.87	87.42
7	1.94	0.1343**	8.77	91.73	95.25
8	1.94	0.1227*	8.16	83.70	85.21
9	1.33*	0.0913	6.88	70.73	70.18
10	2.26	0.1394**	9.29*	99.73	102.51*
11	1.70	0.0831	6.36	63.41	65.27
12	1.88	0.1134	7.39	77.31	79.30
13	2.29	0.1338*	9.28*	94.84*	92.75
14	2.07	0.1174	6.67	71.24	76.57
15-20	2.05	0.1246**	7.81	82.01	83.81
21	1.84	0.1281**	6.46	70.06	70.29
22	2.01	0.0919	6.38	68.92	73.14
23	1.29*	0.0835	5.46	57.42	59.94
24	1.89	0.0955	6.49	66.01	69.92

a/ Based on ten tagged trees per plot;
b/ Based on three felled dominant or codominant trees;
c/ **Treatment means significantly different from the control at the 1% level; * at the 5% level.

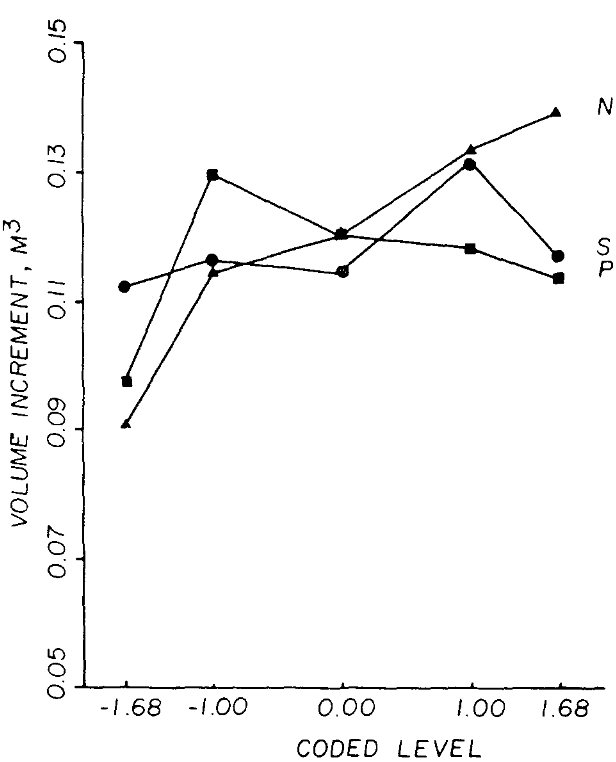

Figure 5.--Periodic tree volume growth increments in response to 5 levels of N, P, and S fertilization.

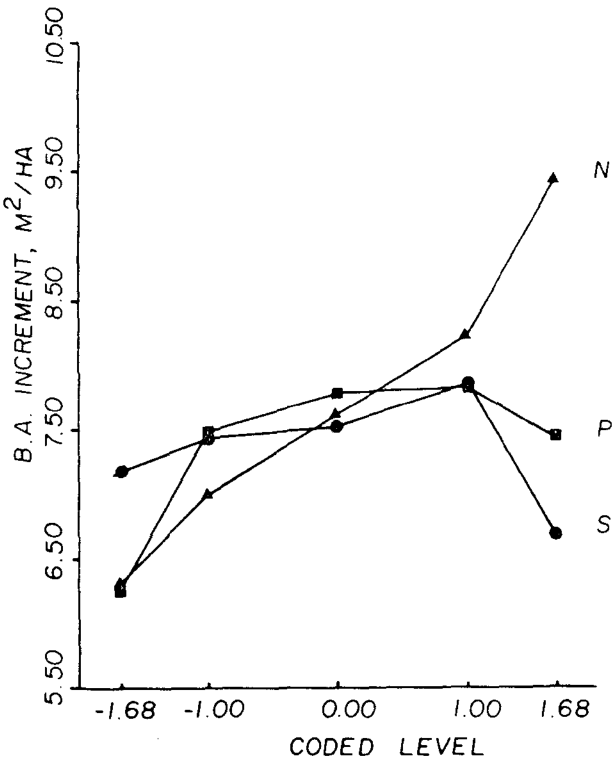

Figure 6.--Periodic basal area growth in response to 5 levels of N, P, and S fertilization.

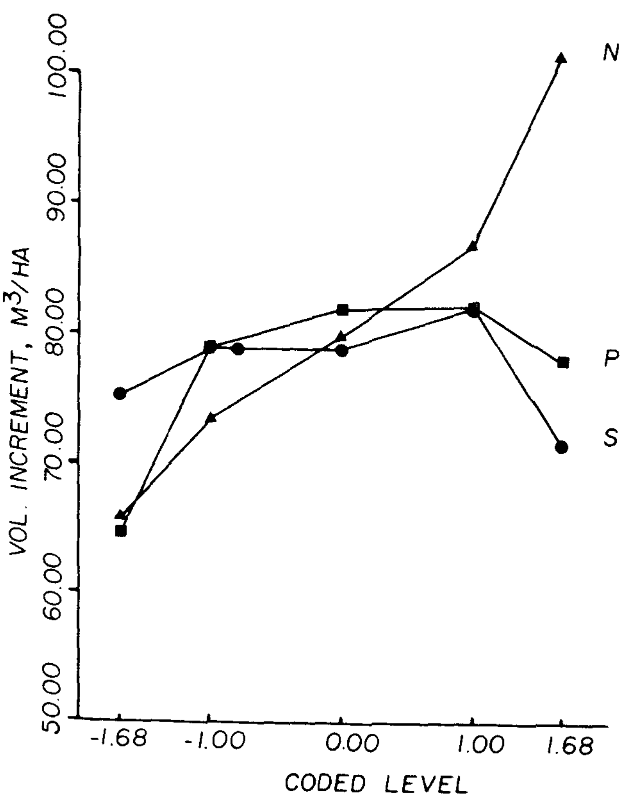

Figure 7.--Periodic total volume growth in response to 5 levels of N, P, and S fertilization.

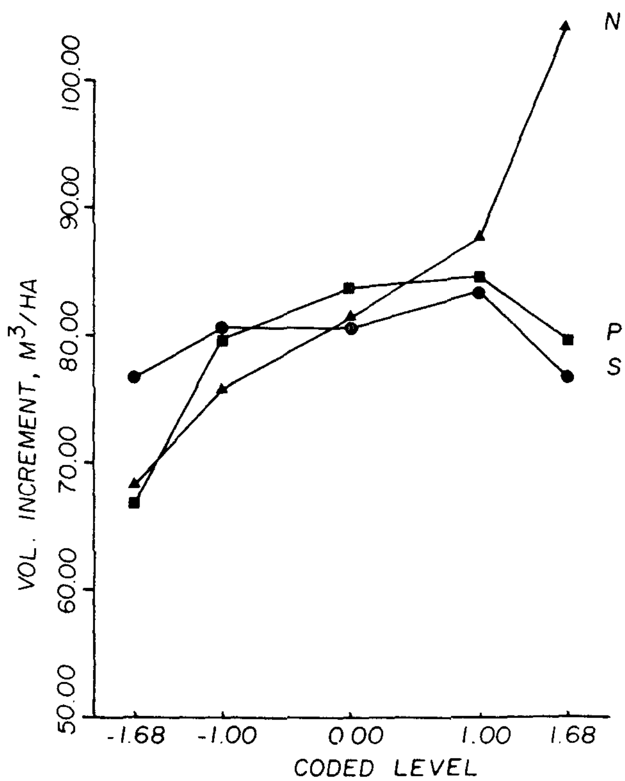

Figure 8.--Periodic merchantable volume growth in response to 5 levels of N, P, and S fertilization.

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