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FERTILIZATION OF A WHITE SPRUCE PLANTATION IN NORTH CENTRAL MINNESOTA: FIVE-YEAR GROWTH RESPONSES[1]

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ABSTRACT

A 16-year-old white spruce (Picea glauca (Moench) Voss) plantation in north central Minnesota was fertilized with varying rates of N, P, and K. After 5 years, volume increment was 8 to 15 percent greater on the fertilized plots compared to the controls; differences were not significant ($p = .05$). The small differences and lack of statistical significance may be due to problems in the experimental design, to climatic (drought) factors, or to this site already having adequate N, P, and K for white spruce.

INTRODUCTION

With the demand for softwood fiber and the use of whole-tree harvesting increasing in Minnesota, fertilization may be a means of augmenting wood production. In other regions, the addition of fertilizer has increased fiber production on nutrient-deficient sites (Leaf and Berglund 1969). Fertilization is also likely to help sustain growth on areas subjected to numerous whole-tree harvests (Ballard 1979).

White spruce (Picea glauca (Moench) Voss) has responded to fertilizers and is important to Minnesota forestry. To determine the response of white spruce to fertilization on Minnesota soils, a field trial was initiated in northern Minnesota during 1976 (Jokela 1978). This paper presents the five-year responses of that field trial in basal area, biomass, and volume.

STUDY AREA

The study area is in northern Aitkin county in north central Minnesota. The land is owned and managed by Blandin Paper Company of Grand Rapids. The level site was planted in 1959 with 3-0 bare root stock at the rate of 3450 white spruce seedlings per hectare. In 1976, 16 years after establishment and at the initiation of this study, the plantation was thinned to 2540 stems ha^{-1}. The average stand volume was then 23 m^3 ha^{-1} (Jokela 1978).

The soil supporting this stand is the Spooner series, a fine-silty, mixed, frigid, Typic Ochraqualf. The soil has medium site quality for white spruce (Jokela 1978).

METHODS

During May 1976, when the plantation was 16 years-old, 18 0.02 ha square fertilizer plots were established (Jokela 1978). A completely randomized block design with three replications and six treatments was used. There were no buffer strips, and hence the control plots were directly adjacent to two to four treatment plots. The plantation was thinned to 70 percent of original density immediately prior to fertilizer application. Each plot within a replicate was then randomly assigned one of six treatments:

[1]We acknowledge assistance of Blandin Paper Company in providing access to their lands. This fertilizer trial was initiated by Dr. Edwin H. White.

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Symbol	Treatment
Control	Control - no fertilizer
N168	168 kg ha^{-1} N as NH_4NO_3
N336	336 kg ha^{-1} N as NH_4NO_3
N504	504 kg ha^{-1} N as NH_4NO_3
NK	N336 + 112 kg ha^{-1} K as KCl
NPK	NK + 112 kg ha^{-1} as triple superphosphate

The plots were measured during August 1980 to determine the number of trees, basal area, and tree of mean basal area per plot (Table 1). These remeasurements only considered the responses on the two replicates that were thinned. The third replicate, because of very poor stocking, was not considered in the analysis. Three trees covering the range of sizes were randomly selected on each plot for destructive sampling. Discs were taken at one meter (m) intervals from each of the 36 sampled trees for stem analysis and bole biomass estimation. The foliage and branches were weighed in the field, and a systematic subsample with respect to crown location was taken for dry weight conversion and estimation of total weight. Regression equations using diameter at breast height as the independent variable were generated from the stem analysis and biomass estimates to determine plot volumes and weights, respectively (Cudworth 1981).

The biomass, basal area, and volume responses were adjusted by analysis of covariance based on the initial volume on each plot. The adjusted values were analyzed using one-way analysis of variance. Differences between treatment means were tested using the HSD (honest significant difference) at the 0.05 level.

RESULTS AND DISCUSSION

The plots were fully stocked, with an average of 2250 stems ha^{-1} (Table 1). The average height of the dominants and codominants after 21 years was 9 m. Total height for all trees ranged from three to 11 m (Cudworth 1981).

The mean annual volume increment was 3.8 $m^3 ha^{-1} yr^{-1}$ (Table 1). This increment is higher than that of 3.0 m^3 for an average high quality site of comparable age in Wisconsin (Wilde et al. 1965). Curves developed for white spruce plantations in Canada, which begin at age 10, indicate site index of the present site to be 23m at 50 years (Stiell and Berry 1973). These comparisons indicate that the quality of the present site may be greater than originally estimated.

The basal area, volume, and biomass responses showed no significant differences among treatments five years after fertilization (Table 2). The effect of blocking, however, was highly significant ($p = .005$). A variation in soil moisture between the two replications may explain this difference (Cudworth 1981). Although not significantly different at the $p = 0.05$ level, the fertilized plots generally showed more growth than did the controls, ranging to 15 percent greater periodic annual volume increment than the controls for N504 (Table 2).

To further examine this trend, the three N treatments and the control were subjected to regression analysis with the N level as the independent variable and periodic annual increment as the dependent variable. The positive slope of the regression line for replicate 2 was significant ($p = .05$) indicating increased growth with N fertilizer. However, the slopes for both replicates together, or replicate 1 alone, were not significant.

The lack of a detectable response to fertilization may result from the high inherent site quality, the high variability between reps of the same treatment, the small sample size, and/or the lack of buffer strips. White spruce have a high degree of lateral root extension in all age classes, and roots of mature trees may extend 13m from the tree (Stiell 1976). Consequently, since there were no buffer strips, roots from trees in the control plots, particularly those on plot borders, may have extended into other treatments. Therefore, the differences between control and fertilized plots may be underestimated and an actual response may have occurred.

Another explanation for the lack of response to fertilizer may be the droughty conditions during 1976. Others have cautioned against the application of fertilizer during dry periods (Shepard 1979). Although applied as NH_4NO_3, an unknown amount of the N may have volatilized (Baule and Fricker 1970), reducing the amount available for plant uptake.

CONCLUSIONS

The application of fertilizers did not significantly increase white spruce growth on the study area. Several factors may have contributed to the low absolute responses and to the lack of statistical differences, including deficiencies in the experimental design, the site heterogeneity, climatic factors, and the initial site quality.

The results of this study should not be interpreted as universally indicative of white spruce response to fertilizers in Minnesota. This project represents only one site and trees of one age.

To develop criteria for fertilizing white spruce in Minnesota a number of field trials will be necessary. These trails should cover all tree ages, major soils, and use various fertilizers and fertilizer rates. The consolidation of these data, along with a knowledge of the soil-site factors important for spruce growth, would allow prediction of those sites likely to respond to fertilization.

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Table 1. Mensurational data for a 21-year-old white spruce plantation in Minnesota measured five growing seasons after fertilization.

Treatment	Stems	Basal area	Diameter of tree of mean basal area	Total stemwood volume	Mean annual volume
	no/ha	m^2/ha	cm	m^3/ha	m^3/ha/yr
Control	2425	24.2	11.3	73.5	3.5
N168	2250	25.6	12.1	77.9	3.7
N336	2225	25.5	12.1	78.4	3.7
N504	2175	30.1	13.3	95.0	4.5
NK	2450	25.5	11.5	77.2	3.7
NPK	1975	24.9	12.6	77.4	3.7
Mean	2250	26.0	12.1	79.9	3.8

Table 2. Growth response by basal area, biomass, and volume (adjusted by analysis covariance) for a 21-year-old white spruce plantation measured five growing seasons after fertilization (means above, standard errors below).[1]

Treatment	Basal area	Total above ground biomass	Stemwood biomass	Total stemwood volume	Periodic annual stemwood volume (1977-1980)	
						Relative to the control
	m^2/ha	kg/ha	kg/ha	m^3/ha	m^3/ha/yr	%
Control	24.8 a[2]	79610 a	33931 a	75.3 a	11.7 a	-
	2.2	7227	3007	6.8	1.7	
N168	25.9 a	83452 a	35623 a	79.0 a	12.6 a	+ 8
	1.8	5807	2538	5.4	1.4	
N336	26.5 a	86095 a	36870 a	81.6 a	13.2 a	+ 13
	2.1	7297	3196	7.0	1.7	
N504	26.3 a	86575 a	37112 a	82.0 a	13.4 a	+ 15
	1.9	7034	3166	6.8	1.7	
NK	26.6 a	85416 a	36431 a	80.8 a	13.1 a	+ 12
	1.3	3292	1307	3.1	0.8	
NPK	25.8 a	84545 a	36358 a	80.3 a	13.0 a	+ 11
	1.2	5116	2449	5.1	1.3	

[1]Means and standard errors represent two observations.

[2]Means within a column followed by the same letter are not significantly different based on the HSD test at the 0.05 level.

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