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THE EFFECTS OF VARIOUS COMBINATIONS OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON PAPER BIRCH SEEDLING GROWTH

Abstract.—The combined effects of various concentrations of N, P, and K on the growth of paper birch seedlings were tested in sand culture tests. All other elements were held constant. The best seedling growth and dry weight of foliage generally occurred at concentrations of 400 p.p.m. N, 50 p.p.m. P or 600 p.p.m. N, 75 p.p.m. P. The concentration of K had relatively little effect. The optimum combination was not found but the results suggested that the amount of K should be increased

The response of paper birch seedlings to varied supplies of a single element while holding constant the supply of all other elements was reported earlier (*1*). However, these results may differ when the supply of two or more elements is varied at the same time.

To gain some insight into these interactions, I tested the combined effect of different levels of nitrogen (N), phosphorus (P), and potassium (K) on the growth of paper birch (*Betula papyrifera* Marsh) seedlings. Also, I wanted to identify the combination of these elements that resulted in optimum response.

The results of this study showed that the greater average heights and the greater average dry weights followed treatments high in N and intermediate in P, with K making little if any contribution at the levels tested. However, the element concentrations for optimum growth were not found.

Methods

The study was conducted in a growth room. Seedlings were grown in 4-inch plastic pots filled with quartz sand and perlite. Fluorescent and incandescent lamps provided about 3,000 foot-candles of light at the top of the seedlings. Day length was 16 hours. Day and night temperatures were kept as close as possible to 85 and 65 degrees F, respectively.

Trials of combined N, P, and K were run, using a response surface design (*3*, *4*) to determine treatment effects. After a number of trials, a promising treatment of 400 p.p.m.

(parts per million) N, 50 p.p.m. P, and 70 p.p.m. K was reached. Using this as the central treatment, the concentrations were calculated to be:

N	*P*	*K*
p.p.m.	*p.p.m.*	*p.p.m.*
64	8	11
200	25	35
400	50	70
600	75	105
736	92	129

The other elements were supplied in the following concentrations:

	p.p.m.		*p.p.m.*
Calcium	120	Manganese	0.500
Magnesium	48	Boron	.500
Sulfur	64	Copper	.060
Iron	3	Zinc	.060
		Molybdenum	.009

A total of 15 treatments were tested, and each treatment was replicated twice.

The treatment solutions were not applied until all seedlings had developed their first true leaves. During this period, all pots received periodic alternate applications of de-ionized distilled water and of nutrient solution. This solution (140 p.p.m. N, 100 p.p.m. P, and 175 p.p.m. K, and other elements as shown above) was applied at one-half strength.

The growth period was 70 days, from the time of the first application of the treatment solutions to seedling harvest. During this period, the treatment solutions were added twice weekly in 50 ml. amounts, alternating with 50 ml. amounts of de-ionized distilled water.

The seedling response was measured in terms of height growth and dry weight of foliage. In addition, the amount of each tested element in the foliage was determined. Nitrogen determinations were made by the semimicro-Kjeldahl method (*6*). Phosphorus determinations were made colorimetrically, using the vanadate-molybdate-yellow method (*2*). Potassium content was measured by atomic absorption spectrophotometry (*7*). Element content was expressed as a percent of the dry weight of foliage.

Height Growth

Because the average height of seedlings varied at the start of treatment, height growth was used to estimate the effect of treatment. On this basis, seedlings in the 600-75-35 (N-P-K) treatment responded best — their average height increased nearly 20 times to 339 mm. Seedlings in the 400-50-129 treatment did nearly as well. The average height of these seedlings increased about 18 times to reach 200 mm.

Ranking treatments in order of average height increase shows that the differences between successive treatments were generally small (table 1).

Table 1.—*Average height at start of treatment, at harvest, and height increase factor, by treatment*

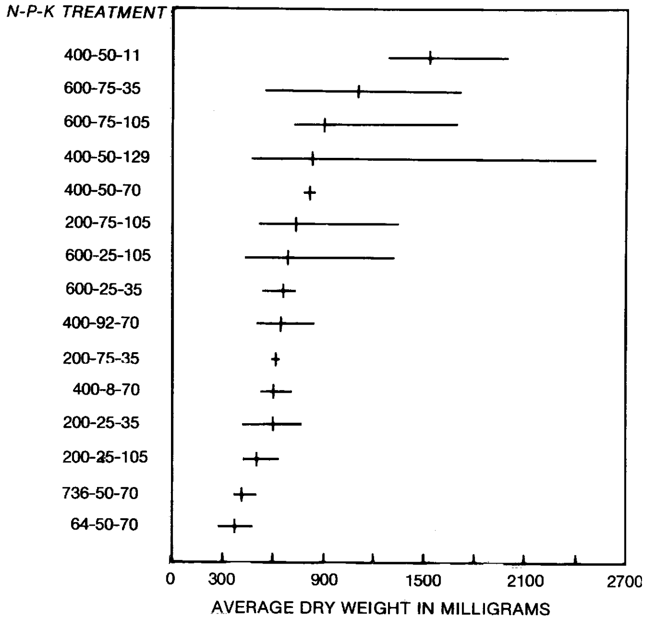
N-P-K treatment	Average height		Increase factor
	Start	Harvest	
	mm.	*mm.*	
600-75-35	17	339	20
400-50-129	11	200	18
400-50-11	17	234	14
400-8-70	14	176	12
400-50-70	15	185	12
200-75-105	15	177	12
600-75-105	17	190	11
200-25-35	14	155	11
736-50-70	17	188	11
600-25-35	15	151	10
400-92-70	19	174	9
200-75-35	14	126	9
600-25-105	20	178	9
200-25-105	16	132	8
64-50-70	18	115	6

Dry Weight of Foliage

The average dry weight of foliage per seedling varied by treatment, but no one level of nutrient supply was best consistently. In general, the treatments resulting in the greater dry weights tended to have both nitrogen and phosphorus in the middle range of concentrations while the concentration of potassium appeared to have little effect (fig. 1). In many cases, the variation in average dry weight of foliage per seedling was greater between replicates of the same treatment than it was between adjoining treatments.

Dry weight of foliage appeared to be a slightly more sensitive indicator of response to treatment than average height or height growth.

Figure 1.—Variation in foliage dry weight is often greater between treatment replications than between adjoining treatments. Here the horizontal lines show the range in dry weight with the mean indicated.



Element Content

As the supply of nitrogen increased, so did the percent nitrogen content in the foliage (table 2). Variations in the content of either phosphorus or potassium in the foliage were much less apparent although the content of these elements tended to increase slightly with increasing supplies.

Response Surface Analysis

A response surface analysis of both average height and of average dry weight indicated that the optimum level of potassium was not tested. However, within the range of concentrations tested, the optimum levels were:

	Nitrogen *p.p.m.*	*Phosphorus* *p.p.m.*	*Potassium* *p.p.m.*
Average height	500	78.3	88.4
Average dry weight	326	60.1	67.5

Discussion

The results of this study suggest that paper birch seedlings are more responsive to changes in nitrogen supply than they are to changes in phosphorus and potassium supplies. Within the conditions of the study, the better height growth and average dry weight of foliage were associated with 400 p.p.m. and 600 p.p.m. N, 50 and 75 p.p.m. P, and almost any concentration of K.

The effects of these elements were not greatly different, whether applied in combination or singly. However, the concentration of N giving the most favorable growth response was greater where N was supplied in combination with P and K than where N only was supplied. Nitrogen was the only element for which the foliar content appeared strongly related to supply.

The optimum combination of these elements was not defined by this study. Ingestad (5), working with *Betula verrucosa* Ehrh., reported that the optimum proportions of N., P, and K should be in the ratio of

Table 2.—*Percent content of nitrogen, phosphorus, and potassium in the foliage of paper birch seedlings, by treatment*

N-P-K treatment	Foliage content		
	N	P	K
	Pct.	*Pct.*	*Pct.*
64-50-70	1.4	1.6	1.8
200-25-35	2.8	1.4	1.2
200-25-105	2.8	1.7	1.7
200-75-35	2.8	2.0	1.3
200-75-105	3.0	1.8	2.2
400-8-70	3.8	1.6	1.4
400-50-11	4.0	1.7	.7
400-50-70	3.9	1.7	1.6
400-50-129	3.8	1.6	2.5
400-92-70	4.4	2.4	1.8
600-25-35	4.9	.9	.9
600-25-105	5.0	1.2	1.5
600-75-35	5.5	1.3	.9
600-75-105	5.1	1.5	1.6
736-50-70	5.3	1.4	1.2

100:13:65. On this basis, the relative amounts of N and P in the central treatment used here were satisfactory while the amount of K should have been 3 to 4 times greater. The response surface analysis of the study data, by indicating that the K supply was low, agrees with these general relationships. Thus, further testing is needed to determine the optimum levels of supply; and the results reported here should be considered as a first approximation only.

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