Effects of FERTILIZER-NUTRIENT INTERACTIONS on Red Oak Seedling Growth

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GROWTH of red oak seedlings was examined in relationship to various levels of nitrogen (N), phosphorus (P), and potassium (K) supplied singly and in all combinations to forest soils from the Barbour series. Results showed that seedling growth was significantly affected by NxP and NxPxK interactions; and that, without nitrogen, P and K alone or in combination with each other did not increase growth. These findings suggest that NxP and NxPxK interactions should be considered in designing fertilization tests on soils that have P and K levels similar to or lower than those tested in this study.

Soils vary in their ability to supply nutrients for tree growth. Forest stands on some soils do not respond to fertilization because nutrient levels are adequate or because growth is controlled by physical limitations such as moisture supply and rooting depth.

Growth response to fertilization can also be drastically reduced or completely eliminated in situations where more than one nutrient is deficient, if each deficiency is not corrected by fertilization. Furthermore, when the supply of a critically low plant nutrient is increased by fertilization, plant requirements for other essential nutrients can rise, and minimal supplies of these nutrients in the soil that were not limiting growth before fertilization can sometimes become deficient and limit growth after fertilization. Several studies have indicated the importance of nutrient interactions on growth of upland hardwoods *(1, 2, 3)*. These studies have shown greater response from simultaneous application of two fertilizer nutrients than from either of the nutrients applied alone.

METHODS

The experiment was designed as a 3^3 factorial (N, P, and K at three levels) in randomized complete blocks with three replications. It was conducted indoors with seedlings grown in gallon-size plastic pots.

Soil from the Barbour series was collected from a 6-inch section of the profile located just beneath the A_1 horizon. Barbour soils have developed from deep, well-drained, moderately coarse-textured alluvium on flood plains. Samples were obtained from three independent locations supporting vigorous and well-stocked stands of yellow-poplar (*Liriodendron tulipifera* L.). Each pot contained approximately 9½ pounds of oven-dry soil. Nutrient characteristics are given in table 1.

Table 1.—*pH and nutrient status of the study soils*[1]

Replication	pH	Total N	P	K	Ca	Mg
		Percent		*Pounds/acre*		
I	4.6	0.029	14	38	109	18
II	4.6	0.039	8	51	141	24
III	4.5	0.043	8	32	106	14

[1]pH by glass electrode in 1:1 soil/water solution; total N by Kjeldahl digestion; P colorimetrically after extraction by .002 *N* H_2SO_4; K, Ca, and Mg by atomic absorption after extraction with NH_4OA_c.

Red oak (*Quercus rubra* L.) seedlings were germinated from uniform-size acorns in sterile sand. Three seedlings of equal size were transplanted into each pot, and after 3 weeks the poorest of the three was removed. The seedlings were grown under a 20-hour photoperiod, with light supplied from a combination of fluorescent and incandescent lamps. Light intensity was maintained at about 1,000 foot-candles near the tops of the seedlings. Soil moisture was brought to field capacity daily with distilled water.

Nutrient treatments included all combinations of three levels of N, P, and K. Nitrogen rates corresponded to 0, 200, and 400 pounds per acre and P and K rates to 0, 100, and 200 pounds per acre. Solutions containing N, P, and K were prepared from reagent grade NH_4NO_3, NaH_2PO_4, and KCl, and these were applied to the seedlings in two equal doses at 14 and 21 days after start of the experiment.

After 91 days the study was terminated. Seedling height was recorded, and plants were dried at 70° C. for determination of top and root weights.

RESULTS

Nitrogen alone significantly (0.01 level) increased seedling height and top dry weight, but had negative effects upon root production (table 2). Nitrogen rates corresponding to 200 pounds per acre usually resulted in one extra flush in height growth while 400 pounds per acre resulted in two and sometimes three extra flushes as compared to seedlings not treated with N.

Phosphorus alone had little effect on seedling height or top dry weight, but had a tendency to depress root dry weight at the 200-pounds-per-acre rate.

Potassium by itself did not significantly (0.05 level) affect height, top dry weight, or root dry weight at residual soil levels of N and P. Plants receiving K varied little in color, height, or weight from seedlings in check treatments.

N and P applied simultaneously had strikingly greater effects upon seedling height and top dry weight than individual applications of N or P (figs. 1 and 2). The data show that

Table 2.—*Effect of N fertilization on height, top dry weight, and root dry weight of red oak seedlings*

N rate	Height		Top dry weight		Root dry weight	
Pounds/acre	*Inches*	*Pct. gain**	*Grams*	*Pct. gain*	*Grams*	*Pct. gain*
0	5.12	—	1.58	—	1.93	—
200	6.33	24	2.19	38	1.73	−11
400	9.36	82	2.69	70	1.51	−22

*Percentage gain over unfertilized seedlings.

Figure 1.—Simultaneous effects of nitrogen and phosphorus upon height growth of red oak seedlings.

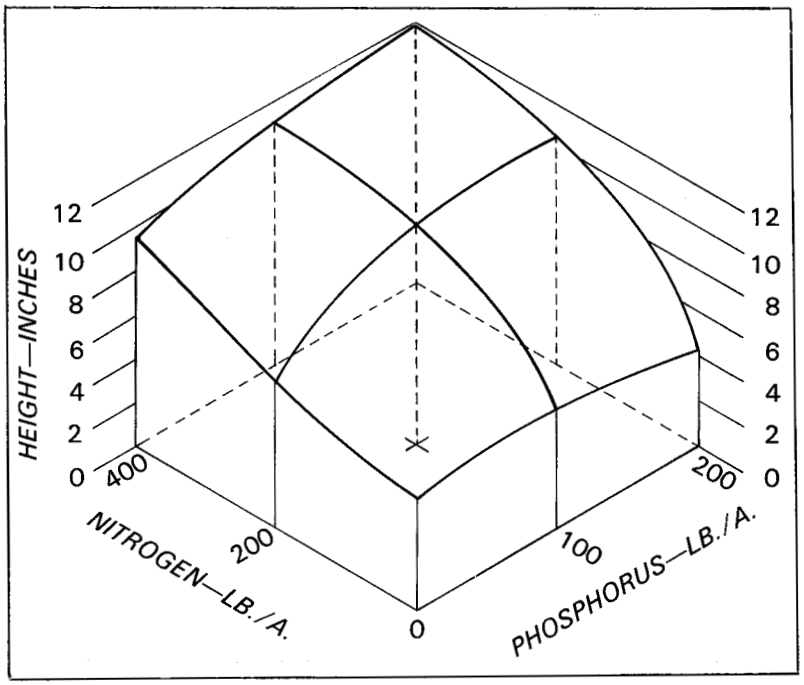


Figure 2.—Simultaneous effects of nitrogen and phosphorus upon top dry weight of red oak seedlings..

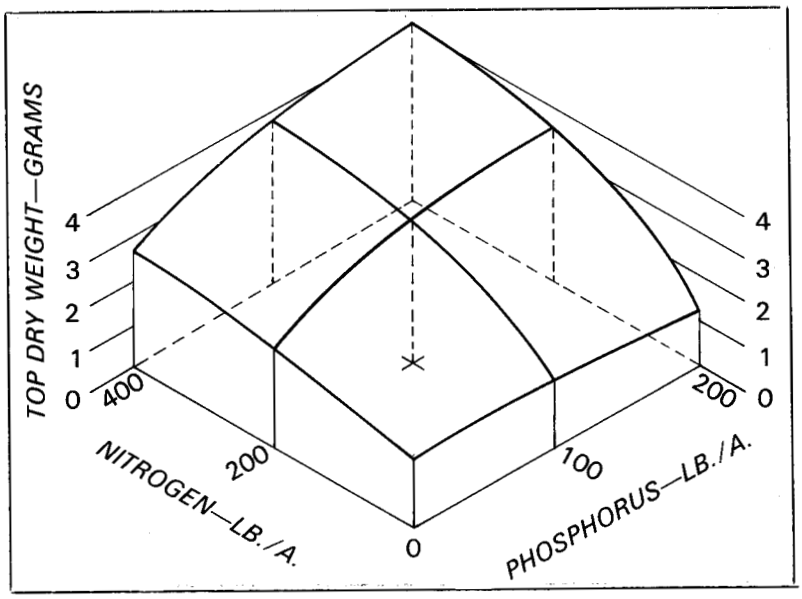
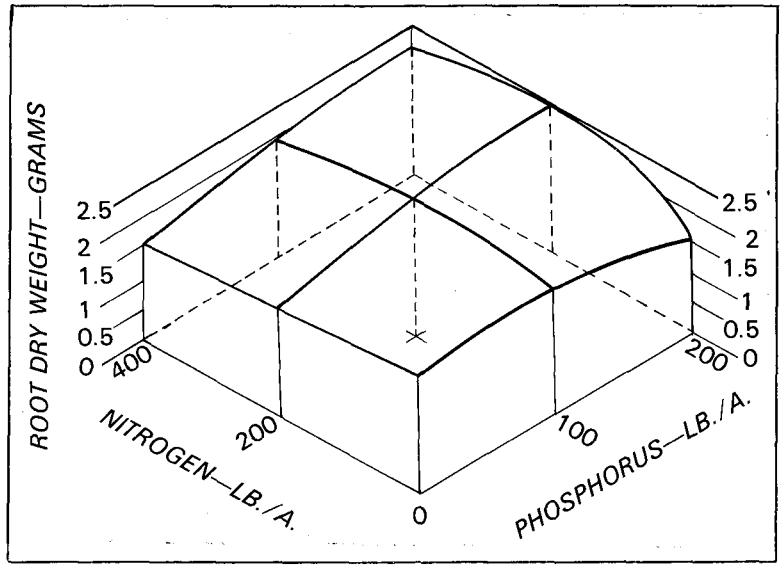


Figure 3.—Simultaneous effects of nitrogen and phosphorus upon root dry weight of red oak seedlings.



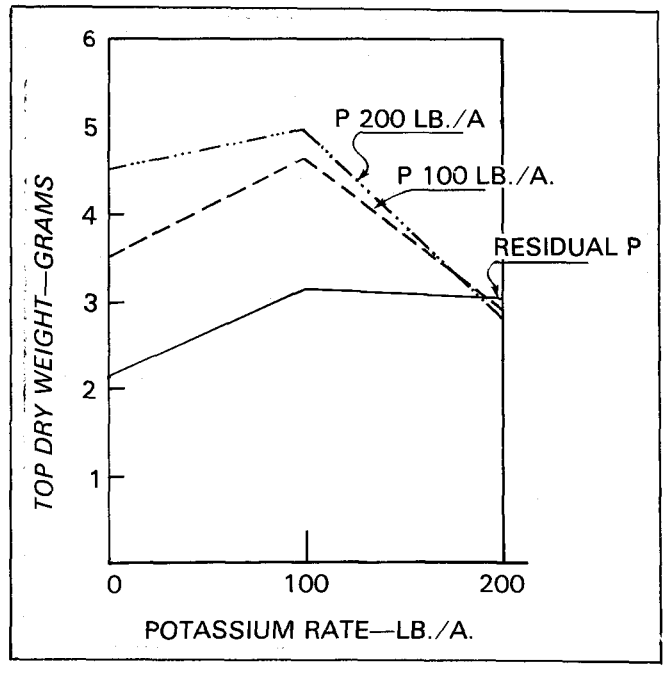
height and top dry weight were initially limited by N deficiency. As N supply was increased, plant requirements for P also increased, and potential yields were limited by lack of available P in the soil.

Root growth was reduced by individual applications of N and P, but was increased when both nutrients were applied together (fig. 3). Phosphorus promoted root activity at both rates of N, but the best production occurred when both elements were supplied at rates of 200 pounds per acre. At N rates of 400 pounds per acre, root response to P was less than at the 200-pounds-per-acre rate.

Potassium in combination with 400 pounds per acre of N significantly (0.05 level) increased top dry weight when it was applied at 100 pounds per acre, but it decreased top weight when it was applied at 200 pounds per acre. The response varied with rate of P fertilization (fig. 4). Potassium in combination with either N or P did not significantly (0.05 level) affect seedling height or root dry weight.

Maximum top dry weight production occurred at rates of 400 pounds per acre of N and 200 pounds per acre of P in combination with 100 pounds per acre of K. Seedlings fertilized at this rate were 227 percent heavier than unfertilized control seedlings. Nitrogen alone accounted for 34 percent of this re-

Figure 4.—Effects of potassium on top dry weight of red oak seedlings supplied with 400 pounds per acre of nitrogen for three levels of phosphorus.



sponse, P in combination with N for 53 percent, and 13 percent was due to K.

Maximum seedling height occurred at rates of 400 pounds per acre of N and 200 pounds per acre of P. Seedlings fertilized at these rates were 129 percent taller than unfertilized control seedlings. Nitrogen alone produced 65 percent of this response, and P in combination with N the remaining 35 percent.

DISCUSSION

The favorable growth response resulting from simultaneous application of N, P, and K over that obtained with either element alone, strongly suggests that nutrient interactions should be considered in designing forest fertilization field tests. Failure to consider these interactions may lead to the erroneous conclusion that nutrients are not limiting growth when they actually are, or to serious underestimates of potential response if there is an additional nutrient deficiency not corrected by fertilization.

The data suggest that growth response to P in acid soils is possible at levels ranging from 8 to 14 pounds per acre and below when N is not limiting. A small response to K when applied in combination with N and P, may also be forthcoming when the soils contain about 50 pounds per acre or less of exchangeable K. However, because these results were developed from seedlings grown in pots in a greenhouse environment, they are subject to a number of limitations; and caution must be exercised in extrapolating to field conditions.

We are uncertain whether P and K levels of the study soils accurately estimate soil-nutrient levels under which a field response to fertilization would be forthcoming. These levels may be considerably below critical concentrations for fast-growing, nutrient-demanding species such as yellow-poplar or above critical levels for slow-growing, low-nutrient demanding species such as chestnut oak (*Quercus prinus* L.).

Moreover, critical soil-nutrient levels may be influenced considerably by the volume of soil on different sites from which nutrients can be absorbed. Until better estimates of plant nutrient requirements become available, fertilization tests with soil having P and K contents similar to those reported in this study should include treatments to evaluate NxP and NxPxK interactions if valid estimates of growth response are to be achieved.

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