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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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FERTILIZATION TESTS WITH POTTED RED OAK SEEDLINGS

ABSTRACT. — Soil-pot tests with red oak seedlings indicated that forest soils supplied more N and P and produced better seedling growth than old-field soils. Growth was closely correlated with content of N and P in the foliage. K fertilization did not improve seedling growth on any of the soils studied.

OXFORD: 114.521.5:114.54:176.1 *Quercus rubra.*
KEY WORDS: soil-pot tests, forest soils, old-field soils, red oak, fertilization, foliage analysis.

Hardwood seedlings may grow poorly if planted on soils deficient in mineral nutrients. However, information on nutrient requirements of hardwood seedlings is scanty and indices of soil nutrient deficiencies inadequate, so fertilizer recommendations are risky.

The purpose of the study reported here was to evaluate soil fertility differences between certain forest and old-field soils in Iowa and Missouri and to find out which fertilizers would most likely increase growth. We also wanted to determine foliar nutrient levels associated with good growth. Such information would be useful in detecting nutrient deficiencies and in planning fertilization practices when planting red oak on these specific soils. The study method used, however, could be used to obtain similar information for other soils in other areas.

MATERIALS AND METHODS

Soil was collected from two forest sites (Lindley and Clarksville soil series) and from two old-field sites (Shelby and Clarksville soil series). These particular soil-site situations were selected because they occupy extensive areas and are commonly planted to forest tree species. Mixed oak stands occupy the forest sites whereas the old-field sites are in grass cover. The Lindley and Shelby soils were collected in southeastern Iowa, the Clarksville soils were collected in southern Missouri.

All soil collected came from the top 8 to 10 inches of the profile at each sampling site. Only the A horizons of the forest soils were sampled, but some upper B horizon was included with the old-field soils.

Each soil was mixed, screened (1-inch mesh), and then placed in 5-gallon plastic pots. Each pot contained 0.5 cubic foot of soil. A sample of each soil was analyzed for various chemical and physical properties (table 1). The soil tests, made by the Iowa State University Soil Testing Laboratory, indicated that all of the soils were low in available nitrogen (N), very low in available phosphorus (P), and medium in available potassium (K) on the basis of agricultural soil standards.

Fertilizer treatments were applied (a) as a 2^3 factorial series with applications of 90 pounds of N, 80 pounds of P, and 80 pounds of K per acre, and (b) as a rate series in which 0, 30, 90, 180, and 360 pounds of N were added per acre with 80 pounds of P and K per acre. Nitrogen was added as NH_4NO_3, P as liquid H_3PO_4, and K as K_2CO_3. These fertilizers were added only once (before planting) and were thoroughly mixed into the soil in each pot. Pots of unfertilized soils also were included in the study. Each fertilizer treatment was replicated in three pots.

Five acorns were planted in each pot. All acorns came from one local seed tree and were stratified

Table 1.—*Some chemical and physical properties*[1] *of the soils studied*

Property		Forest soils: Lindley	Forest soils: Clarksville	Old-field soils: Shelby	Old-field soils: Clarksville
pH		5.8	5.5	5.5	5.5
O.M.	percent	5.7	4.3	5.1	2.8
C.E.C.	meq/100g	20.9	14.8	19.0	15.8
Base saturation	percent	66	31	57	30
Texture		L	SiL	CL	L
Avail. N	pound/acre	45	35	33	27
Exch. P	pound/acre	<15	<15	<15	<15
Exch. K	pound/acre	196	208	184	155

1/ Average of duplicate analyses.

in sand prior to planting. About midsummer the seedlings were thinned to three seedlings per pot. The soil was covered with sphagnum, and water was added at frequent intervals during the growing season to maintain soil moisture near field capacity.

At the end of the growing season, the seedlings were harvested and separated into roots, stem, and leaves. Dry weight of each of the component parts of the seedlings was obtained after ovendrying for 24 hours at 68° C. Chemical analyses for N, P, K, and 11 other elements were made on samples of the combined leaf material from the three replications (3 pots) of each treatment. Because seedlings on the two forest soils responded similarly to treatment, as did those on the two old-field soils, the data for the two soils within the two soil-site groupings were combined to simplify the results.

RESULTS AND DISCUSSION

The red oak seedlings grown on the forest soils averaged about one-third more in total dry weight than seedlings grown on the old-field soils, regardless of the fertilizer added (fig. 1). The foliage analyses indicated that the better growth on the forest soils was probably due to greater uptake of N and P, as indicated by the higher percent N and P in the leaves of these seedlings (table 2). On the other hand, the concentrations of K, and other macro- and micro-nutrients in the foliage of the seedlings did not differ greatly on the different soils or show any consistent relation with the observed growth trends. For the different soils, there was good correlation between percent N in the foliage and available soil N, as indicated by the soil tests (table 1). However, poor correlation was evident between the percent P and percent K in the foliage and exchangeable P (Bray's Method 1 using a weak extracting solution) in the soil.

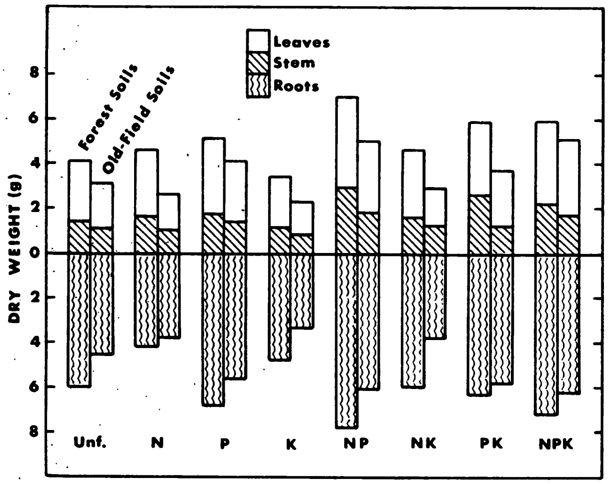

Figure 1.—*Effect of different fertilizers on growth of red oak seedlings on forest and old-field soils.*

Table 2.—*Effect of fertilizers on average N, P, and K content*[1] *in leaves of red oak seedlings on forest and old-field soils*

(In percent)

FOREST SOIL

Fertilizer	Foliar nutrient: N	Foliar nutrient: P	Foliar nutrient: K
None	2.04	.158	0.48
N	2.44	.201	.43
P	2.04	.202	.48
K	2.22	.155	.46
NP	2.25	.241	.44
NK	2.45	.176	.45
PK	1.95	.219	.46
NPK	2.38	.242	.47
OLD-FIELD SOIL			
None	1.92	.098	0.75
N	1.85	.149	.58
P	1.63	.148	.51
K	1.84	.092	.66
NP	2.11	.169	.43
NK	1.90	.122	.64
PK	1.56	.135	.55
NPK	2.24	.168	.52
± s.e.[2]	.10	.016	.05

1/ Average of duplicate analysis.

2/ Standard error based on mean square of highest order interaction with 21 d.f.

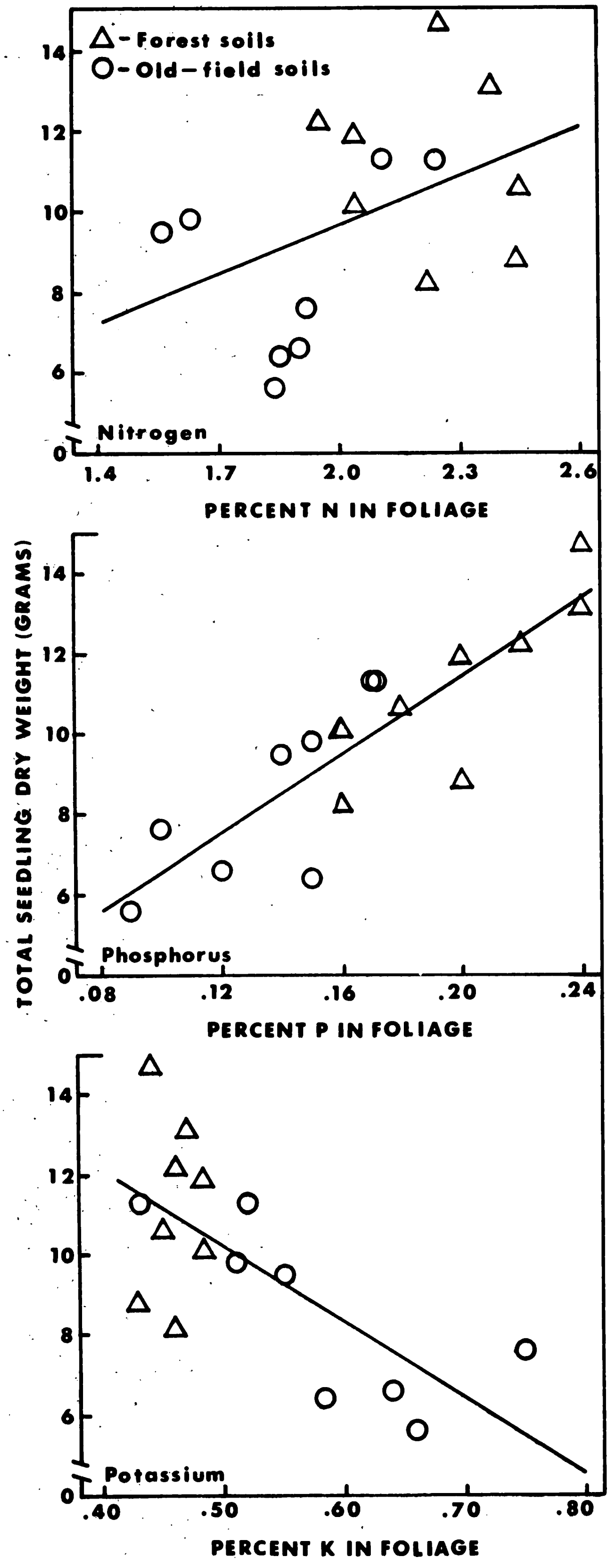

Figure 2. — *Relation between total dry weight of the red oak seedlings (data from figure 1) and concentration of N, P, and K in the foliage (data from table 2), for all soils and fertilizer treatments.*

Phosphorus was the most deficient nutrient in the soils studied, as indicated by the response to P fertilization. Adding the equivalent of 80 pounds of P per acre increased seedling dry weight about 38 percent on the forest soils and about 62 percent on the old-field soils.

Associated with the positive response to P fertilization, was a strong correlation between total dry weight of the seedlings and concentration of P in the foliage (fig. 2). Unfertilized seedlings contained 0.09 to 0.16 percent P, while P fertilized seedlings contained 0.20 to 0.24 percent P on the forest soils and 0.14 to 0.17 percent P on the old-field soils. These concentrations are comparable to those reported by Mitchell and Chandler and by McComb for red oak trees and seedlings. Optimum P percentages could not be determined because of the linear relationship observed, but less than 0.20 percent P in red oak leaves probably indicates a significant P deficiency and a need for fertilization.

The only growth stimulation obtained from N fertilization was when P was also included in the fertilizers. Even when heavier rates of N were added (table 3), the increases in growth from N fertilization were small on all of the soils studied. The optimum rate of N application appeared to be between 90 and 180 pounds of N per acre. Heavier rates of N fertilization actually depressed total dry weight growth and resulted in high shoot/root ratios.

Table 3. — *Effect of different levels of N fertilizer on growth and N nutrition of red oak seedlings on forest and old-field soils*

FOREST SOIL

N level1/	Dry weight: Shoot	Root	Total	Shoot/root ratio	Foliar2/ nitrogen
Pounds per acre	Grams	Grams	Grams		Percent
0	5.2	6.9	12.2	0.76	1.95
30	5.5	7.0	12.5	.80	2.09
90	5.9	7.2	13.1	.82	2.38
180	6.2	6.9	13.1	.90	2.65
360	4.9	5.4	10.5	.95	2.71
OLD-FIELD SOIL					
0	3.7	5.8	9.5	0.65	1.56
30	4.3	6.1	10.4	.72	1.88
90	5.1	6.2	11.3	.84	2.24
180	5.4	5.7	11.1	.95	2.49
360	4.8	4.6	9.4	.97	2.47

1/ P and K were added at the rate of 80 pounds per acre to each pot.
2/ Average of duplicate analyses.

Even though the response to N was small, there was a positive relationship between growth and N content of the foliage in the basic fertilizer series (fig. 2), and up to the point where heavy N fertilization reduced growth in the nitrogen fertilizer series (table 3). The foliar N content associated with maximum growth ranged from 2.2 to 2.7 percent, and averaged about 2.5 percent on all soils. Mitchell and Chandler found that the N concentration in leaves of fast-growing 40-year-old red oak trees also may range between 2.46 and 2.57 percent. Apparently, different age trees contain about the same concentration of foliar N when growing satisfactorily.

Including K in the fertilizers had no significant effect on growth. Thus, K apparently was not deficient in these soils, which already contained 150 to 200 pounds of exchangeable K per acre. Over all treatments, there was a significant negative relationship between total dry weight and concentration of K in the foliage. The cause for this negative relationship is not completely clear, but may be the result of dilution effects. The levels of K observed (0.43 to 0.75 percent) were much lower than has been reported for this species by other researchers. Bard and Mitchell and Chandler, for example, reported K concentrations ranging from 1.79 to 2.21 percent in red oak leaves. Regardless of the cause for the low K concentration in the foliage of the seedlings in the present study, there was no evidence that K fertilization would benefit growth.

CONCLUSIONS

Any extensive planting of red oak on these soils obviously should take into account the observed differences in soil fertility and the possible need for fertilization. The forest soils were able to supply more N and P and produce better growth than the old-field soils. Nevertheless, the results indicate that all of the soils studied were too deficient in N and P to produce maximum growth of planted red oak seedlings. Higher rates of N and P fertilization would be needed on the old-field soils than on the forest soils to bring soil fertility up to more acceptable levels. Fertilization with K would probably not be beneficial on these soils.

While soil-pot tests have certain limitations, the results obtained probably more clearly express the potential need for fertilization on a given soil than do standard soil and foliage analyses. The reason is that there are few reliable guidelines to determine what soil and foliar nutrient levels are considered adequate, since most published guidelines are generally based on agricultural soil and crop standards. Foliage analyses may frequently be misleading, especially when using percent concentrations, because of dilution effects from dry matter accumulation. Also, many forest tree species have unique modes of nutrition, such as mycorrhizal fungi, which are especially important on soils as different as forest and old-field soils. As was seen in this study, neither the soil tests nor the foliage analyses completely and unequivocally explained the growth differences obtained on the forest and old-field soils. Thus, soil-pot tests appear to be most informative when all available information on growth response to fertilization, soil tests, and foliage analyses is examined simultaneously.

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