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Soil Phosphorus Level Adequate for Growth of Ocala Sand Pine Seedlings, A Greenhouse Evaluation[1]

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ABSTRACT

A greenhouse study was conducted to determine the level of soil P adequate for satisfactory growth of Ocala sand pine (*Pinus clausa* (Chapm.) Vasey) seedlings. Various quantities of Lakeland sand with low and high P contents were blended to provide soil mixtures with a range of available P. Ocala sand pine seedlings were grown in these mixtures for 10 months. On the basis of the seedlings' dry matter production, the level of soil P adequate for satisfactory growth of Ocala sand pine is in the neighborhood of 1 ppm available [NH_4OAc (pH 4.8)-extractable] P. Seedlings growing in soils containing < 1 ppm available P showed a marked reduction in dry weight. Tissue analyses indicate that concentrations of foliar P of < 0.15% may denote a deficiency of available soil P.

Additional Index Words: **optimum foliar P, P-deficient soils, soil P uptake, sandhills soil.**

THE OCALA RACE of sand pine (*Pinus clausa* (Chapm.) Vasey), although native only to peninsular Florida, has been planted on sandhill soils throughout the state. These soils are excessively-drained sands (frequently containing < 10% silt + clay) that are generally low in inherent fertility. However, the available phosphorus (P) content (ammonium acetate [pH 4.8] extractable) may vary from approximately 0.3 ppm in northwest Florida soils to approximately 4 ppm in soils of localized areas near outcrops of phosphate rock in central Florida. A typical representative of sandhill soils is the Lakeland series, a member of the siliceous, thermic family of Typic Quartzipsamments.

Sandhills soils in northwest Florida undoubtedly are deficient in available P for optimum growth of Ocala sand pine, whereas the sands in some areas of central Florida probably contain ample quantities of this nutrient for its growth. The available soil P required for optimum growth of these pines is not known but apparently falls between the range of 0.3 and 4 ppm. The purpose of this study was to determine, by pot culture techniques, the level at which available soil P becomes limiting for satisfactory growth of Ocala sand pine seedlings.

METHODS

Soil was collected from the 0- to 25-cm depth from typical sandhill sites in northwest and central Florida. The soil collected from both areas was similar in physical and chemical properties, except for available P (Table 1). The northwest Florida soil was low in NH_4OAc(pH 4.8)-extractable P (< 0.5 ppm), whereas the soil from central Florida contained a relatively high content of available P (ca. 4 ppm).

After both soils were air-dried and screened to remove large pieces of organic debris, various quantities of the soils with low and high P contents were blended to provide soil mixtures with the contents of available P listed in Table 2.

The appropriately blended soils were placed in 7.6-liter earthenware pots, and the soil moisture content was brought to field capacity with distilled water. Ten recently germinated Ocala sand pine seedlings were transplanted to each pot. The nine soil mixtures were arranged in a completely random design with three replications. One additional replication was included in which ammonium nitrate (at the rate of 56 kg N/ha) was applied shortly after seedling establishment. After 10 months' growth in a greenhouse, the seedlings were washed from the pots and separated into foliage, stems, and roots. Oven-dry weights and total P concentration of the seedling components were obtained.

RESULTS AND DISCUSSION

Seedling growth was significantly (0.05 level) affected by levels of available soil P. In general, best growth occurred when the soil contained ca. 1.0 to 1.5 ppm P (Fig. 1, line A). Seedlings grown at this level of soil P were

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Table 1—Physical and chemical properties of soils blended for soil mixtures

Soil source	Particle size distribution			Matter	Nutrient content			pH
	Sand	Silt	Clay		N	P	K	
	%				ppm			
Central Florida	94.5	0.8	4.7	1.37	0.026	4.25	13.17	5.1
Northwest Florida	93.9	1.0	5.1	1.36	0.025	0.30	13.17	5.1

Table 2—Content of available P in soil mixtures

Soil mixture	Quantity of low-P soil	Quantity of high-P soil	Available P* (Lab assay)
	kg†		ppm
1	11.8	0.0	0.3
2	10.4	1.4	0.5
3	8.9	2.9	1.1
4	7.4	4.4	1.6
5	5.9	5.9	2.1
6	4.4	7.4	2.6
7	2.9	8.9	3.2
8	1.4	10.4	3.7
9	0.0	11.8	4.2

* NH_4OAc (pH 4.8) extractable.
† Kilograms of soil in designated mixtures.

Table 3—Concentrations of foliar P needed for optimum growth of several conifers

Species	P concentration	References
Pinus taeda L.	0.14 to 0.16	Fowells and Krauss (1959)
P. echinata Mill.	0.14 to 0.16	Fowells and Krauss (1959)
P. sylvestris L.	0.15 to 0.4*	Ingestad (1962)
P. banksiana Lamb.	0.18 to 0.35	Swan (1970)
P. elliottii var. elliottii	0.09 to 0.10	Pritchett (1968)
Picea mariana Mill.	0.18 to 0.30	Swan (1970)

* Extrapolated value.

taller and had longer, more abundant needles than those seedlings grown at greater or lesser levels of P nutrition. Soil containing < 1 ppm P was apparently deficient in this nutrient, and seedling growth was retarded.

Available P at levels in excess of 1.5 ppm adversely affected seedling growth, perhaps because of a nutrient imbalance (an inadequate supply of nitrogen). The basis for this assumption is the growth response resulting from the addition of nitrogen at the rate of 56 kg/ha to an identical series of blended soils (Fig. 1, line B).

Tissue analysis showed that P uptake followed a pattern similar to the seedling growth responses (Fig. 2). The quantity of P contained in seedling needles increased rapidly from ca. 0.09 to 0.16% as available soil P increased from 0.3 to ca. 1 ppm, with only a slight increase occurring beyond this level. On the basis of these data on growth and foliar analyses, a foliar P concentration of 0.15 to 0.18% P is suggested as the optimum range for maximum growth of Ocala sand pine seedlings. These values tend to be in agreement with data reported elsewhere and summarized in Table 3.

Needle coloration of seedlings for all soil P mixtures was essentially the same (Munsell color value 7.5 GY 6/6). No deficiency symptoms within or among treatments were noted. It is conceivable then that the seedlings produced in the study reported here were growing under what Ingestad (1962, p. 80) termed "moderate deficiency" to "optimum nutrient status." Levels of available soil P, although quite low, were still too high to produce symptoms characteristic of "strong deficiency" in Ocala sand pine.

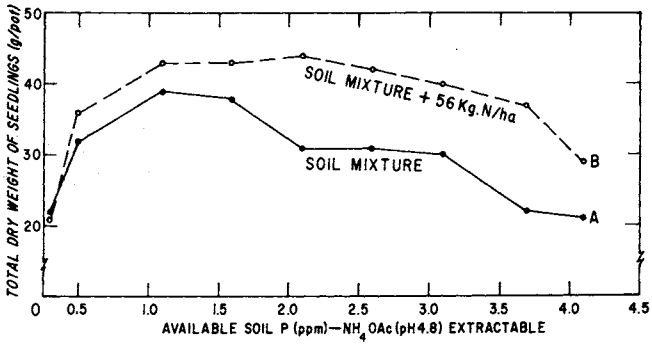

Fig. 1—Total dry weight of Ocala sand pine seedlings in relation to available P in the soil.

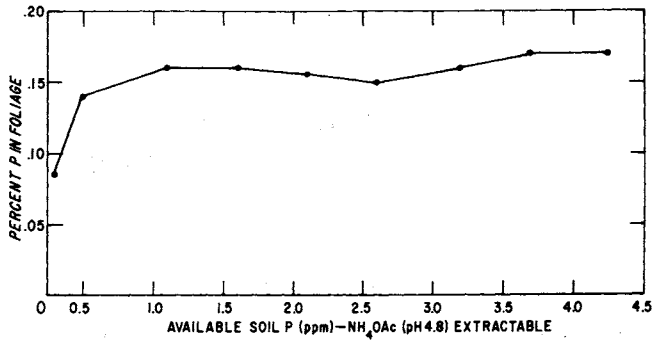

Fig. 2—Phosphorus status of Ocala sand pine seedlings in relation to available P in the soil.

CONCLUSIONS

Within the scope of this greenhouse study, the following conclusions may be drawn with regard to 1-year-old Ocala sand pine seedlings growing on Lakeland sand and similar soils:

1) The deficiency level of available soil P for seedling growth is in the neighborhood of 1 ppm NH_4OAc-(pH 4.8)-extractable P.
2) Concentrations of foliar P < 0.15% may indicate a deficiency in available soil P.
3) Seedlings growing on Florida's sandhills soils should respond favorably to P fertilization if the soil contains < 1 ppm available P. If the soil contains available P in excess of 1.5 ppm, additions of fertilizer P alone may result in a reduction in growth as a result of a nutrient imbalance.

LITERATURE CITED

1. Fowells, H. A., and R. W. Krauss. 1959. The inorganic nutrition of loblolly and Virginia pine with special reference to nitrogen and phosphorus. Forest Sci. 5:95–112.
2. Ingestad, Torsten. 1962. Macro element nutrition of pine, spruce, and birch seedlings in nutrient solutions. Medd. Statens Skogsforskningsinst. [Stockholm] 51 (7):1–150.
3. Pritchett, W. L. 1968. Progress in the development of techniques and standards for soil and foliar diagnosis of phosphorus deficiency in slash pine. p. 81–87. *In* Forest fertilization theory and practice. TVA, Muscle Shoals, Ala.
4. Swan, H. S. D. 1970. Relationships between nutrient supply, growth, and nutrient concentrations in the foliage of black spruce and jack pine. Pulp & Pap. Res. Inst. Can. Woodlands Pap. W. P. 19. 46 p.