

Pot Studies Indicate Need of Fertilization in Reforestation of Abandoned Cropland in Southern Indiana

PETER R. HANNAH, U. S. Department of Agriculture, Forest Service, Central States Forest Experiment Station, Bedford, Indiana and
HELMUT KOHNKE, Purdue University¹

Planted hardwoods generally survive and grow poorly on abandoned farmland in southern Indiana. To devise methods for successful reforestation on such sites it is necessary to understand the underlying causes of failure. Various reasons for poor results have been suggested. However, the relations of specific physical, chemical, and biotic soil factors to tree growth have not been completely explained.

Recent studies (1) show that tree seedlings grown in pots of undisturbed soil taken from under various plant cover types could be used as a bio-assay to demonstrate gross differences in site quality. In natural forest soil, 12-week-old yellow-poplar (*Liriodendron tulipifera* L.) seedlings averaged 9.7 grams (green weight), while in soil from an abandoned field in weeds and grass, seedlings averaged only 2.9 grams.

Since seedling growth differed sharply in soils from under the various cover types, the next step was to find out how the soils differed. Subsequent study shows good correlation of yellow-poplar seedling growth with pore volume, bulk density, and organic matter content of the soil for all covers studied except black locust (*Robinia pseudoacacia* L.). Despite the poor physical condition of the soil under the black locust plantation, yellow-poplar seedlings grew almost as fast as those on natural forest soil.

Nutrient analysis showed that available phosphorus was highest in the locust soil, but all soils rated very low. With this information it was decided to study the response of pot-grown seedlings to applications of nitrogen, phosphorus, and potassium in soil supporting four different cover types. Black locust and tomato were used as the study species.

Study Area and Methods

The soils studied came from the Paoli Experimental Forest, Orange County, Indiana. All sites are on a single, broad ridge, and all except the forest site are part of a single abandoned field. The field varies slightly in topography and degree of erosion; consequently, there are inherent differences in soil properties among the selected sites. Mechanical analysis of the A and B horizons using the Bouyoucos Hydrometer method showed slight to moderate differences in the amounts of sand, silt, and clay among the four sites.

The sites are on unglaciated sandstone-shale soils of the Zanesville and Tilsit series. These are residual soils overlain with wind-deposited material. Tilsit silt loam occurs on broad, flat, upland ridges and de-

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velops from loess deposits ranging from 40 to 60 inches thick. A fragipan begins at about 24 inches causing poor internal drainage. Zanesville silt loam is similar to Tilsit but the pan begins at about 32 inches and internal drainage is better. This soil type is found on ridges and hill-sides with slopes up to about 15 percent.

Site 1 supports a second-growth, mixed-hardwood forest on a Zanesville silt loam on a 10 percent slope. Internal and surface drainage conditions are good. The present stand has a basal area² of 143 square feet per acre.

Site 2 supports a 23-year-old shortleaf pine (*Pinus echinata* Mill.) plantation on Zanesville silt loam. This site is on a 4 percent slope and the fragipan begins at 33 inches. Internal and surface drainage are good. The stand basal area is 137 square feet per acre.

Site 3 supports a 23-year-old black locust plantation on an eroded portion of the field. The soil type is Zanesville silt loam on a 9 percent slope. The A horizon and part of the B horizon have been eroded and a firm fragipan begins at 22 inches. Under the present vegetation a new A horizon is beginning to develop. Basal area is 68 square feet per acre.

Site 4 is a part of the field presently supporting grasses and sedges. The soil is Tilsit silt loam on a 5 percent slope. A fragipan begins at 21 inches creating imperfect drainage.

Chemical tests for plant nutrient availability in the 0- to 3-inch and 3- to 6-inch zones of each site were made by the Purdue Soil Testing Laboratory. These tests showed that potassium ranged from "medium" to "very low," while phosphorus was "very low" in all cases (table 1), according to the scale used for agricultural crops.

TABLE 1. Phosphorus and potassium in 0- to 3-inch and 3- to 6-inch layers of soil

Plant cover	(In pounds per acre)			
	P ₂ O ₅		K ₂ O	
	Layer	(inches)	Layer	(inches)
	0-3	3-6	0-3	3-5
1. Mixed-hardwood forest	10	10	200	180
2. Pine plantation	10	10	160	90
3. Locust plantation	20	10	200	125
4. Abandoned field	10	10	110	70

Soil from the A and B horizons of the natural forest, pine plantation, and abandoned field was individually sampled, thoroughly mixed, and potted. In the locust plantation, samples were collected from the developing A horizon and from the B horizon. Tomato was planted in three replications on A- and B-horizon soil from all sites and black locust was planted in two replications on A-horizon soil from all sites. Nutrient

2. Basal area is the cross-sectional area of the tree stems at 4½ feet above ground in square feet per acre, and is used as a measure of stand density.

combinations of N-P-K, N-P, N-K, and P-K were compared with an unfertilized control. Application rates were 400 pounds of actual nitrogen, 200 pounds of actual phosphorus, and 200 pounds of actual potassium per acre. After 12 weeks' growth in a greenhouse the stems and leaves were oven-dried and weighed. Differences due to fertilizers and sites were compared by analysis of variance.

Results and Discussion

Both locust and tomato seedlings grew best when phosphorus was added to the soil in combination with nitrogen and potassium (Fig. 1a).

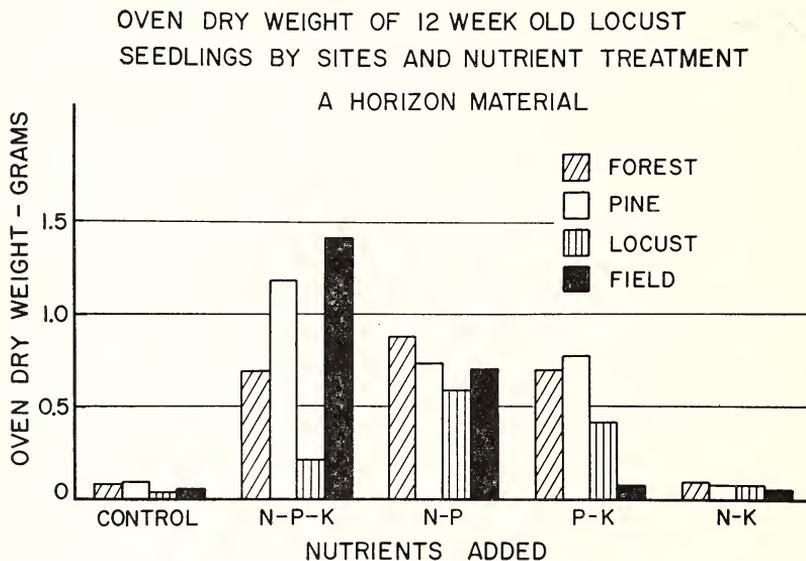


Figure 1a. Locust on A-horizon soil.

When phosphorus was omitted from the treatments there was no increase in growth over unfertilized plants. Generally, the addition of N-P-K yielded the best growth, followed by the N-P, P-K, and N-K treatments. Differences among fertilizer treatments were statistically significant at the 1 percent level. There was no consistent difference in growth due to site. The poor growth of the N-K treatment demonstrates that phosphorus is the main nutrient limiting growth of locust and tomato seedlings on the sites studied. Plants grew better with the N-P treatment than with the P-K treatment. This indicates that nitrogen may be slightly more important than potassium. Tomato plants proved to be a more sensitive indicator of phosphorus deficiencies than locust plants.

Fertilized tomato plants grew better on A-horizon soil than on B-horizon soil. This difference is likely due to higher original fertility and better physical conditions. Relative growth differences due to fertilizer treatments were greater on B-horizon soil than on A-horizon soil (Fig. 1b and 1c). This shows that nitrogen and potassium deficiencies are more critical in the B horizon than in the A horizon. On abandoned

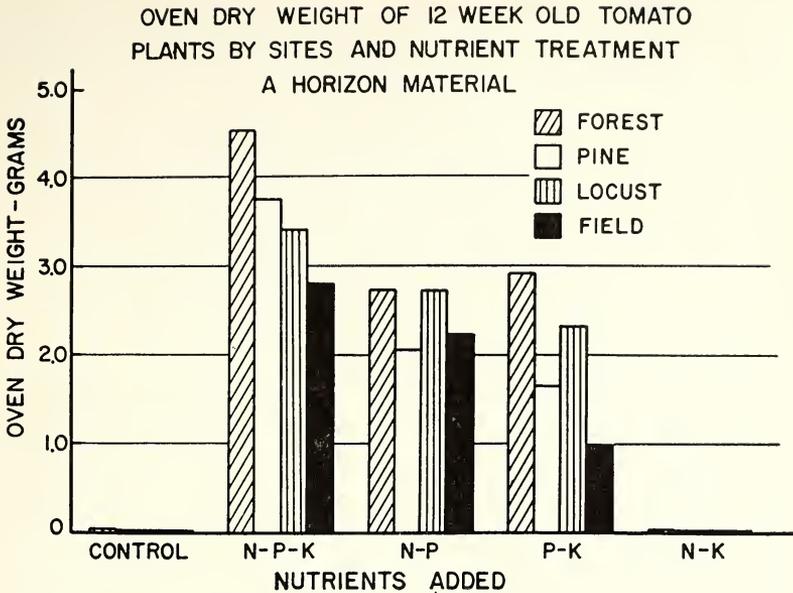


Figure 1b. Tomato on A-horizon soil.

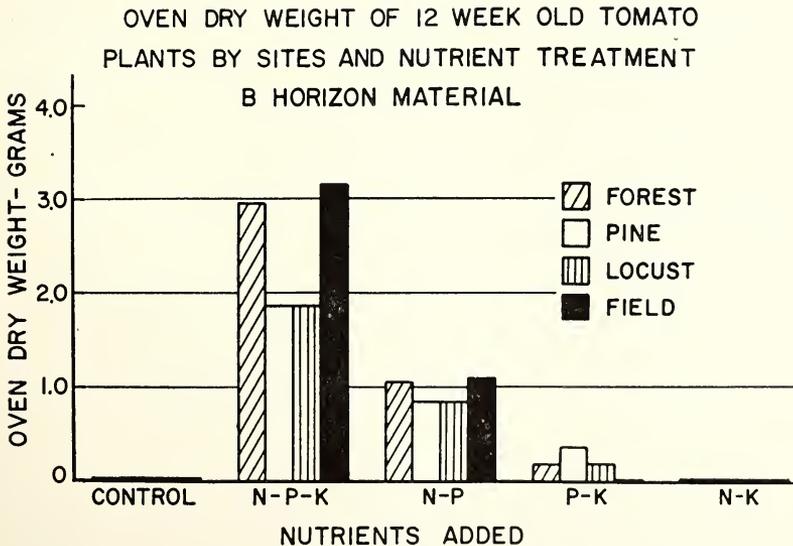


Figure 1c. Tomato on B-horizon soil.

fields where erosion has been severe and trees are planted directly on B-horizon soil, heavier applications of nitrogen and potassium may be necessary.

In an earlier study on the same sites, growth of yellow-poplar seedlings was correlated with pore volume, bulk density, and organic content of the soil for all except the locust site. The physical properties of soil from the locust site appeared unfavorable for seedling growth, and available phosphorus was only slightly higher than on the other sites. In spite of these conditions, yellow-poplar seedlings grew almost as much as on a natural forest soil. The present study shows that available phosphorus was lacking in all four soils investigated and does not explain the relatively good growth of yellow-poplar seedlings on the soil from the black locust site. It appears clear, however, that fertilization, especially with phosphorus, can be expected to benefit the establishment of hardwood stands on sites similar to the ones studied.

Conclusion

This study shows that available phosphorus may be one factor limiting the growth of planted hardwoods on abandoned old fields in southern Indiana. After phosphorus is applied, nitrogen then potassium appear to be limiting factors. Nitrogen and potassium deficiencies are more critical on B-horizon soil than on A-horizon soil. Chemical as well as physical soil factors must be considered in evaluating old field sites for survival and growth of hardwoods with high site requirements. In future tree planting research on old fields the application of fertilizer, especially phosphorus, should be evaluated.

Literature Cited

1. CLARK, F. B. 1960. Pot culture—an aid to site evaluation. *Ind. Acad. Sci. Proc.* **70**:234-237.