Reprinted from the *Soil Science Society of America Journal*
Volume 40, no. 4, July-August 1976
677 South Segoe Rd., Madison, WI 53711 USA

Response of Potted Slash Pine Seedlings on Imperfectly Drained Coastal Plain Soil to Additions of Zinc

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ABSTRACT

In a greenhouse study, seedling dry weights and uptake of Zn, K, Mg, and Ca were increased by applying 1 ppm of Zn to Caddo silt loam soil fertilized with 123 ppm of N, 0.31 meq of K/100 g, and varying amounts of P and lime. Zinc interacted with P and lime to alter N uptake. Zinc uptake rose with increasing amounts of Zn and available P in the soil at harvest, but declined with increasing levels of exchangeable Mg, K, and Ca.

Additional Index Words: ***Pinus elliottii*** **Engelm. var.** ***elliottii,*** **fertilization, nutrient uptake, Caddo silt loam soil.**

Moderate to heavy applications of N–P–K fertilizers have markedly increased volume growth of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) in recent studies on Coastal Plain soils in Louisiana and Mississippi (Shoulders, 1974; Schmidtling, 1973). Since Zn often improves rice yields in the same region (Sedberry et al., 1971), the present study was undertaken to learn if adding Zn might enhance pine response to other nutrients. Such responses have been reported for slash pine on some Florida Coastal Plain soils (Van Lear and Smith, 1972). The study was conducted with Caddo silt loam soil, an extensive pine forest soil of the West Gulf. Because high levels of lime and P sometimes restrict Zn uptake, treatments included both moderate and heavy applications of these amendments together with moderate applications of N and K.

MATERIALS AND METHODS

Two levels each of lime, P, and Zn were imposed in factorial combination on Caddo silt loam topsoil (Typic Glossaqualf, fine silty, siliceous, thermic) from three locations in central Louisiana. The 24 treatments were replicated three times in a randomized block design. Blocks were locations in the greenhouse.

At each soil location, the A1 horizon (3 to 10 cm depth) was sampled over an area about 10 m^2. Vegetation on the sites consisted of native grasses, post (*Quercus stellata* Wangenh.) and black jack (*Q. marilandica* Muenchh.) oaks, longleaf (*Pinus palustris* Mill.) and loblolly (*P. taeda* L.) pine saplings, and waxmyrtle (*Myrica cerifera* L.). The sites occupied a low topographic position, had imperfect drainage, and had never been cultivated.

The soils were typical of the Caddo series (USDA-SCS, 1966). They were acid and retained 21 to 23% moisture (based on dry weight) at one-third atm. Organic matter content ranged from 2.0 to 4.6%, clay content from 7 to 16%, and available P (modified Bray P2 extraction) from 2.0 to 7.3 ppm. Exchangeable Ca ranged from 0.70 to 1.90 meq, Mg from 0.38 to 0.80 meq, K from 0.05 to 0.07 meq, and total bases from 1.14 to 2.77 meq/100 g.

Soil samples from individual profiles were air dried, shredded to pass a 2.5-mm screen, and thoroughly mixed. Care was taken to avoid their contacting galvanized metal or other sources of Zn contamination. The equivalent of 6.81 kg of ovendry soil was placed in each of 72 plastic pots (25-cm diam) lined with polyethylene bags.

Phosphorus (NH_4H_2PO4) was added to each pot at rates of either 22 or 88 ppm of P. Pots receiving the moderate P treatments were given additional N as $(NH_4)_2\ SO_4$ so that all pots received a total of 39 ppm of N initially. Lime was applied as reagent grade $CaCO_3$, equal to 0.5 and 2.0 meq of Ca/100 g of soil. Potassium was applied to all pots as K_2SO_4 at 0.31 meq/100 g to insure that the response to the other nutrients was not masked by a K deficiency. The P, N, K, and lime treatments were mixed with the soil as a dry salt. Zinc sulfate was applied as an aqueous solution at 0 or 1 ppm of Zn. An additional 84 ppm of N was supplied by applying equal quantities of a solution containing NH_4NO_3 to the surface of each pot monthly for 6 months.

In early January 1971, wind-pollinated seeds previously collected from a single tree were germinated in acid-washed sand. One week after sowing, 10 seedlings were transplanted into each pot.

The pots were brought to 90% of field capacity with distilled-deionized water whenever the soil moisture content as determined by weight fell below 50% of field capacity. The greenhouse temperature was maintained above 16°C in winter and averaged < 36°C in summer. The pots were rotated within blocks to offset possible effects of their position in the greenhouse such as shading.

Immediately prior to harvesting in late November 1971, four 2.5 cm cores were taken from top to bottom of the soil mass in each pot. The roots in these cores comprised < 5% of the total root mass. The samples were dried, ground to pass a 2.5-mm screen, and thoroughly mixed.

Soil pH was measured with a glass electrode on a 1:2 soil/water mixture. Exchangeable bases were determined by atomic absorption on extracts made with 1*N* NH_4OAc (Jackson, 1958). Available P was determined by extracting 2.5 g of soil with 20 ml of Bray P2 solution (Bray and Kurtz, 1945). Available Zn was determined by extraction with 0.1*N* HCl (Viets and Boawn, 1965).

The plants were then removed from the pots, and the soil was washed from the roots. After drying at 70°C for 24 hours, the plant material was segmented into roots, stems, and needles; weighed; and ground to pass a 16 mesh/cm screen. One gram of plant material was then dry ashed at 450°C for 2 hours, and the ash was taken up in 0.3*N* HNO_3. Phosphorus was determined by the molybdovanadate procedure (Jackson, 1958), and Ca, Mg, and K by atomic absorption. Nitrogen content was determined by Kjeldahl analysis (Jackson, 1958).

Zinc content was determined as follows: one g of plant material was dry-ashed at 450°C for 2 hours, and the ash was taken up in 6*N* HCl; this procedure was followed by H_2O_2 oxidation of any remaining organic material in the ash, which was then evaporated to dryness. Next, the salt residue was dissolved in 0.1*N* HCl, and Zn content was determined by atomic absorption.

After total amounts of individual nutrients in roots, stems, and foliage were computed, values were summed to determine the total amount of nutrients that the plants had extracted from the soil. Differences in plant weight and total nutrient uptake due to treatment

Table 1—Influence of zinc fertilization on the dry weight of roots, stems, and foliage of 11-month-old slash pine.

Plant component	Zn treatment: None	Zn treatment: 1 ppm
	g/pot	
Foliage*	39.6	41.8
Stems*	10.3	11.0
Roots	18.4	20.6
Total*	68.3	73.4

* Significant response to Zn (0.05 level).

[1]Contribution from the Southern Forest Exp. Stn., Forest Service—USDA, New Orleans, Louisiana. Received 5 Jan. 1976. Approved 30 Mar. 1976.

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were tested by analysis of variance. Results significant at the 0.05 level are reported here.

RESULTS AND DISCUSSION

Since location had no significant effect on seedling response to Zn, results for the three locations were averaged. Zinc fertilization significantly increased total dry weight of seedlings by 8% and of needles and stems by 6 and 7% (Table 1). Roots of plants treated with Zn weighed 12% more than those of their untreated counterparts, but because of large variation in root weights among replicates, the difference was not significant.

The growth response to Zn was not significantly influenced by the amount of lime or P added to the soil. Moreover, there were no significant differences in total dry weight due to lime and P treatments, an indication that the moderate applications of these nutrients were sufficient to ensure rapid growth.

Total Zn uptake was increased significantly by adding 1 ppm of Zn (Table 2); the plants recovered about 11% of the added nutrient. Concentrations of Zn in roots, stems, and needles were increased 13 to 27% by fertilization. Thus, the plants apparently accumulated more Zn than was necessary for achieving the added growth. Foliage of plants fertilized with Zn contained an average of 52 ppm of Zn; unfertilized plants averaged 46 ppm. These concentrations are within the range considered normal for slash pine foliage (Stone, 1968).

The Zn treatment also significantly increased total uptake of K, Mg, and Ca. The increases were about proportional to the growth response to Zn and corresponded to extraction of an additional 2.39 kg of K, 0.60 kg of Mg, and 2.54 kg of Ca per ha from the soil. Adding Zn may have made these nutrients more available to the pines. At the end of the study, soils fertilized with Zn contained no less exchangeable K than unfertilized soils and contained significantly more exchangeable Mg and Ca, even though the plants had removed more of these nutrients from soils to which Zn was added. There was no evidence in the literature of a similar soil response to Zn fertilization.

Zinc also interacted with lime and P treatments to alter N uptake (Fig. 1); there was no immediate explanation for the interaction. Phosphorus had no significant effect on N uptake if Zn was added or if the lime application was heavy. However, significantly less N was absorbed by plants given heavy applications of P than by those given moderate applications, when Zn was not added and when the lime application was moderate (0.5 meq Ca/100 g soil). Uptake of P was not significantly affected by the Zn treatment.

Extractable Zn in the soil at the end of the study was positively correlated with plant uptake of N, K, Ca, Mg, and Zn

Table 2—Nutrient content of seedlings with and without added Zn.

Nutrient	Zn treatment None	Zn treatment 1 ppm
	mg/pot	
P	100	105
K*	371	387
Mg*	80	84
Ca*	225	242
Zn*	3.02	3.76

* Significant response to zinc (0.05 level).

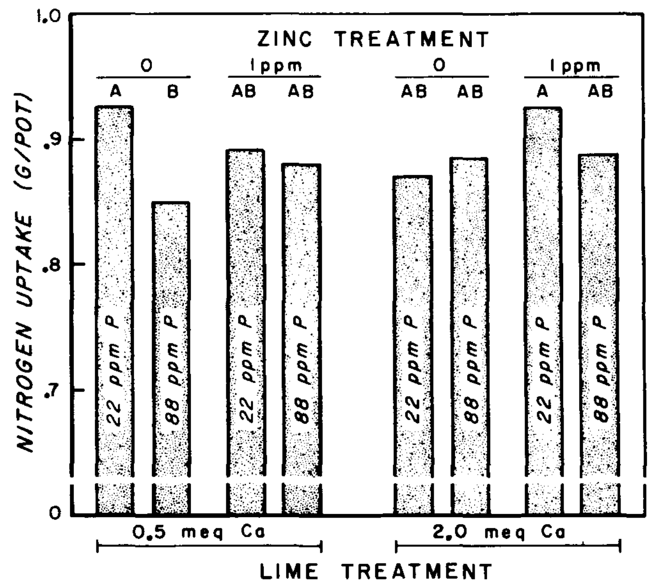

Fig. 1—Effect of Zn, P, and lime on N content of 11-month-old slash pine seedlings. Bars headed by the same letter are not significantly different at 0.05 level.

(Table 3). While these relationships were significant, none accounted for more than 30% of the variation in uptake of individual nutrients. The strongest relationship was between the level of Zn in the soil and that in the plants.

The analysis of variance showed that lime and P treatments had no significant effect on Zn uptake. Correlation analyses, however, indicated that available P in the soil at the end of the test was positively related to total Zn uptake ($r^2 = 0.32$). These results agree with Smilde's (1973) findings that P fertilizer enhanced total Zn uptake by Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings grown on acid soil. However, Lindsay (1972) and Melton et al. (1970) reported that heavy applications of P may depress Zn uptake. The threshold for this antagonism to develop with slash pine on Caddo soil may be above the 88 ppm of P supplied by the heavy application in this study.

Exchangeable Mg, Ca, and K were negatively correlated with Zn uptake and accounted for 40, 7, and 22%, respectively, of the variation in plant Zn content. All of these correlations were significant. These relationships generally support the findings of Chaudhry and Loneragen (1972). In a laboratory experiment with wheat, they observed that Mg was more antagonistic to Zn uptake than was Ca. They also found that K was antagonistic to Zn absorption, but less so than were the alkali earth cations. The relatively low negative correlation between Zn uptake and soil Ca in the current study may be partially due to the moderately acid soil reac-

Table 3—Relationships between available Zn in the soil at the termination of the study and uptake of nutrient by slash pine seedlings (n = 72).

Nutrient in plant	r value*
Zn	.55
N	.41
K	.41
Mg	.35
Ca	.24
P	.17

* Values above 0.23 are significant (0.05 level).

tion. Lindsay (1972), Melton et al. (1970), and Hossner and Blanchar (1969) observed that liming reduced Zn uptake if soil pH were raised above 6.5. In the present study, soil pH at the end of the test averaged 5.0 for the moderate and 5.3 for the heavy lime applications.

CONCLUSIONS

For Caddo silt loam soil, the results indicate that Zn was marginally limiting to slash pine growth when N, P, K, and Ca were supplied at optimum or superoptimum levels. Moreover, Zn deficiencies are increasingly likely to occur if levels of exchangeable bases—especially Mg—are unusually high. Varying the levels of lime and P did not alter the pines' response to Zn fertilization.

These results were obtained under near optimum soil moisture conditions, and it is not known if additional Zn would be necessary in the field, where Caddo soils are typically waterlogged in winter and dry in summer. Because Zn deficiencies tend to develop more frequently in greenhouse pot studies than under field conditions (Lindsay, 1972), Zn fertilization may be unnecessary for slash pines planted on Caddo soil in the field. Until more is known about field responses to Zn, however, an application of 1.0 kg/ha of Zn in conjunction with additions of macro-nutrients would prevent possible Zn deficiencies.

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