COPPER DEFICIENCY IN PINE PLANTATIONS IN THE GEORGIA COASTAL PLAIN

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Abstract—Copper deficiencies have been observed on several intensively managed pine plantations in the Georgia Coastal Plain. Loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* var. *elliottii* Engelm.) displayed plagiotropic growth within a year after planting on very acid, sandy soils. Typically, symptoms show up during the summer after transplanting. The needles on severely affected seedlings are thin and flaccid. After the roots reach greater depths, a branch or stem regains apical dominance, and the seedling usually recovers. Although many trees achieve a normal appearance, some stems remain twisted. Three tests were conducted in Pierce County, GA, to determine if the addition of copper (36 kg per ha of copper sulfate) or dolomitic lime (6.7 metric tons per ha) would ameliorate the problem on a Mascotte soil. The treatments were useful in maintaining the vigor of newly planted pine seedlings. Both the copper and lime treatments affected growth of the newly planted, as well as older, symptomatic seedlings. Both treatments were more efficacious when applied as a prophylactic treatment (before planting) than as a curative treatment (after symptoms develop). The lime treatment increased the population of herbaceous weeds.

INTRODUCTION

Copper is an essential element for normal growth of pines. Copper deficiencies have been reported on slash pine (*Pinus elliottii* var. *elliottii* Engelm.) in Australia (Simpson and Grant 1991), Monterey pine (*Pinus radiata* D. Don) in New Zealand (Hunter and others 1990), and maritime pine (*Pinus pinaster* Aits) in France (Saur 1994). In the Southern United States, many sites are not deficient in copper, and pines typically do not exhibit copper deficiency symptoms. Forest soils in the Lower Coastal Plain typically have from 0.3 to 1.4 ppm copper (NCSFNC 1992). However, most of the copper ions are bound to organic matter, so soil testing may provide a poor indication of levels available to the trees (Landis and Van Steenis 1999).

In the Southeastern United States, copper in pine needles has been correlated with soil acidity—the lower the soil pH, the lower the copper level in the foliage (NCSFNC 1992). Copper is easily desorbed when soil pH is low (McLaren and others 1990). Also, on some sites, soil cultivation could have a lasting effect on soil copper. For example, Schmidtling (1985) reported that plowing and disking effects could reduce soil copper levels to 1.1 ppm (vs. 1.6 ppm for controls). This difference was detected 24 years after the initial cultivations.

About 1990, a copper deficiency was noted on a Pamilco muck soil in Bladen County, NC (personal communication: Gregory Conner). The area had been treated with triple super phosphate prior to planting loblolly pine seedlings. No reports of copper deficiency of pines growing in the Southern United States are known prior to 1990. However, we have received reports of copper deficiencies of pines on intensively prepared Spodosols in Echols, Effingham, and Pierce Counties, GA. The soils are very acid (pH 3.5 to 4.3) and are represented by the Mascotte and Leon soil groups. These soils have a Bh horizon with many sand grains coated with organic matter. Pines have been planted on these soils for decades without obvious signs of copper deficiency.

Symptoms

A loss of the upright growing habit was observed at all three sites (fig. 1). On many seedlings there were twisted branches, and there was a “limpness” of needles. In some cases, needles were stunted (fasical dry weight reduced by 40 percent or more).

Intensive site preparation was conducted prior to the onset of plagiotropic growth. The Effingham County site was disk-harrowed, bedded, and planted with slash pine in November

Figure 1—Loblolly pine seedling showing symptoms of copper deficiency. (Photo taken by Scott Cameron in April 2001.)

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of 1998. Herbicides (atrazine and sulfometuron) were applied to control herbaceous weeds on part of the area, and there was no fertilization. Symptoms began to appear the following year on areas treated with herbicides and on areas where no herbicides were applied. The Pierce County site was disk-harrowed in April, bedded in June, and double-bedded in August 1997. The area was treated with triclopyr and imazapyr on November 25, 1997, and loblolly pine seedlings were machine planted on March 15, 1998. Herbaceous weeds were treated with hexazinone and sulfometuron in May 1998, and the area was fertilized with 140 kg per ha of diammonium phosphate on June 19, 1998. Symptoms were observed in the summer of 1998.

Foliar Analyses

Typically, copper levels in needles of healthy loblolly pine seedlings in nurseries range between 2 and 10 ppm (Boyer and South 1985). On sites in the Lower Coastal Plain, the mean for young pine stands may be 3 ppm with a range of 1 to 5 ppm (NCSFNC 1992). Analyses of foliage sampled in the fall at the Pierce County site indicated 0 ppm of copper for affected seedlings and 2.8 ppm for unaffected seedlings (Auburn University Soils Lab.). Analyses of older needles collected in the spring at the Effingham County site indicated affected seedlings had 1.3 to 1.9 ppm of copper. Affected needles collected from the Echols county site had 2 to 3 ppm of copper (analysis from a different laboratory). Some believe the timing of foliage sampling is important, and that xylem sap may be a better predictor of copper deficiency than foliar analysis (Saur and others 1995).

METHODS

Three experiments were installed on a Mascotte soil in Pierce County, GA. The studies tested the hypothesis that adding copper or lime does not ameliorate plagiotropic growth. Two preliminary studies (Tests 1 and 2) were installed in 1999 and an operational study (Test 3) was installed in 2000.

Tests 1 and 2: Treatments Applied Before And After Planting

For Test 1, each plot contained two rows of newly planted seedlings (planted on November 5, 1999), and treatments were replicated five times. In Test 2, plots contained one or two rows of seedlings that were planted on January 16, 1999, and were already showing symptoms of copper deficiency. Treatments included: a copper treatment of 36 kg per ha of copper sulfate, a dolomitic lime treatment of 6.7 metric tons per ha, a combination of copper and lime, and untreated controls. Treatments were applied by hand on October 1, 1999, and then the area was bedded. Treatments were replicated five times. Loblolly pine seedlings were planted on November 5, 1999, and herbicides (hexazinone and sulfometuron) were applied in early May. Seedling measurements were recorded on March 27, 2001.

Test 3: Operational Treatments Applied Before Planting

Treatments included: a copper treatment of 36 kg per ha of copper sulfate, a dolomitic lime treatment of 6.7 metric tons per ha, a combination of copper and lime, and untreated controls. Plots contained six rows of seedlings, and treatments were replicated four times in a randomized complete block design. The lime was applied with a skidder and pull wagon on November 16, 2000. The copper was applied to the beds by hand, and the area was bedded for the second time on November 17. The entire area was treated with triclopyr (3.36 kg a.i. per ha) and imazapyr (140 g a.e. per ha) on October 10. Loblolly pine seedlings were planted on December 15, at approximately 2,500 trees per ha. The herbicide sulfometuron (105 g a.i. per ha) was applied in bands on May 22, 2001. The entire area was fertilized with diammonium phosphate (280 kg per ha) on August 30, 2001. Seedling measurements (50 trees per plot) were recorded on December 13, 2002.

RESULTS AND DISCUSSION

Both the copper and the lime treatments affected growth of newly planted and symptomatic seedlings (table 1). Both treatments were more efficacious when applied as a prophylactic treatment (before planting in Tests 1 and 3) than as a curative treatment (Test 2). The lime treatment increased soil calcium, magnesium, phosphorus, and also increased the weed population and soil pH.

Test 1: Treatments Applied Before Planting

Both the copper treatment and the lime treatment increased seedling height and groundline diameter, and reduced plagiotropism. Untreated seedlings were about 67 cm tall

Table 1—Probability of a greater F-value of treatment effects on height, groundline diameter and deficiency symptoms of loblolly pine seedlings

		Test 1			Test 2			Test 3	
Source	df	Height	GLD	DS	Height	GLD	DS	Height	DS
		P > F value							
Block	3 – 4	0.214	0.552	0.078	0.001	0.001	0.001	0.062	0.357
Lime	1	0.001	0.083	0.001	0.740	0.568	0.537	0.013	0.001
Copper	1	0.003	0.056	0.003	0.011	0.059	0.009	0.016	0.002
L x C	1	0.253	0.334	0.001	0.953	0.400	0.920	0.989	0.001
Error	9 – 12								

GLD = groundline diameter; DS = deficiency symptoms; B = block; L = lime; C = copper.

compared with 88 cm tall for copper-treated seedlings. Seedlings treated with both copper and lime were 102 cm tall. The copper treatment increased ground-line diameter by 5 mm (table 2). Tree form was abnormal for 61 percent of the untreated seedlings whereas lime or copper seedlings were 9 to 18 percent abnormal (table 3). Needle symptoms were evident on 75 percent of the untreated seedlings but only 15 to 18 percent of the seedlings growing in copper- or lime-treated plots had needle symptoms.

Test 2: Treatments Applied After Symptoms Appear

Copper and lime were applied over-the-top of seedlings and there was no soil incorporation for this treatment. Therefore, the material remained on the soil surface until rain washed into the soil. In this case, only the copper treatment produced a statistically significant effect. Although not statistically different from the controls, the lime plus copper treatment was intermediate between the lime-only treatment and the copper-only treatment. The copper treatment increased seedling height by 36 cm and increased groundline diameter by 7 mm (table 2). Tree form was affected on 91 percent of the untreated seedlings whereas 68 percent of the seedlings treated with copper had poor form. Needle symptoms were evident on 86 percent of the untreated seedlings and on 63 percent of the copper-treated seedlings.

Test 3: Treatments Applied Before Planting

Results were similar for Test 1. Both the copper treatment and the lime treatment increased seedling height and reduced plagiotropism. Untreated seedlings were about 187 cm tall compared with 219 cm tall for copper-treated seedlings (table 2). Seedlings treated with both copper and lime were 252 cm tall. Soil analyses indicated unamended soil had a pH of 3.95 (table 4) whereas soil with lime averaged a pH of 4.8 ($P > F = 0.0469$). The lime treatment increased calcium and magnesium to 443 and 165 ppm, respectively ($P > F \leq 0.017$). Phosphorus availability increased slightly to 7.4 ppm ($P > F = 0.0378$) as did chromium (0.25 ppm; $P > F = 0.0182$). No other nutrients were increased with the lime treatment.

Table 2—The effect of lime and copper on height and groundline diameter of loblolly pine seedlings

Treatment	Test 1	Test 2	Test 3	Test 1	Test 2
	- - - - - *height* (*cm*) - - - - -			- - *GLD* (*cm*) - -	
Control	67	73	187	2.8	3.4
Copper	88	109	219	3.3	4.1
Lime	91	73	220	3.3	3.3
Lime + copper	102	102	252	3.5	3.9

GLD = groundline diameter.

Table 3—The effect of lime and copper on deficiency symptoms of loblolly pine seedlings

Treatment	Test 1	Test 2	Test 3
	- - - - -*percent*[a]- - - - -		
Control	61	91	41
Copper	18	68	2
Lime	9	89	1
Lime + copper	13	68	2

[a] Percent of seedlings with copper deficiency symptoms.

Table 4—Soil analysis of control plots in Trial 3

Soil factor	Mean	Low value	High value
pH	3.95	3.9	4.1
OM[a] (*percent*)	3.9	1.9	4.7
CEC (*meq per l*)	6.6	4.1	7.7
Pb	4.4	2.8	5.9
K	13.6	7.0	17.6
Mg	43.4	17.8	56.5
Ca	83.0	25.4	118.3
Cu	0.18	0.0	0.7
Fe	11.3	5.8	13.9
Mn	2.3	1.1	3.3
Zn	0.5	0.1	0.8
B	0	0	0
Al	77.6	41.3	115.3
Ba	0.77	0.4	1.0
Co	0	0	0
Cr	0.025	0	0.1
Pb	0.35	0.3	0.4
Na	11.8	10.2	15.6

All elements are in ppm.
[a] OM = organic matter.

Future Research

Several factors likely contribute to the development of copper deficiency of pines on acid, sandy Coastal Plain soils. Fertilization with nitrogen or phosphorous can induce copper deficiency in some pines (Saur 1993, 1994; Turvey and Grant 1990). It seems quite likely that an application of diammonium phosphate prior to planting could induce copper deficiency on some acid podzoils (Saur 1990). Studies in Australia suggest nitrogen could be omitted at time of planting, and this may reduce copper deficiencies (Boomsma and others 1997). Studies should be conducted to determine if delaying fertilizer applications until the third year after planting could reduce the onset of symptoms. Although symptoms occurred without fertilization in Effingham County, the addition of nitrogen and phosphorous at planting likely increases the probability of copper deficiency occurring during the first year after planting.

CONCLUSIONS

After intensive site preparation, copper deficiencies can occur in loblolly pine and slash pine plantations on Leon and Mascotte soil groups in Georgia. Symptoms can be reduced by either applying copper sulfate at 36 kg per ha or by raising the soil pH with 6.7 metric tons of dolomite limestone. These treatments are more effective when incorporated into the soil prior to planting seedlings.

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