Micronutrient Limitations and Fertilizer Interactions in Juvenile Southern Pine Stands Growing on Florida Spodosols

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Introduction

1) Visual symptoms from previously established research plots that were heavily fertilized with N suggest induced micronutrient deficiency in slash and loblolly pine (Fig. 1, 2).
2) Application of micronutrient mixes could also result in negative interactions between elements.
3) Interaction of visual symptoms with drainage and mortality suggests Cu deficiency can be accentuated by soil moisture status on Spodosols (Fig. 2).

Research Questions

1) Are micronutrient limitations and negative fertilizer interactions responsible for poor growth of intensively managed southern pines?
2) Does N fertilization exacerbate micronutrient deficiency?

Approach

1) Two experiments with a common design were installed in north central Florida (est. 2003; Fig. 3, Fig. 4)
2) Spodosols (Ultic alaquods): Poorly drained (Slash) and very poorly drained (Loblolly)
3) Split plot design using 4 blocks per location (Fig. 4):

Whole plots of 4 nitrogen treatment (0,110,220,330 kg ha^{-1})

Split plots -- 6 minus element treatments (-B, -Cu, -Fe, -Mn, -Mo, -Zn) and an "All" and "Nil" micronutrient treatment (Table 1.)

Measurements

1) Foliage nutrient concentrations in year 1, 3, and 5.
2) Tree heights at age 1-3, and 5
3) Tree diameters at age 5; volume derived from height and diameter at age 5.
4) Soil profile nutrient concentrations in control or 'Nil' plots (Mehlich III extraction).

Regional examples of micronutrient deficiencies on poorly-drained Spodosols

Fig 1. Spindly from and poor apical dominance for slash pine trees exhibiting putative Cu deficiency symptoms.

Fig 2. Stem deformation and tree mortality patterns accentuated by poor soil drainage and putative Cu deficiency in loblolly pine.

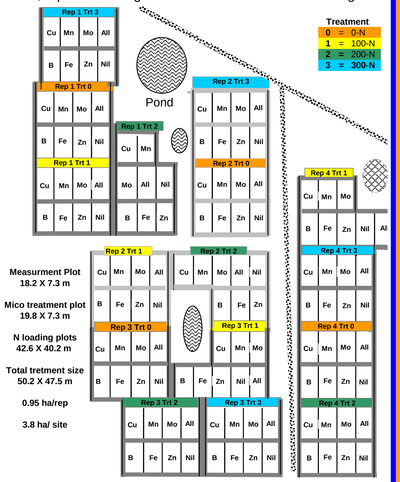
Overview of Study Layout

Fig 3. Study locations in north central Florida

Table 1. Micronutrient application rates and fertilizer sources for the minus-element micronutrient plots.

Nutrient	Rate	Source
B	1.1 kg/ha	Borax
Cu	4.4 kg/ha	$CuSO_4$
Mn	6.6 kg/ha	$MnSO_4$
Zn	3.3 kg/ha	$ZnSO_4$
Fe	16.5 kg/ha	$FeSO_4$
Mo	0.6 kg/ha	Na_2MoO_4

Fig 4. Example of experimental layout from the loblolly pine site, reps or blocking were located based on soil drainage



Statistical Model and Approach

For the split-plot model, the micronutrient treatments were nested within the nitrogen treatments. The model equation was:

$$Y_{ijk} = \mu + \alpha_i + w_{ik} + \beta_j + \gamma_k + (\alpha\beta)_{ij} + v_{jk} + e_{ijk}$$

Where Yijk denoted tree height, foliar nutrients, or volume on the k^{th} block assigned to the ijth ($\alpha_i \times \beta_j$) treatment combination and

μ was the overall mean,

α_i was the main effect of nitrogen treatment and w_{ik} was the associated random error

β_j was the main effect of the micronutrient treatment

γ_k was the main effect of the year of measurement (loblolly height only, Slash pine year 5 only)

$\alpha\beta_{ij}$ was the interaction of nitrogen and micronutrient treatments and v_{ik} was the associated random error

e_{ijk} was random experimental error

Analyses were conducted using the mixed model application in SAS 9.1.3.

Foliar Nutrients

Significantly lower foliar concentrations (ppm) for 'Nil' vs. micronutrient fertilized plots.

Loblolly

Element	Critical Level	No Fertilizer	Fertilized	P-value
B	4 - 8	9 – 15*	12 - 20	p<0.001
Cu	1.5 - 3.0	1.8 - 2.4	1.9 - 2.7	p=0.02
Mn	20 - 40	80 - 150	170 - 266	p<0.001
Zn	10 - 20	24 - 38	36 - 44	p=0.001

Slash

Element	Critical Level	No Fertilizer	Fertilized	P-value
B	4 – 8	10 - 13	13 - 15	p<0.001
Mn	20 - 40	50 - 260	72 - 304	p<0.001

*range represents yearly average across 3 years of measurement

Nitrogen treatments did not significantly dilute the concentrations of any micronutrient

Acknowledgements

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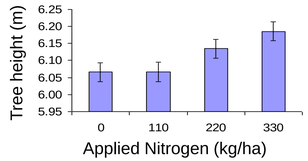
Height Growth and Total Volume

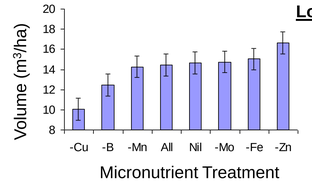
Slash



Main effects (height)	DF	P-value
Nitrogen (ntrt)	3	0.012
Micronutrient (mtrt)	7	0.67
Ntrt*Mtrt	21	0.59

Volume not significantly affected by nitrogen (not shown); neither volume nor tree height affected by micronutrient treatments.

Loblolly



Main effects (Volume)	DF	P-value
Nitrogen (ntrt)	3	0.40
Micronutrient (mtrt)	7	<0.001
Ntrt*Mtrt	21	0.75

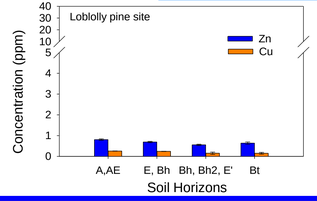
-Cu< -Mn, All, Nil, -Mo, -Fe and –Zn (Tukey's adjusted pairwise comparison)

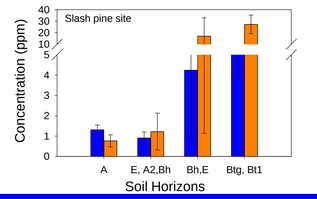
Cu limitation was likely accentuated by addition of Zn fertilizer

Tree height follows trends in volume

Soil Analyses

Taxonomically similar Spodosols varied in extractable micronutrients, which could explain the differential response of the two sites.





Conclusions

Cu limitation, accentuated by the addition of Zn, significantly reduced loblolly pine growth on a Florida Spodosol. Nitrogen fertilization did not exacerbate micronutrient limitations.

- Soil micronutrient availability differed greatly between two taxonomically similar Spodosols.
- Micronutrient deficiencies will become more likely on poorly drained Spodosols with multiple rotations. As a result, detailed information on fertilization interactions will be required.