Nutrition challenges of longleaf pine in the Southeast

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INTRODUCTION

Signs of poor vigor have been reported in isolated stands of longleaf pine (*Pinus palustris* Mill.) at Fort Benning in Georgia, and at Eglin Air Force Base in Florida. At Fort Benning, poor vigor was observed as chlorotic foliage with brown or yellow discoloration. At Eglin Air Force Base, poor vigor was seen as stunted annual height growth. Poor vigor coincided with low soil fertility, sandy soil textures that limit soil water holding capacity, and severe drought.

Longleaf pine responds to water and nutrient limitations by natural mechanisms that allow trees to avoid resource stress. In response to water deficit, for example, downward leaf area adjustment conserves water to maintain physiological processes at the whole-crown level (10, 13). At the same time, the supply of water and nutrients for aboveground processes is maintained by a shift in carbon allocation that increases the vertical growth of deep roots and expands root system surface absorbing area (1, 4, 14). Furthermore, when cellular physiology is limited by the availability of mobile nutrients such as potassium and nitrogen, these elements are translocated from one plant component to another (2, 5, 8, 9). Across Fort Benning and Eglin Air Force Base, the vigor of longleaf pine is sustained by these physiological processes. Isolated observation of poor longleaf pine vigor, however, suggests that mechanisms of resource stress avoidance may be challenged in some situations.

OBJECTIVES

- **Evaluate the basic foliar nutrition of longleaf pine at Fort Benning and Eglin Air Force Base.**
- **Hypothesize the cause of poor vigor using nutrition as a diagnostic tool.**

METHODS AT FORT BENNING

- 16 stands of longleaf pine across Fort Benning were identified.
- Within each stand, permanent plots were established using USFS Forest Health Protection protocols.
- Stand ages were < 10 years, 10 to 40 years, and > 40 years.
- Soils were sandy with low water-holding and cation exchange capacities (Cowarts fine sandy loam, Ailey loamy sand, Troup fine sand).
- 3 dominant and healthy-appearing trees were identified per plot (i.e., 48 trees).
- In July 2007, one upper-crown branch was sampled per tree.
- Fascicles were separated by cohort, dried, ground, and analyzed for N, P, K, Mg, Ca, Na, B, Cu, Fe, Zn, Mn, and Al by A&L Agricultural Laboratories, Inc. (Lubbock, TX).
- Visual observations of fascicles were recorded.
- Trees were labeled as "Unhealthy" if fascicles from the last flush of 2006 (i.e. previous year foliage) were abnormal in appearance. Trees were labeled as "Healthy" if this cohort of foliage appeared normal.

In July 2007 at Fort Benning, one upper-crown branch was shot from each tree and foliage was separated by cohort.

METHODS AT EGLIN AIR FORCE BASE

- 19 stands of longleaf pine and 5 stands of slash pine were identified.
- Stand age ranged between 12 and 51 years.
- Soils were sandy with low water-holding and cation exchange capacities (Lakeland fine sand, Troup fine sand).
- In February 2006, foliage from the most recent mature flush produced in 2005 was sampled in each stand.
- Foliage was dried, ground, and analyzed for N, P, K, Mg, Ca, B, Cu, Fe, Zn, and Mn by Waters Agricultural Laboratories, Inc. (Camila, GA).
- Annual height growth was calculated.
- Based on annual height growth, seven stands were labeled as "Unhealthy" because their height growth was stunted. The remaining 17 stands were labeled as "Healthy" because their height growth was normal.

BASIC NUTRITION RESULTS

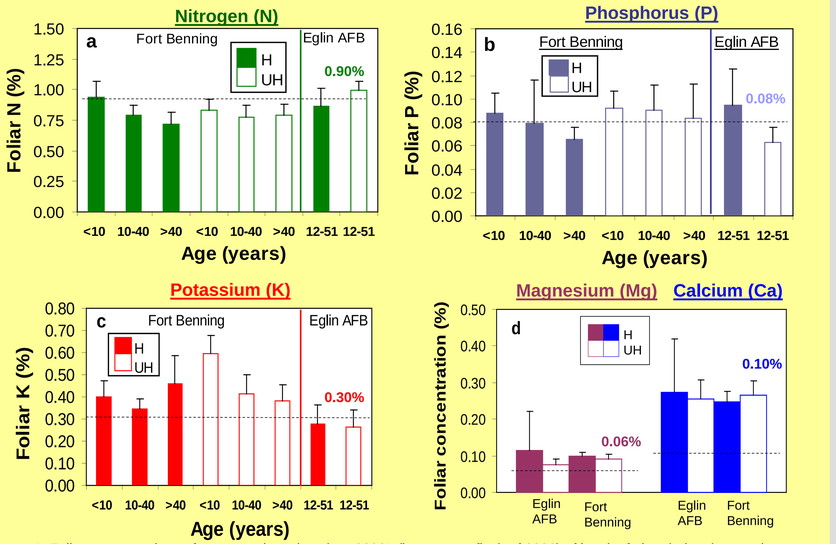

Figure 1. Foliar concentrations of macronutrients in cohort 2006L (last mature flush of 2006) of longleaf pine during the growing season (July 2007) at Fort Benning, and in cohort 2005L (last mature flush of 2005) of longleaf and slash pine during the dormant season (February 2006) at Eglin Air Force Base. Poor vigor is shown by "UH" and unfilled bars, and normal vigor is shown by "H" and filled bars. Dashed lines represent longleaf pine sufficiency (3, 7). Error bars are one standard deviation of the mean.

- Foliar nutrition did not differ between healthy (H) and unhealthy (UH) trees at either location.
- Foliar N, P, K, and Mg at both locations were sufficient or nearly sufficient (3, 7) (Figure 1a-d).
- Foliar Ca at both locations was elevated (Figure 1d).
- Foliar B, Zn, Fe, and Cu at both locations were sufficient (Figure 2a).
- Foliar B was 5.3 times greater at Fort Benning compared to Eglin Air Force Base (Figure 2a).
- Foliar Mn was sufficient (Figure 2b) and averaged greater than 300 ppm which has been reported to be toxic to slash pine seedlings (12).
- For UH trees, foliar Mn was 69% less at Fort Benning than at Eglin Air Force Base (Figure 2b).

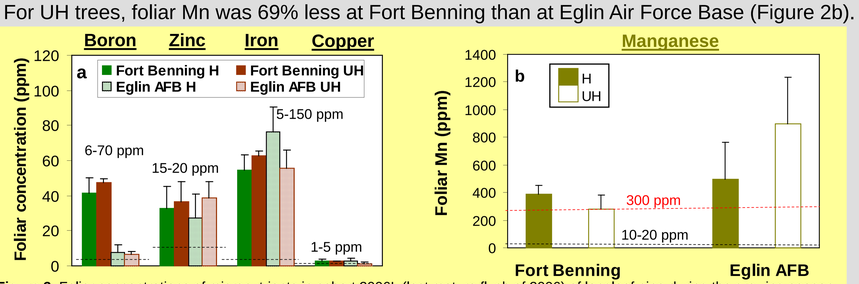

Figure 2. Foliar concentrations of micronutrients in cohort 2006L (last mature flush of 2006) of longleaf pine during the growing season (July 2007) at Fort Benning, and in cohort 2005L (last mature flush of 2005) of longleaf and slash pine during the dormant season (February 2006) at Eglin Air Force Base. Poor vigor is shown by "UH" and normal vigor is shown by "H". Black dashed lines represent plant sufficiency (5, 11). The red dashed line represents Mn toxicity (12). Error bars are one standard deviation of the mean. At Fort Benning, foliar Al was tolerable (2006L: 342±87 ppm; 2007-1: 236±66 ppm) (6). Foliar Al was not assessed at Eglin Air Force Base.

ACKNOWLEDGEMENTS

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DIAGNOSTIC NUTRITION RESULTS

- At Eglin Air Force Base, foliar P, K, Mg, and Ca were sufficient, but soil P, K, Mg, and Ca were deficient (Figure 3a-b).
- Annual height growth was positively correlated with foliar P and Mg concentrations (Figure 4a-b).
- Annual height growth was negatively correlated with foliar Mn concentration (Figure 5a).

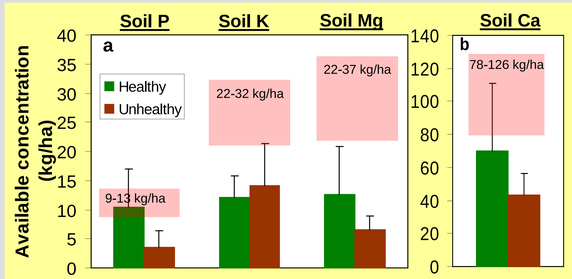

Figure 3. Soil nutrient availability associated with poor (Unhealthy) and normal (Healthy) longleaf and slash pine vigor at Eglin Air Force Base (a, b). Pink bars represent a recommended range of soil nutrition for slash pine (3, 7). For longleaf pine, a recommended range of available soil phosphorus is 11 kg/ha (3, 7).

Tree vigor depends on foliar P and Mg sufficiency. When soil P and Mg are low, inherent mechanisms of soil resource stress avoidance insure their supply.

Elevated soil Mn interferes with root uptake of Mg. Once translocated to the foliage, elevated Mn interferes with the function of Mg. This has the potential to reduce C-fixation and carbohydrate transport to roots and ectomycorrhizae.

Inadequate carbohydrate supply to the root system reduces P absorption.

Low soil fertility but sufficient foliar nutrition suggests that natural mechanisms of resource stress avoidance are functioning at both locations.

These include the downward adjustment of leaf area to maintain cellular nutrient sufficiency, a shift in C allocation in favor of root system expansion, and mobilization and re-translocation of mineral nutrients.

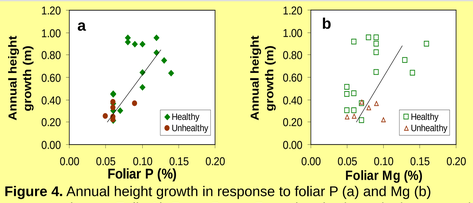

Figure 4. Annual height growth in response to foliar P (a) and Mg (b) concentrations at Eglin Air Force Base. Poor vigor is shown by brown symbols (Unhealthy), and normal vigor is shown by green symbols (Healthy).

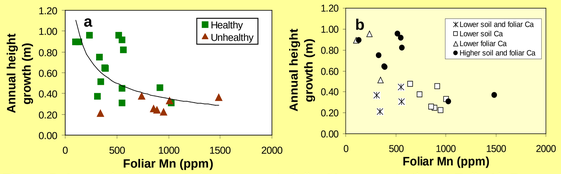

Figure 5. Annual height growth in response to foliar Mn concentration at Eglin Air Force Base. Poor vigor is shown by brown symbols (Unhealthy), and normal vigor is shown by green symbols (Healthy) (a). Greater annual height growth was seen where soil and foliar Ca levels were higher (b).

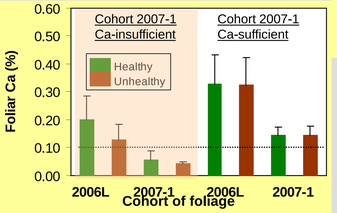

Figure 6. Measurement trees at Fort Benning were separated into 2 groups based on the Ca concentration of the 2007-1 cohort (first flush of 2007). Trees with values < 0.10% were considered Ca-deficient, and trees with values ≥ 0.10% were considered Ca-sufficient. Poor vigor is shown by brown bars (Unhealthy), and normal vigor is shown by green bars (Healthy).

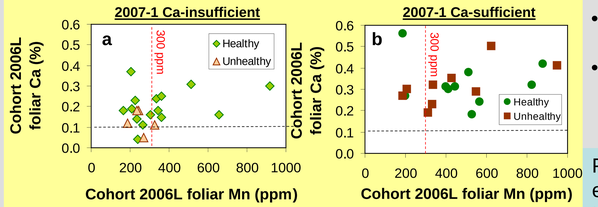

Figure 7. Relationship between foliar Ca and Mn concentrations at Fort Benning for measurement trees that were considered Ca-insufficient (a) and Ca-sufficient (b). Poor vigor is shown by tan and brown symbols (Unhealthy) and normal vigor is shown by light and dark green symbols (Healthy). Black dashed lines represent Ca sufficiency for longleaf pine (3, 7). The red dashed line represents Mn toxicity to slash pine seedlings (12).

- For trees with insufficient Ca at Fort Benning (Figure 6), the range of foliar Mn was greater for the H trees compared to the UH trees (Figure 7a).
- For trees with sufficient Ca at Fort Benning (Figure 6), the relationship between foliar Mn and Ca was similar for H and UH trees (Figure 7b).
- The Ca-Mn ratio of foliage was lower for trees considered Ca-insufficient compared to those considered Ca-sufficient.
- At Eglin Air Force Base, annual height growth was greater across a wider range of foliar Mn concentrations when soil Ca was > 40 kg/ha and foliar Ca was > 20% (Figure 5b).

Plants tolerate excess Mn in the foliage in two ways. First, extracellular callose is exuded which deters Mn from entering the cell. Second, if excess Mn enters the cell, it is compartmentalized in the vacuole (5).

Both of these processes depend on Ca (5).

DEVELOPING HYPOTHESIS

Signs of poor vigor at Fort Benning and Eglin Air Force Base are initiated, in part, by disfunctional Mn tolerance mechanisms. This may be caused by several factors: (1) High soil Mn concentrations that overwhelm Mn tolerance mechanisms, (2) Poor function of Mn tolerance mechanisms due to inadequate Ca uptake, (3) Downward leaf area adjustments (in response to drought or the demand for cellular Ca) that inadvertently lower carbohydrate support of the root system. The problem is worsened by naturally low soil P and Mg. An indirect consequence of failed Mn tolerance is P deficiency caused by carbohydrate limitations to root system expansion and as a result, less root and ectomycorrhizal interception of available P in the soil.

Signs of poor longleaf pine vigor at Fort Benning and Eglin Air Force Base may be remedied by management choices that support the production and maintenance of leaf area and conserve the water-holding capacity of the soil, and by careful amendment with Ca, Mg, and P where their availability is low or where soil Mn availability is high.

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