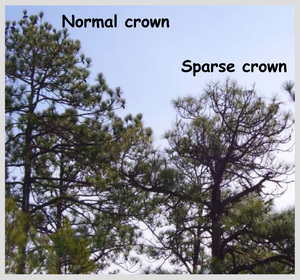
Longleaf pine nutrition and decline symptoms- their application in responding to pine decline at Fort Benning Military Reserve

Mary Anne Sword Sayer[1], Lori G. Eckhardt[2], and Emily A. Carter[1]

[1]USDA Forest Service, Southern Research Station, [2]School of Forestry and Wildlife Sciences, Auburn University

INTRODUCTION

Pine decline threatens the sustainability of southern pines on localized sites across the Southeast. It appears as: (1) sparse, chlorotic crowns, (2) low annual growth, and (3) root deterioration and disease, and is stress-driven by interaction among resource availability, climate, insects, pathogens, anthropogenic disturbances, and forest management. At Fort Benning, the decline of mid-rotation pine threatens the age-class distribution needed to train military troops and sustain the red-cockaded woodpecker.



A risk map that predicts the likelihood of loblolly pine decline in central AL was developed (2). Using this tool, 32 of Fort Benning's longleaf pine stands were identified as either likely (PD+) or unlikely (PD-) to suffer from pine decline. The symptomology, annual growth, and root disease of these stands is being evaluated to test the effectiveness of this tool in longleaf pine settings. **Our present objective is evaluation relationships between PD+ and PD- status, upper crown fascicle appearance, and growing season mineral nutrition. With this information, a model of the physiological condition of pine decline at Fort Benning is being developed.**

METHODS

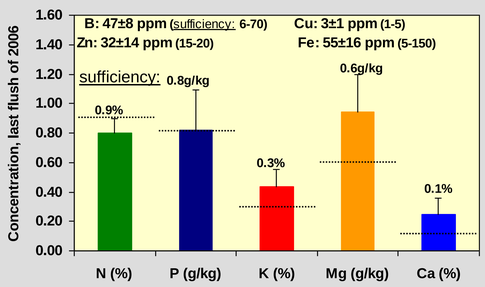
- 32 Fort Benning longleaf pine stands, all characterized by low water-holding and cation exchange capacities, were assigned PD- or PD+ status using the Loblolly Pine Decline Risk Map (2).
- One permanent plot per stand was established using USFS Forest Health Protection protocols.
- 16 of these plots were sampled in July 2007; seven were PD+ and nine were PD-.
- 3 healthy, dominant or co-dominant longleaf pine were sampled per plot (i.e., 48 trees).
- 4 30 cm soil cores/tree were pooled and wet-sieved; roots were dried to determine root biomass.
- 1 upper-crown branch was sampled per tree and visual observations were recorded; fascicles were separated by cohort, dried, ground, and analyzed for N, P, K, Mg, Ca, Na, B, Cu, Fe, Zn, Mn, and Al.

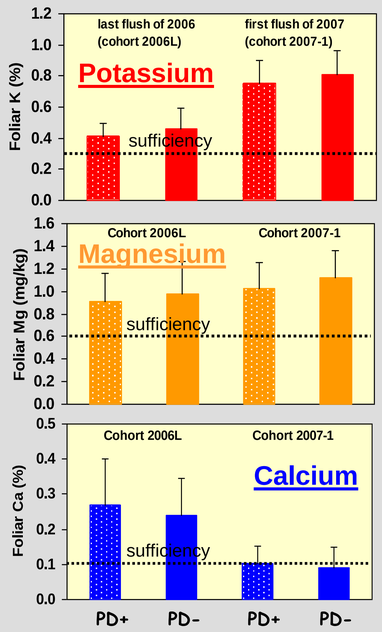
GENERAL RESULTS

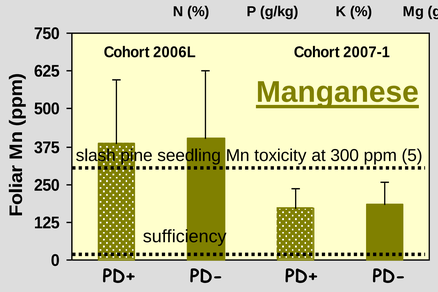
Regardless of PD+ or PD- status:
(1) fine root biomass was low and lacked vigor, (2) fascicles and internodes were stunted, (3) fascicles were often abnormal in color, and (4) nutrition was sufficient or nearly sufficient (1, 3).

This suggests that across all PD+ and PD- plots, soil resource limitations in the form of water and/or nutrients reduced fine root and branch growth and led to abnormal fascicle color. Furthermore, **normal foliar nutrition reflects stress avoidance by a downward adjustment of leaf area.**

Foliar mineral nutrient concentrations







Further analysis of foliar nutrition yielded three key results.
(1) Not only were foliar K, Mg, and Ca sufficient they were high considering the soil's ability to supply cations.
(2) K was being mobilized from older to younger foliage.
(3) Mn in older foliage was high while foliar Al was tolerable (2006L: 342±87 ppm; 2007-1: 236±66 ppm) (4).

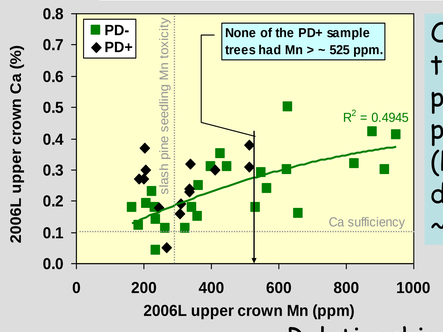
This suggests that across all PD+ and PD- plots, **forest sustainability depends on high foliar Mg and Ca, mobilization of foliar K, and tolerance of high foliar Mn.**

DIAGNOSTIC RESULTS

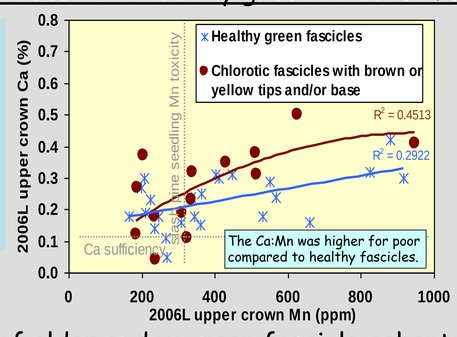
Background

- Mn toxicity induces deficiencies of Mg, Ca, and Fe.
- Mn tolerance in plants is achieved by vacuolar complex formation with oxalate and isolation by the exocytosis of callose.
- Ca is necessary for these mechanisms of Mn tolerance.

Foliar Mn x Ca on PD- or PD+ plots, and for trees with healthy green or abnormally colored foliage

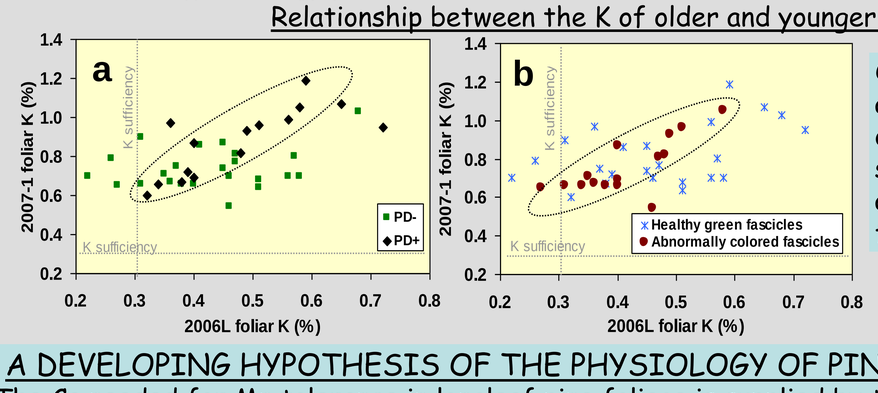


On plots mapped to have a higher probability of pine decline (PD+), foliar Mn did not exceed ~525 ppm.



Compared to trees with healthy green fascicles, those with abnormally colored fascicles had more foliar Ca per unit of foliar Mn when foliar Mn was > 300 ppm.

Relationship between the K of older and younger fascicle cohorts



On the PD+ plots (a) and for trees with abnormally colored fascicles (b), the K of older and younger foliage was more strongly correlated than on PD- plots and for trees with healthy green fascicles.

A DEVELOPING HYPOTHESIS OF THE PHYSIOLOGY OF PINE DECLINE AT FORT BENNING

- The Ca needed for Mn tolerance in longleaf pine foliage is supplied by transpiration.
- During drought, desiccation is avoided by stomatal regulation and osmotic adjustment to maintain turgor.
- K is essential to these processes, and its mobilization from older to younger foliage is one way K is supplied when soil K is low.
- Thus, the Ca needed for Mn tolerance during drought is dependent on the supply and mobilization of K.
- Correlation between the K of older and younger foliage reflects efficient mobilization of K, and/or low soil K available on the PD+ plots (a) and for trees with abnormally colored fascicles (b).
- When the demand for K cannot be met, stomatal regulation and turgor maintenance decrease which not only disrupts C fixation and allocation, but also reduces the supply of Ca for Mn tolerance.
- Failure to meet the foliar demand for K and Ca appears to play a role in pine decline at Fort Benning.

APPLICATION TO FOREST MANAGEMENT AND RESTORATION AT FORT BENNING

Our general results substantiate two mechanisms of resource stress avoidance at Fort Benning: the downward adjustment of leaf area and nutrient mobilization. These mechanisms facilitate adequate supplies of water, nutrition, and energy at the cellular level, while maintaining a positive whole-tree C balance. At this point, diagnostic results indicate that K and Ca nutrition in excess of foliar sufficiency, may be needed to confront drought and high Mn at Fort Benning.

Root uptake of water and nutrients, especially Ca and K, is critical to the health of Fort Benning's longleaf pine. If downward leaf area adjustment has led to a neutral or only slightly positive whole-tree C balance, belowground C allocation may limit the growth of deep roots, fine absorbing roots, and ectomycorrhizae. Management and restoration activities that encourage the **maintenance of leaf areas large enough to support root system growth** are desirable. **Stand density management** is one tool that can be used to encourage C allocation belowground. Insufficient C allocation to the root system can also be avoided by the application of **prescribed fire at times during the year when physiological conditions are optimal for leaf area re-establishment** after scorch. Because much Ca uptake occurs in a localized zone behind the root tip, forest practices that facilitate root growth will benefit Ca nutrition and therefore, Mn tolerance. Finally, **forest floor conservation** could potentially reduce water loss by evaporation and therefore, lower the risk of insufficient K for stomatal regulation and turgor maintenance.

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For more information, contact Dr. Mary Anne Sword Sayer at msword@fs.fed.us