Nutrition challenges of longleaf pine in the Southeast

Mary Anne Sword Sayer[1], Lori G. Eckhardt[2], Emily A. Carter[3]

[1]U.S. Forest Service, Southern Research Station, Pineville, LA; msword@fs.fed.s
[2]School of Forestry and Wildlife Sciences, Auburn Univ., Auburn, AL; eckhalg@auburn.edu
[3]U.S. Forest Service, Southern Research Station, Auburn, AL; eacarter@fs.fed.us

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Eglin Air Force Base's Forestry Element, Natural Resources Section, Environmental Management Division, 96th Civil Engineering Group (96 CEG/CEVSNF) for the use of their foliar nutrition data.

ABSTRACT

Low vigor of longleaf pine has been reported at Fort Benning in Georgia, and Eglin Air Force Base in Florida. In an effort to determine the cause of this problem, foliar nutrition was assessed. Results indicated that macro- and micronutrients were generally sufficient regardless of vigor status. Foliar Mn, however, was elevated at both locations. Excess Mn has the potential to interfere with physiological processes and the function of other elements if natural Mn tolerance mechanisms are inadequate. A summary of foliar nutrition at Fort Benning and Eglin Air Force Base is presented as baseline information for further investigation to determine the cause of poor vigor.

Keywords—boron, calcium, manganese, *Pinus palustris* Mill., potassium, transpiration

INTRODUCTION

Several reports have suggested that localized forest health problems are increasing in southern pine forests (Eckhardt et al. 2007, Hess et al. 2005, Menard 2007, Otrosina et al. 1999), and the growth rate of these forests appears to have declined over the last decade (Gadbury et al. 2004). A recent analysis of U.S. Forest Service, Forest Heath Monitoring data collected in the Southeast between 1991 and 2005 indicated that drought has been a significant cause of these growth declines and increases in mortality (Klos et al. 2009).

Low annual growth rates and the stunted appearance of longleaf pine (*Pinus palustris* Mill.) trees have been reported in isolated plantations at two military installations on sandy soils in the southeastern United States. These locations are at Fort Benning Military Reserve, Georgia, and Eglin Air Force Base, Florida which are characterized by nutrient-poor and droughty soils. A preliminary investigation of foliar nutrition at both locations was conducted for two reasons. First, it is likely that soil resource limitations are at least part of the problem, and effective remedial action requires knowledge of localized nutritional imbalances. Second, southern pines are well adapted to physiological conditions that arise from resource limitations (i.e., inadequate light, water, or essential mineral nutrients). Both locations provide an opportunity to observe stand responses to water and mineral nutrient limitations. Subsequently, observation of the function or malfunction of inherent resource stress tolerance mechanisms will provide valuable information regarding the cause of regional declines in forest production and health. With sound knowledge of stand environmental and tree physiological conditions that predispose the loss of vigor in southern pines, corrective silvicultural responses can be proposed. Our present objective is to summarize the foliar nutrition of longleaf pines that were sampled from these two locations to set the stage for additional research to determine the cause of poor vigor.

MATERIALS AND METHODS

Study sites. At Fort Benning Military Reserve, GA, 32 circular permanent plots, each 0.07 ha, dominated by one of three age classes (i.e., < 10, 10-40, and > 40 yr) of longleaf pine were established in 2006 (Menard et al. 2006). Soil texture is dominated by sand across the study area (e.g., Cowarts fine sandy loam, Ailey loamy sand). Using topographic features as predictors of pine decline (Eckhardt and Menard 2008), one-half of the plots were labeled as likely (UH) or unlikely (H) to experience low vigor symptoms typical of pine decline. These symptoms include sparse and chlorotic crowns, low annual stemwood production, and root disease (Otrosina et al. 1999, Eckhardt et al. 2007). Sixteen of these plots (7 UH plots, and 9 H plots) were sampled for foliar nutrition in July 2007. On each plots, one upper crown branch was shot from the crowns of three dominant and healthy-appearing longleaf pines with a rifle. Foliage was separated by cohort, cold-stored until processing, oven dried to equilibrium at 70 °C, and ground. Foliage tissue from the last mature flush of 2006 was analyzed for N (nitrogen), P (phosphorus), K (potassium), Mg (magnesium), Ca (calcium), B (boron), Cu (copper), Fe (iron), Zn (zinc), and Mn (manganese) by A&L Plains Agricultural Laboratories, Inc. (Lubbock, TX).

At Eglin Air Force Base, FL, the foliage of 19 stands of longleaf pine and five stands of slash pine was sampled in February 2006. The dominant soil series in all but one of these stands is Lakeland sand. One stand is dominated by Troup fine sand. Stand age ranged between 12 and 51 years. The trees in seven of these 24 stands appeared "stunted" (UH); whereas, the trees in 17 of these 24 stands appeared healthy (H). A sample of the most recently mature fascicles was collected at each location. Foliage was processed and analyzed for N, P, K, Mg, Ca, B, Cu, Fe, Zn, and Mn by Waters Agricultural Laboratories, Inc. (Camila, GA). Means and standard deviations of all foliar mineral nutrient concentrations were calculated.

RESULTS AND DISCUSSION

Mean foliar concentrations of essential macronutrients were compared with values that are considered sufficient for longleaf pine (Blevins et al. 1996, Dickens et al. 2003). Specifically, critical values of foliar N, P, and K were 0.90%, 0.80 g/kg, and 0.30%, respectively. Critical values of Mg and Ca were 0.060% and 0.10%, respectively. Mean concentrations of N (Figure 1a) and P (Figure 1b) were either sufficient or nearly sufficient in foliar samples collected at Fort Benning and Eglin Air Force Base. Two exceptions to this were observed: foliar N and P concentrations on the > 40-year-old H plots at Fort Benning and foliar P concentration of the UH (i.e., "stunted") trees at Eglin Air Force Base. Absence of an obvious trend between H and UH plots and trees, however, suggests that N and P nutrition at the fascicle level was not the cause of poor vigor. Foliar K was sufficient across the H and UH plots and age classes at Fort Benning, and was sufficient or nearly sufficient at Eglin Air Force Base regardless of H and UH status (Figure 1c). The sandy soils at these two locations are characterized by only trace levels of K (Soil Survey Staff 2008). These trees, therefore, have adapted so that adequate K is supplied. Root system expansion, maintenance of healthy ectomycorrhizal associations, and mobilization of K (Addington et al. 2006, Nambiar and Fife 1991) are likely mechanisms by which the demand for K is met on these xeric sites.

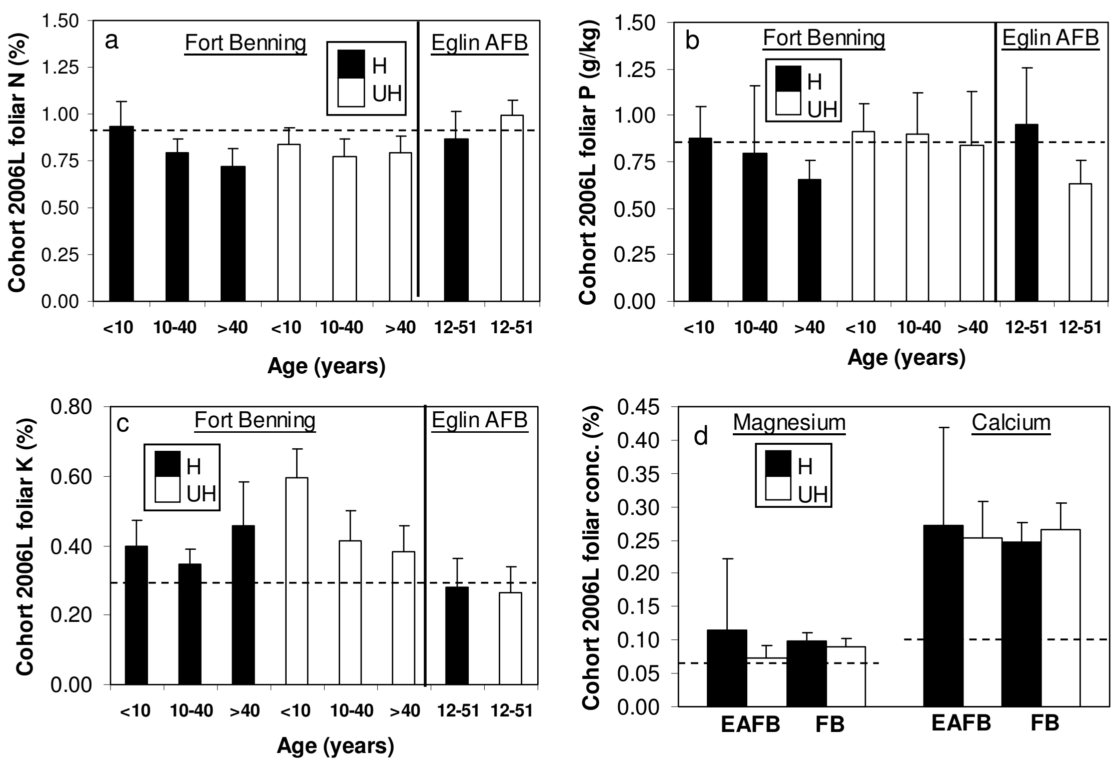

Figure 1. Foliar concentrations of N, P, K, Mg, and Ca at Fort Benning in July 2007 (FB) and at Eglin Air force Base (EAFB) in February 2006. Data were partitioned by health likelihood or apparent vigor (H and UH), and age class (N, P, K only). Dotted lines represent critical values associated with the onset of deficiency (Blevins et al. 1996, Dickens et al. 2003). Bars represent one standard deviation of the mean.

Of particular interest are the elevated foliar K concentrations observed at Fort Benning regardless of H and UH status. At this location, foliage was collected during a prolonged drought. Foliar K may have been elevated in an effort to intensify stomatal function, improve osmotic adjustment, or protect cell components from oxidative damage (Cakmak 2005, Marschner 1995).

Foliar Mg and Ca were also sufficient at Fort Benning and Eglin Air Force Base regardless of H and UH status (Figure 2d). Similar to foliar K at Fort Benning, foliar concentrations of Ca were much higher than the critical value of 0.10% and appeared to be unaffected by H and UH status.

Foliar concentrations of essential micronutrients were sufficient regardless of H and UH status at Fort Benning and Eglin Air Force Base using general critical values for plant tissue (Marschner 1995) (Figure 2a). Foliar concentrations of 6-70 ppm B, 15-20 ppm Zn, 5-150 ppm Fe, and 1-5 ppm Cu were considered adequate. Although foliar micronutrient status did not differ by H and UH status, foliar B concentrations were dramatically different between the locations. Foliar B concentrations at Eglin Air Force Base were near deficient and nearly five times less than those at Fort Benning. Although low, the concentration of foliar B itself may not be problematic at Eglin Air Force Base. However, the large difference in B values between locations may be an indicator of differences in physiological function at these locations. For example, once B enters the root system, it is strictly transported in the xylem with the occurrence of transpiration (Marschner 1995). If differences in foliar B cannot be explained by B availability in the soil, then differences may be attributed to site differences in water use. Further investigation of these site differences could reveal inadequacies or efficiencies in longleaf pine's response to water stress that are linked to regional trends in poor vigor.

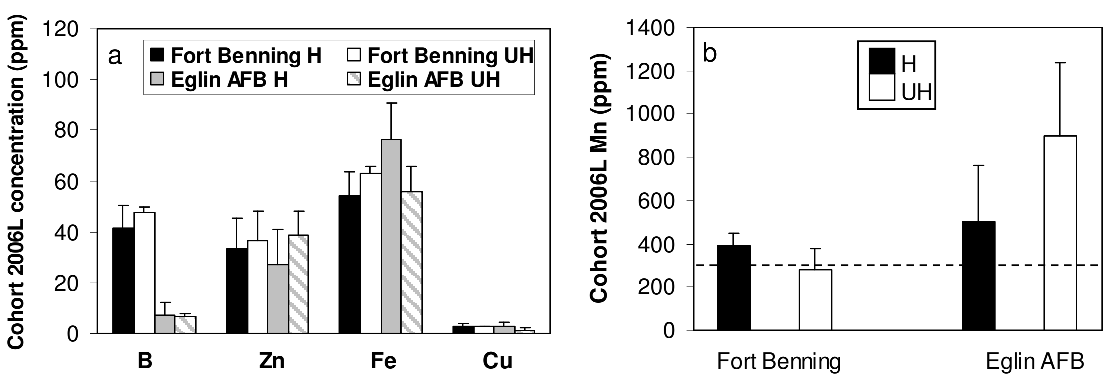

Figure 2. Foliar concentrations of B, Zn, Fe, and Cu (a) and Mn (b) at Fort Benning in July 2007 and at Eglin Air force Base in February 2006. Data were partitioned by health likelihood or apparent vigor (H and UH). The dotted line represents the toxic level of foliar Mn for slash pine seedlings (Van Lear and Smith 1990). Bars represent one standard deviation of the mean.

Micronutrient analyses also revealed that foliar Mn concentrations were elevated at both locations regardless of UH and H status (Figure 2b). Sufficient concentrations of Mn in plant tissues are 10 to 20 ppm (Marschner 1995). The range of Mn concentration that is toxic to plants is broad. For example, Mn becomes toxic to cotton and soybean tissues at approximately 600 ppm (Marschner 1995). Van Lear and Smith (1990) reported that Mn was toxic to slash pine seedlings at 300 ppm.

Although foliar Mn may be elevated at these two locations, longleaf pines possess several mechanisms that compartmentalize Mn so it does not interfere with cellular physiological processes (Marschner 1995). The malfunction of one or more of these mechanisms, however, leads to disruption of photosynthetic reactions and phenolic biochemistry (Marschner 1995). Furthermore, because it is capable of displacing Mg, Mn interferes with the uptake of Mg by roots and the function of this element in physiological processes. Coincidentally, Ca is an important factor in the natural mechanisms of Mn tolerance (Marschner 1995). Perhaps the high concentration of foliar Ca observed at Fort Benning and Eglin Air Force Base was, in part, a response to elevated foliar Mn. Disruption of the physiological events needed to obtain high foliar Ca concentrations could be detrimental to tree health and vigor if Mn interferes with photosynthetic reactions, phenolic biochemistry, or Mg function. Further research is needed to understand the mechanisms and requirements of longleaf pine's tolerance to elevated foliar Mn. This information may help us to understand the cause of poor vigor in isolated stands at Fort Benning and Eglin Air Force Base as well as the predisposing conditions of regional declines in southern pine production.

LITERATURE CITED

Addington RN, Donovan LA, Mitchell RJ, Vose JM, Pecot SD, Jack SB, Hacke UG, Sperry JS, Oren R. 2006. Adjustments in hydraulic architecture of *Pinus palustris* maintain similar stomatal conductance in xeric and mesic habitats. Plant, Cell and Environment 29: 535-545.

Blevins D, Allen HL, Colbert S, Gardner W. 1996. Nutrition management for longleaf pinestraw. Woodland Owner Notes. Raleigh, NC: NCSU Cooperative Extension Service.

Cakmak I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. Journal of Nutrition and Soil Science 168: 521-530.

Dickens ED, Moorehead DJ, McElvany B. 2003. Georgia pine plantation fertilization. Better Crops 87(1):1 2-15.

Eckhardt LG, Menard RD. 2008. Topographic features associated with loblolly pine decline in central Alabama. Forest Ecology and Management 255: 1735-1739.

Eckhardt LG, Weber AM, Menard RD, Jones JP, Hess NJ. 2007. Insect-fungal complex associated with loblolly pine decline in central Alabama. Forest Science 53: 84-92.

Gadbury, GL, Williams MS, Schreuder HT. 2004. Revisting the southern pine growth decline: where are we 10 years later? General Technical Report RMRS-GTR-124. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station: 10 p.

Hess NJ, Eckhardt LG, Menard RD, Goddard AJ, Carter EA. 2005. Assessment of loblolly pine decline on the Shoal Creek/Talladega Ranger Districts, Talladega National Forest, Alabama and Choccolocca State Forest. Report No. 2005-02-05. Pineville, LA: Alexandria Field Office, USA Forest Service, Forest Health Protection. 36 p.

Klos RJ, Wang GG, Bauerle WL, Rieck JR. 2009. Drought impact on forest growth and mortality in the southeast USA: an analysis using Forest Health and Monitoring data. Ecological Applications 19: 699-708.

Marschner H. 1995. Mineral Nutrition of Higher Plants. Second edition. The Netherlands: Elsevier, Ltd. 889 p.

Menard RD. 2007. An assessment of loblolly pine decline risk mapping system for the use of managing loblolly pine decline sites within Red Cockaded Woodpecker (RCW) habitat. Masters Thesis. Baton Rouge, LA: Louisiana State University. 128 p.

Menard RD, Eckhardt LG, Hess NJ. 2006. Assessment of loblolly pine decline on Fort Benning Military Reservation, Fort Benning, Georgia. Report No. 2006-02-01. Pineville, LA: USDA, Forest Service, Forest Health Protection. 21 p.

Nambiar EKS, Fife DN. 1991. Nutrient retranslocation in temperate conifers. Tree Physiology 9: 185-207.

Otrosina WJ, Bannwart D, Roncadori RW. 1999. Root-infecting fungi associated with a decline of longleaf pine in the southeastern United States. Plant and Soil 217: 145-150.

Soil Survey Staff. 2008. National Soil Survey Characterization Data [Online]. Lincoln, NE: Soil Survey Laboratory, National Soil Survey Center, U.S. Department of Agriculture, Natural Resources Conservation Service. Available: http://ssldata.nrcs.usda.gov/querypage.asp.

Van Lear DH, Smith WH. 1990. Relationships between macro-and micro-nutrient nutrition of slash pine on three coastal plain soils Plant Soil 36: 331-347.