

Tree Nutrition and Forest Fertilization of Pine Plantations in the Southern United States

Thomas R. Fox, H. Lee Allen, Timothy J. Albaugh, Rafael Rubilar, and Colleen A. Carlson

ABSTRACT

The growth of many pine plantations in the southern United States is limited by soil nutrient availability. Therefore, forest fertilization is a common silvicultural practice throughout the South. Approximately 1.2 million ac of pine plantations were fertilized in 2004. In the last 10 years, considerable advances have been made in identifying the ecophysiological basis for stand growth and the response to fertilizer additions. Nitrogen (N) and phosphorus (P) are the nutrients that most commonly limit growth of southern pine. On wet clay soils in the lower Coastal Plain and on some well-drained soil in the upper Coastal Plain, severe P deficiencies exist. On these soils, P fertilization with 25–50 lb of P per acre at the time of planting produces a large and sustained growth response, on the order of $50 \text{ ft}^3 \text{ ac}^{-1} \text{ yr}^{-1}$ ($1.5 \text{ tn ac}^{-1} \text{ yr}^{-1}$) throughout the rotation. On most other soils in the South, chronic deficiencies of both N and P exist. On these sites, soil nutrient availability often is adequate early in the rotation when tree demand is small. However, around the time of crown closure, N and P frequently become limiting. Fertilization with both N and P in these intermediate aged stands typically increases growth for 8–10 years. The growth response to a combination of 25 lb of P per acre plus 200 lb of N per acre averages around $55 \text{ ft}^3 \text{ ac}^{-1} \text{ yr}^{-1}$ ($1.6 \text{ tn ac}^{-1} \text{ yr}^{-1}$) for an 8-year period. The amount of leaf area in the stand is the main factor determining the current growth rate of the stand and the potential growth response after fertilization. When stand leaf area index is less than 3.5, light capture by the stand is restricted and growth is negatively affected. In many of these stands, fertilization will increase leaf area because of increased soil nutrient availability and thus increase growth. The financial return after fertilization depends on the growth response that occurs, the cost of the fertilizer treatment, and the stumpage value of the timber produced. Using a growth response of $55 \text{ ft}^3 \text{ ac}^{-1} \text{ yr}^{-1}$ over 8 years, a fertilizer cost of $\$90 \text{ ac}^{-1}$, and stumpage values from the first quarter of 2006, the internal rate of return from midrotation fertilization of a loblolly pine plantation with N and P would be approximately 16%.

Keywords: loblolly pine, slash pine, forest productivity, leaf area, nitrogen, phosphorus

The southern United States produces more industrial timber than any other region of the world from a forest base that now comprises almost one-half of the world's industrial forest plantations (Prestemon and Abe 2002). Currently, there are 32 million ac of pine plantations in the South (Wear and Greis 2002), predominantly comprised of loblolly pine (*Pinus taeda* L.) and, to a lesser extent, slash pine (*Pinus elliotii* Engelm.).

Historically, forest landowners in the South have focused on minimizing per acre costs associated with plantation establishment and tending. This approach has resulted in millions of acres of pine plantations in the southern United States with growth rates averaging less than $166 \text{ ft}^3 \text{ ac}^{-1} \text{ yr}^{-1}$ ($5 \text{ tn ac}^{-1} \text{ yr}^{-1}$). These growth rates are substantially lower than plantations in many other parts of the world (Yin and Sedjo 2001). However, theoretical models (Sampson and Allen 1999, Landsberg et al. 2001), empirical field trials (Allen and Lein 1998, Martin et al. 1999, Amatrís et al. 2000, Jokela et al. 2000, Borders and Bailey 2001), and operational experience show that these growth rates are well below what is possible in the southern United States. With investment in appropriate intensive plantation silvicultural systems, growth rates exceeding $560 \text{ ft}^3 \text{ ac}^{-1} \text{ yr}^{-1}$ ($10.8 \text{ tn ac}^{-1} \text{ yr}^{-1}$) are biologically possible, financially profitable, and environmentally sustainable for a broad range of site

types (Yin et al. 1998, Fox 2000). The greater inputs typically associated with intensive silviculture may increase per acre costs, but the resultant increases in production can substantially reduce production costs per ton of wood when variable (treatment) and fixed (land and annual management) costs are considered (Allen et al. 2005). Forest fertilization typically must be included in silvicultural regimes that are designed to increase plantation growth in the South (Allen 1987). Considerable research in tree nutrition and forest fertilization has been conducted in recent years. Results from this research have improved our understanding of the growth response that occurs after fertilization and the ecophysiological basis for this increased growth. This review provides a summary and synthesis of the current state of knowledge of tree nutrition and forest fertilization in the southern United States.

Modern Concepts of Ecophysiology and Tree Nutrition

Much of the variation in biomass and wood production in forest plantations is caused by variation in light interception (Linder 1987, Cannell 1989, Landsberg and Gower 1997). Light interception is principally a function of the amount of leaf area in the stand (Figure 1). Differences in duration of leaf area display, individual tree crown

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Nutrition In Forest Trees In Plantations

**Laurence C. Walker, Robert Lincoln
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Nutrition In Forest Trees In Plantations:

Nutrition of Plantation Forests Glynn D. Bowen, E. K. Sadanandan Nambiar, 1984 Plantation forests The scope and a perspective on plantation nutrition The dynamics of plantation growth Dynamics of nutrient cycling in plantation ecosystems Soil characteristics influencing nutrient supply in forest soils Biological factors influencing nutrient supply in forest soils Biological factors influencing nutrient supply in forest soils Tree roots and the use of nutrients Nutrient storage retranslocation and relationship of stress to nutrition Effects of mineral nutrition on carbon dioxide exchange and partitioning of carbon in trees The genetic basis of forest tree nutrition Diagnosis of nutrient deficiencies in plantations Wood yield and quality in relation to tree nutrition Fertilization of plantations Nitrogen fixation systems in forest plantations Consequences of forest management on soil tree relationships Environmental aspects of plantation management Design and analysis of tree nutrition experiments The role of modelling in tree nutrition research and site nutrient management Future directions in plantation nutrition research *Water and Nutrient Dynamics of Pinus Caribaea Plantation Forests on Former Grassland Soils in Southwest Viti Levu, Fiji* Maarten Johannes Waterloo, 1994

Commercial Forest Plantations on Saline Lands Marcia J. Lambert, John Turner, 2000 Provides information that will allow users to recover salt degraded land with selected plantation timbers and ultimately to make a profit

Nutrient Uptake and Cycling in Forest Ecosystems L.O. Nilsson, Reinhard F. Hüttel, U.T. Johansson, 2012-12-06 From the research results and discussions presented in this book it becomes clear that a profound understanding of the various interrelationships of the nutritional aspects allows the implementation of specific management strategies to improve stability and productivity of forest ecosystems In particular the effects of environmental changes as related to the impacts of air pollution global change and land use on nutrient uptake and cycling processes in forest ecosystems are dealt with in detail The book is divided into six main issues and each topic contains reviews as well as selected results of recent studies

Normal Foliar Nutrient Levels in North American Forest Trees Charles R. Blinn, Edward R. Buckner, 1989 *Crop Physiology of Forest Trees* Peter M. A. Tigerstedt, Pasi Puttonen, Veikko Koski, 1985 [The CABI Encyclopedia of Forest Trees](#) CABI, 2013 The CABI Encyclopedia of Forest Trees provides an extensive overview of 300 of the world's most important forest trees Tropical subtropical temperate and boreal trees of major economic importance are included covering tree species used in agroforestry practices around the world Many of the species covered are considered to be multipurpose trees with uses extending beyond timber alone the land uses such as watershed protection or provision of windbreaks and non wood uses such as the production of medicines resins food and forage are also listed Comprehensive information is presented on each tree's importance with a summary of the main characteristics of the species its potential for agroforestry use and any disadvantages it possesses The tree's botanical features such as habit stem form foliage inflorescence flower and fruit characters and phenology are covered in detail with over 70 color plate pictures to aid identification Also included are specific sections devoted to pests and diseases distribution

and silvicultural characteristics and practices including seed sowing nursery care planting thinning and harvesting In addition to the wealth of information detailed based on datasheets from CABI s Forestry Compendium selected references for further reading are provided for each entry making this book an essential reference work for forestry students researchers and practitioners

Invasive Forest Insects, Introduced Forest Trees, and Altered Ecosystems Timothy D. Paine,2007-05-24 Demand for timber and fibre continues to grow and is being met by increased reliance on plantation forestry Many of the plantations that are being grown around the globe are non native species that have characteristics of rapid growth and good commercial qualities In some cases the high rates of production are a result of the absence of native herbivore and diseases This limited pest status is threatened as pest species move around the globe At the same time there is concern about threats of these non native plantation species on native communities and the impact of changing climates on forest productivity This volume explores many of these issues for the first time

Mineral Nutrition of Trees Duke University. School of Forestry,1959 Fertilizer Response with Forest Trees in North America Laurence C. Walker,Robert Lincoln Beacher,1963 **Pacific Islands Forests & Trees** ,1998 *New Zealand Journal of Forestry Science* ,1987

Attributes of Trees as Crop Plants Melvin G. R. Cannell,John Ellwood Jackson,1985 Domestication Perspectives on the evolutionary history of tree crops The basis of selection management and evaluation of multipurpose trees an overview Forest tree breeding and fruit tree breeding strategies achievements and constraints Strategies for optimizing the yield of tree crops in suboptimal environments Tree growth at cool temperaturea and prospects for improvement by breeding The ideotype concept applied to forest trees Definition and exploitation of forest tree ideotypes in Finland The capacity for vegetative propagation in trees The vegetative structure Biometrical structural and physiological relationships among tree parts Dry matter partitioning in tree crops Forest productivity in relation to carbon partitioning and nutrient cycling a mathematical model Prospects for manipulating vascular cambium productivity and xylem cell differentiation Branching crown structure and the control of timber production Trees as producers of exudates and extractives Trees as producers of fuel Trees as fodder crops Roots symbionts and soils Roots as a component of tree productivity Improving tree crops using micro organisms in designed systems Trees as soil improvers in the humid tropics Exploiting tree crop symbiont specificity Flowering and fruiting Promotion of flowering in the crops different mechanisms and techniques with special reference to conifers Variability in flower initiation in forest trees Reproduction behaviour of fruit tree crops and its implications for the manipulation of fruit set Some attributes of nut bearing trees of temperate forest origin Trees in stands Future fruit orchard design economics and biology Transpiration and assimilation of tree and agricultural crops the omega factor The competition process in forest stands Forest canopy design biological models and management implications Future forest design economic aspects Wood properties and future requirements for wood products *Research Report* ,1983 Sustainability of Forest Plantations Julian Evans,1999 **Journal of Tropical Forest Science** ,2000 **Forest Fertilization: Theory and**

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