Forest Fertilization in Southern Pine Plantations

By T.R. Fox, H.L. Allen, T.J. Albaugh, R. Rubilar, and C.A. Carlson

Forest fertilization is a widespread silvicultural practice in the southeastern U.S. About 1.2 million acres of pine plantations were fertilized with phosphorus (P) or nitrogen (N) plus P in 2004. The average growth response of loblolly pine plantations following midrotation fertilization with N+P is approximately 50 ft³/A/yr for 8 years. Internal rates of return in excess of 10% can be obtained after midrotation fertilization under current market conditions.

The southeastern U.S. produces more timber than any other region of the world from a forest base that now includes almost half of the world's forest plantations. There are currently 32 million acres of pine plantations in the southeastern states, predominantly comprised of loblolly pine (*Pinus taeda* L.) and to a lesser extent slash pine (*Pinus elliottii* Englemn.) The growth rate in the pine plantations in the region currently averages around 5 green tons/A/yr, which is substantially lower than in many forest plantations in other parts of the world. Theoretical models, empirical field trials, and operational experience show that these growth rates are well below what is possible. With investment in appropriate intensive plantation silvicultural systems, growth rates exceeding 10 tons/A/yr are biologically possible and financially attractive for a broad range of site types. Forest fertilization should be included in silvicultural regimes that are designed to enhance plantation growth in the region.

Ecophysiology and Tree Nutrition

It is now generally accepted that much of the variation in wood production in forest plantations is caused by variation in light interception. Light interception is principally a function of the amount of leaf area in a stand. Studies with loblolly pine and slash pine have shown that leaf area, and consequently wood production, are below optimum levels in most of the Southeast (**Figure 1**). Low nutrient availability is a principal factor causing subop-

Increased growth of pine trees with fertilization (left), compared to trees without fertilization (right), is illustrated in these Alabama plots.

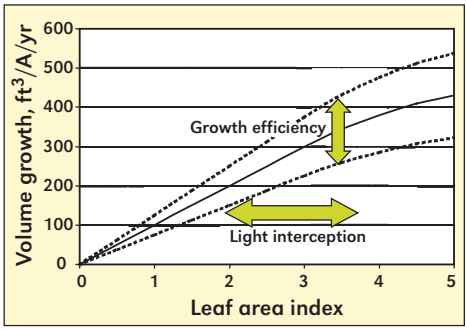

Figure 1. Relationship between annual volume growth and leaf area in southern pine plantations in the Southeastern U.S.

timal leaf area in many areas.

From a resource availability perspective, water availability…whether too little or too much…has historically been considered the principal resource limiting pine productivity in the South. While this is true for recently planted pine seedlings on many sites and for specific soil types (e.g. very wet or very dry soils) throughout the rotation (planting to tree harvest), recent analyses suggest that chronically low levels of available soil nutrients, principally N and P, and additionally potassium (K) and boron (B) on loamy or sandy soils, are more limiting to growth in established stands than water. Fortunately for forest managers, most nutrient limitations are easily and cost-effectively ameliorated with fertilization.

Why are nutrient limitations so common in southern pine plantations? Simply, nutrient limitations develop when a stand's potential nutrient use cannot be met by soil nutrient supply (**Figure 2**). Typically, nutrient availability is rather high following harvesting and site preparation (for planting) as these disturbances provide suitable conditions for rapid decomposition and release of nutrients from the accumulated forest floor and slash material. Use of nutrients by newly-planted crop trees is minimal owing to their small size, but as trees grow, nutrient demand and use increase rapidly. Simultaneously, the supply of readily available nutrients is being rapidly sequestered within the accumulating forest floor and tree biomass. Consequently, a stand's nutrient requirement for maximum growth generally outstrips soil supply (particularly for N) near canopy closure. As the available nutrient supply diminishes, leaf area production and tree growth become limited. It is not surprising that the majority of field trials in intermediate-aged southern pine stands (from 8 to 20-years old) have shown strong responses to additions of N and P. In young stands, the development of nutrient limitations is still possible when levels of available nutrients (particularly P) in the soil are low and the soil volume exploited by roots is small. As other silvicultural treatments (e.g. vegetation control and/or tillage) are used to improve water availability, crop tree growth and use of nutrients will be increased at young ages. Fertilization will be needed to sustain rapid growth on all but the most fertile sites.

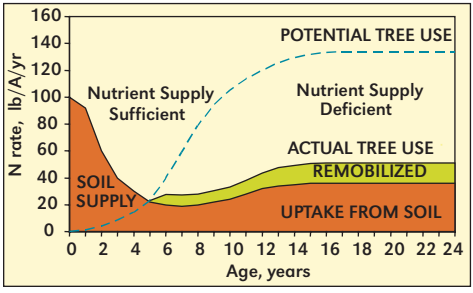

Figure 2. The concept of soil N supply and a stand's potential and actual use of N as related to stand development (age).

Fertilization as a Component of Site-Specific Silvicultural Regimes for Southern Pine Plantations

The key to optimizing leaf area, thereby increasing tree growth, is the development and implementation of site-specific silvicultural prescriptions. Forest managers now recognize that intensive plantation silviculture is like agronomy–both the plant and the soil need to be actively managed to optimize production. Silvicultural treatments must form an integrated management regime that opti-

mizes growth throughout the life of the plantation. High quality seedlings from the best genetic families of the right species must be planted on sites prepared to ameliorate soil physical properties that limit root growth. Competing vegetation must be controlled throughout the life of the stand. Thinning is required to provide crop trees with adequate growing space as trees get larger. Improving stand nutrient supply through fertilization is a key component of intensive management regimes in southern pine plantations because nutrient limitations are very widespread.

P Fertilization at Stand Establishment

The benefits of early P fertilization on poorly drained, P-deficient Ultisols of the Atlantic and Gulf Coastal Plain have long been recognized. Volume growth gains averaging 40 to 50 ft^3/A/yr are typical on severely P-deficient sites. Because the duration of response to a single application of 50 lb P/A[1] may last for 20 or more years, P fertilization on deficient sites may yield volume gains of over 100% and consequently is viewed as an improvement in site quality. Site index gains (height of trees at age 25) of 6 to 10 ft. or more are typical when P is applied at or near time of planting. Recent results from several Forest Nutrition Cooperative (FNC) trials have shown that large areas of well-drained sites on the upper Gulf Coastal Plain are also P-deficient. Identification of stands in need of early fertilization is based on landscape position, soil type, geology, soil and foliar tests, and experience. The critical value for soil P below which a fertilizer response is expected is 6 parts per million (ppm, Mehlich-3 extraction procedure). Critical values for foliar P concentrations vary by species and range from 0.09% for slash pine to 0.11% for loblolly pine. The sources of fertilizer P that are typically used include diammonium phosphate (DAP), triple superphosphate (TSP), and rock phosphate. DAP is now the most widely used source for fertilization at time of planting. Rates of application vary from 25 to 50 lb P/A (125 to 250 lb DAP/A).

N+P Fertilization During Midrotation

By age 5 or earlier, a plantation's potential to use N and P typically outstrips the available soil supply resulting in restricted leaf area development and growth. At canopy closure, stands are generally very responsive to additions of N+P rather than P alone, as long as gross P deficiencies were corrected at or soon after planting. Results from an extensive series of intermediate-aged fertilizer trials in loblolly pine stands established by the FNC indicate that over 85% of the stands responded to N+P fertilization. Growth gains averaging 30% (50 ft^3/A/yr) over an 8-year period following a one-time application of 200 lb N/A and 25 lb P/A are typical. Responses of over 100 ft^3/A/yr are possible on some sites. For the majority of stands, additions of N+P result in much greater effects than either element applied alone (**Figure 3**). A prescription of 150 to 200 lb N/A plus 25 lb P/A is used for loblolly pine or slash pine on most sites. The growth response is proportional to the N rate applied. Lower doses of N are recommended for longleaf pine (*Pinus palustris* Mill.) to prevent aggravation of insect and disease problems.

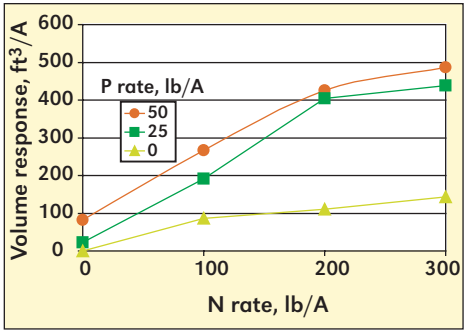

Figure 3. Eight-year cumulative growth response of midrotation loblolly pine stands to N and P fertilization in the southeastern U.S.

[1]Note: Phosphorus fertilizer application rates are given as lb P/A in this article. To convert P to P_2O_5, multiply by 2.29.

Aerial application is used for the majority of operational fertilization in Southeast pine forests.

Financial returns from N+P fertilization of intermediate-aged stands are strongly dependent on fertilizer cost, the wood product mix (sawlog, chip and saw, pulpwood) and price that can be realized for the additional wood produced, and the number of years before harvest. Application of 200 lb N/A plus 25 lb P/A presently costs around $100/A. At this price, midrotation fertilization (between ages 8 and 15) is an attractive investment with average internal rates of return exceeding 10%. Fertilization is frequently conducted in conjunction with a first or second thinning, to maximize returns on investment. Because of the attractive financial returns that are possible, fertilization is a widespread silvicultural treatment in the Southeast. In 2004, over 1.2 million acres of pine plantations were fertilized (**Figure 4**). It is estimated that about three-fourths of operational fertilization in southeastern pine forests is by aerial application.

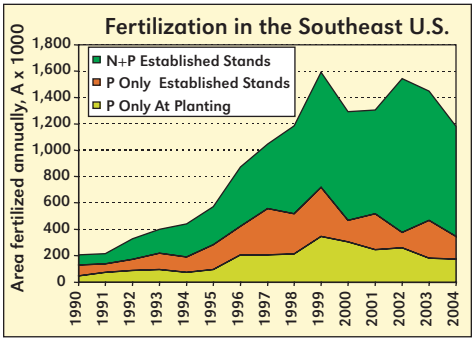

Figure 4. Area of southern pine plantations annually fertilized in the southeastern U.S. (FNC data).

Conclusion

FNC research indicates that the growth potential of southern pines planted in the southeastern states is much higher than commonly thought just a few years ago. The challenge now is to develop and implement the appropriate silvicultural systems to realize this potential in a cost-effective and environmentally sustainable manner. The FNC is aggressively pursuing several opportunities for improving plantation growth and value through the management of site resources. Additional information on the FNC work is available at the website: >**www.forestnutrition.org**<. BC

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