UPTAKE OF ^{15}N LABELED FERTILIZER IN LOBLOLLY PINE PLANTATIONS OF THE SOUTHERN UNITED STATES

Jay E. Raymond, Thomas Fox, and Brian Strahm[1]

Forests in the southeastern United States managed extensively (minimal silvicultural treatments) generally have low productivity rates (Fox and others 2007). Conversely, intensively managed stands have significantly increased productivity in this region, from 2 m^3 ha^{-1} $year^{-1}$ to a range of 6 to 10 m^3 ha^{-1} $year^{-1}$ (Fox and others 2007). Yet theoretical models and empirical field trials indicate that production in excess of 20 m^3 ha^{-1} $year^{-1}$, with stand rotations of < 15 years, are biologically possible (Allen and others 2005, Borders and Bailey 2001, Fox and others 2007). These productivity increases can occur if forest plantations are intensively managed as agroecosystems through the development of site-specific silvicultural prescriptions to address factors limiting growth. The growth rates of extensively managed forests are not adequate to sustainably produce the raw materials required to support the current and future forest products and bioenergy industries, and more intensively managed forest plantations will be required to adequately and sustainably supply the raw materials required (Sedjo and Botkin 1997).

One factor contributing to low forest productivity is low levels of available soil nutrients, principally nitrogen (N) (Albaugh and others 1998, 2004; Jokela and Martin 2000; Sampson and Allen 1999). Low nutrient availability restricts leaf area production resulting in reduced photosynthetic capacity and growth. Soil N availability is normally greatest following harvesting and site preparation early in the rotation but gradually decreases as canopy closure occurs and N becomes immobilized in the forest floor and plant biomass (Fox and others 1986, Miller 1981, Vitousek and Matson 1985). Because of this pattern, N fertilization is needed in many plantations to maintain rapid growth. Fertilization can increase soil nutrient availability, gradually increase the leaf area of the stand, and improve the overall growth of the forest. Empirical results from fertilization trials in loblolly pine indicate that most nutrient limitations can be easily and cost-effectively ameliorated with fertilization (Fox and others 2007).

The precise fate of fertilizer-applied N in loblolly pine plantations is not well understood. It is estimated that 10 to 25 percent fertilizer-applied N is incorporated by crop trees (Blazier and others 2006, Mead and Pritchett 1975). Yet the remainder of the fertilizer N is assimilated in various ecosystem components (forest floor, mineral soil, understory competition, etc.) or lost (N volatilization, leaching, etc.) from the system. The variability in fertilizer-N uptake in the crop trees may contribute to the variability in growth response observed in fertilizer studies. A better understanding of the fate of applied N fertilizer in forests is needed to improve economic and environmental decisions.

Fertilizer enriched with the stable isotope ^{15}N is a technique that can accurately and precisely measure N uptake and the fate of applied N fertilizer in forest ecosystems. We used fertilizers enriched with ^{15}N (0.5 atom percent; approximately 370 per mil, 224 kg ha^{-1} N) to compare N uptake following fertilization with four conventional and enhanced-efficiency N fertilizers [urea, polymer-coated urea (PCU), urea+NBPT (NBPT), and controlled release N (CUF+NBPT)] in loblolly pine (*Pinus taeda* L.) plantations. The primary research objective of this study is to improve the fundamental understanding of N dynamics in forested systems by: (1) determining the fate of N in mid-rotation loblolly pine stands across the southern United States by using ^{15}N enriched fertilizers; and (2) comparing N dynamics following fertilization with conventional (urea) and enhanced-efficiency fertilizers enriched with ^{15}N.

Five 100-m^2 circular plots were installed at sites during 2011 and 2012 in a wide range of

[1]Graduate Research Assistant, Professor, and Assistant Professor, respectively, Virginia Polytechnic Institute and State University, Department of Forest Resources and Environmental Conservation, Blacksburg, VA, 24061.

Citation for proceedings: Holley, A. Gordon; Connor, Kristina F.; Haywood, James D., eds. 2015. Proceedings of the 17th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–203. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 551 p.

representative soil and stand conditions in the primary physiographic regions of the South. The rate of N uptake from different fertilizers was evaluated by periodic foliage sampling in 2011. Total N uptake in the growing season was determined by biomass sampling of individual tree components (foliage, fine branches, coarse branches, and stem) to determine the N mass and concentration in each component. Additional ecosystem components analyzed to determine the fate of applied N included understory vegetation, forest floor, mineral soil, litter, and roots. N volatilized following fertilization was measured using a microplot experiment.

Preliminary results at a site in the Virginia Piedmont indicate potential differences exist between urea and enhanced-efficiency fertilizers after winter fertilizer application. For example, when comparing the ^{15}N isotopic signature (per mil) in the forest floor in the N-volatilization microplots, urea had a lower value (105 per mil) compared to all enhanced-efficiency fertilizers (CUF=210 per mil, NBPT=204 per mil, PCU=186 per mil) in the forest floor 1 day after the winter fertilizer application. A larger ^{15}N value may indicate less volatilization from enhanced-efficiency fertilizers when compared to urea. Ongoing analysis is investigating if this finding is consistent across the major physiographic regions of the southern United States that this study encompasses.

LITERATURE CITED

Albaugh, T.J.; Allen, H.L.; Dougherty, P.M. [and others]. 1998. Leaf-area and above- and belowground growth responses of loblolly pine to nutrient and water additions. Forest Science. 44: 317-328.

Albaugh, T.J.; Allen, H.L.; Dougherty, P.M.; Johnsen, K.H. 2004. Long term growth responses of loblolly pine to optimal nutrient and water resource availability. Forest Ecology and Management. 192: 3-19.

Allen, H.L.; Fox, T.R.; Campbell, R.G. 2005. What's ahead for intensive pine plantation silviculture in the South? Southern Journal of Applied Forestry. 29(2): 62-69.

Blazier, M.A.; Hennessey, T.C.; Dougherty, P.; Campbell, R. 2006. Nitrogen accumulation and use by a young loblolly pine plantation in southeast Oklahoma: effects of fertilizer formulation and date of application. Southern Journal of Applied Forestry. 30: 66-78.

Borders, B.; Bailey, R.L. 2001. Loblolly pine - pushing the limits of growth. Southern Journal of Applied Forestry. 25(2): 69–74.

Fox, T.R.; Burger, J.A.; Kreh, R.E. 1986. Effects of site preparation on nitrogen dynamics in the southern Piedmont. Forest Ecology and Management. 15: 241-256.

Fox, T.R.; Jokela, E.J.; Allen, H.L. 2007. The development of pine plantation silviculture in the southern United States. Journal of Forestry. 105(5): 337-347.

Jokela, E.J.; Martin, T.A. 2000. Effects of ontogeny and soil nutrient supply on production, allocation, and leaf area efficiency in loblolly and slash pine stands. Canadian Journal of Forest Research. 30: 1511-1524.

Mead, D.J.; Pritchett, W.L. 1975. Fertilizer movement in a slash pine ecosystem. 1. Uptake of N and P and N movement in the soil. Plant and Soil. 43: 451-465.

Miller, H.G. 1981. Forest fertilization: some guiding concepts. Forestry. 54(2): 157-157.

Sampson, D.A.; Allen, H.L. 1999. Regional influences of soil available water and climate, and leaf area index on simulated loblolly pine productivity. Forest Ecology and Management. 124: 1-12.

Sedjo, R.A.; Botkin, D. 1997. Using forest plantations to spare natural forests. Environment. 30: 15-20.

Vitousek, P.M.; Matson, P.A. 1985. Intensive harvesting and site preparation decrease soil nitrogen availability in young plantations. Southern Journal of Applied Forestry. 9: 120-125.