EFFECTS OF FERTILIZATION AND WEED CONTROL ON SECOND ROTATION GROWTH AND SOIL NUTRIENT AVAILABILITY IN JUVENILE LOBLOLLY PINE PLANTATIONS IN NORTH FLORIDA

Praveen Subedi, Eric J. Jokela, Timothy A. Martin, and Jason G. Vogel[1]

Evolution in silvicultural practices during the past few decades has resulted in increased productivity over a wide range of southern pine sites (Fox and others 2007). Improved site preparation, competing vegetation control, fertilization, and deployment of genetically superior planting stock have all enhanced the productive potential and yield of these forests (Colbert and others 1990, Jokela and others 2004). Although the costs for adopting intensive management systems for southern pine plantations are high, financial returns from these short-rotation and high-yielding systems are promising (Allen and others 2005). As a result, southern pine plantations in the southern United States are now among the most intensively managed forests in the world.

At the same time, concerns over the sustained productivity of intensively managed forests is increasing as a result of possible site nutrient depletion from frequent harvests, alteration of soil properties (Powers 1999), and depletion of soil carbon from sustained elimination of competing vegetation (Vogel and others 2011). Fertilization and weed control treatments are commonly adopted in southern pine plantations to enhance overall productivity (Fox and others 2007). The areal extent of annual fertilization in southern pine plantations has, thus, increased by almost 5-fold when compared to the early 1990s (Albaugh and others 2007). In the last decade, fertilizer prices have increased by almost 3-fold due to changing global supply and demand (USDA 2012). In that context, understanding the role that historic silvicultural treatments like nutrient additions and competing vegetation control have on growth dynamics and soil nutrient availability in successive rotations is critical to improve our understanding and development of intensive forest management systems.

On a north Florida Spodosol, we investigated the inter-rotational effects of fertilization and weed-control treatments on the growth and soil nutrient availability of juvenile loblolly pine (*Pinus taeda* L.) stands using two randomized complete block design experiments, each consisting of three replicates. These experiments were established on the same site (Ultic alaquods) and treatment plots as the first rotation. The first rotation's treatments were: control (C); fertilizer only (F); weed control only (W); and fertilizer + weed control (FW). Total nutrient additions over the first rotation for the F and FW treatments were (kg ha^{-1}): 1,088 N; 230 P; 430 K; 108 Ca; 72 Mg; 72 S; 4.1 Mn; 5.4 Fe; 0.9 Cu; 4 Zn; and 0.9 B (Jokela and others 2010). Competing understory vegetation in the first rotation was controlled mechanically and chemically in the W and FW treatments for the first 10 years until canopy closure suppressed further establishment (Vogel and others 2011). Prior to the establishment of the second rotation, the understory vegetation was mulched in the C and F treatments to retain this nutrient pool within the plot boundaries. Mulching was not done in the W and FW plots because of the history of sustained understory competition control from the first rotation. The original experiment was whole-tree harvested in May 2009, with harvested trees processed off the treatment plots. Following harvest, a single full-sib loblolly pine family was planted at a 1.8- by 3.0-m spacing in both experiments using containerized seedlings. One experiment was actively retreated (C, F, W, and FW – Actively Managed, Retreated) as in the previous rotation,

[1]Graduate Student, Professor, and Professor, respectively, University of Florida, School of Forest Resources and Conservation, Gainesville, FL 32611; and Assistant Professor, Texas A&M University, Department of Ecosystem Science and Management, College Station, TX 77843.

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.

Table 1--Analysis of variance of total aboveground biomass accumulation by stand age[a] for juvenile loblolly pine stands growing on Spodosols in north Florida

		Stand age (*years*)		
Experiments	Treatments	1	2	3
Actively managed retreated	Control (C)	A	A	A
	Fertilizer only (F)	AB	AB	B
	Fertilizer+ weed control (FW)	B	B	C
	Weed control only (W)	AB	A	AB
	p-Value	0.048	0.004	<0.001
Untreated carryover	Control (C_C)	A	A	A
	Fertilizer only (C_F)	B	B	B
	Fertilizer+ weed control (C_{FW})	A	A	A
	Weed control only (C_W)	A	A	A
	p-value	<0.001	0.001	<0.001

[a]Within a given stand age, treatments followed by same letter are not significantly different (Tukey's HSD at $\alpha = 0.05$).

while the second experiment was left untreated (C_C, C_F, C_W, and C_{FW} – Untreated Carryover).

We estimated total aboveground biomass and nutrient accumulation in loblolly pine by using existing allometric equations developed for the same family growing on similar soil types, along with treatment-specific nutrient concentrations for the various biomass components (Adegbidi and others 2002). In addition, destructive sampling of understory vegetation was conducted to estimate aboveground biomass and nutrient pools among all treatments. Soil nutrient supply rates were estimated for 8 weeks during the growing season using PRS™-probes (Western Ag Innovations, Inc., Saskatoon, SK, Canada) that were buried in the upper 15 cm of the soil. We also estimated the Mehlich III extractable soil nutrient concentrations in the upper 100 cm of soil in the untreated carryover experiment.

Early results, through age 3 years, showed that loblolly pine growth in the second rotation consistently out-performed the first rotation. While the actively retreated FW treatment had significantly higher aboveground biomass accumulation (27.9 Mg ha^{-1}) than the F (17.7 Mg ha^{-1}), W (14.5 Mg ha^{-1}), and C (7.7 Mg ha^{-1}) treatments, the untreated C_F treatment (17.9 Mg ha^{-1}) had higher aboveground pine biomass than the C_{FW} (12.3 Mg ha^{-1}), C_C (9.8 Mg ha^{-1}), and C_W (9.6 Mg ha^{-1}) treatments (fig. 1, table 1). Nutrient accumulations in the pine mostly followed the biomass accumulation trends [e.g. N (kg ha^{-1}): 124 in the FW versus 37 in the C treatment].

We also observed a shrub-dominated community [e.g. *Ilex glabra* (L.) A. Gray and *Serenoa repens* (Bartr.) Small] in the F and C treatments and a grass-dominated community (e.g. *Andropogan* spp. and *Dicanthelium* spp.) in the FW and W treatments. Similar community composition differences were observed in the untreated carryover experiment. *Ilex glabra* was a major accumulator of nutrients (e.g. N, 45 percent; B, 62 percent; Mn, 82 percent of total understory pool) in the F treatment, and it affected loblolly pine growth. For instance, control of competing vegetation in the FW treatment resulted in an almost 1.5-fold gain in aboveground pine biomass compared to the F treatment.

In the untreated carryover experiment, early differences in pine biomass accumulation between the C_F and C_{FW} treatments was unexpected given the history of comparable nutrient additions during the first rotation. However, higher soil P availability (20.8 µg/10cm^2/8 weeks in C_F versus 8.2 µg/10cm^2/8 weeks in C_{FW}) in the surface soil horizons and its strong correlation with pine growth ($r = 0.8$; $p < 0.01$) suggested that the nutrient pools present in the forest floor and understory vegetation from the first rotation (Vogel and others 2011) served as an important nutrient source, especially for P, upon their mineralization in the second rotation.

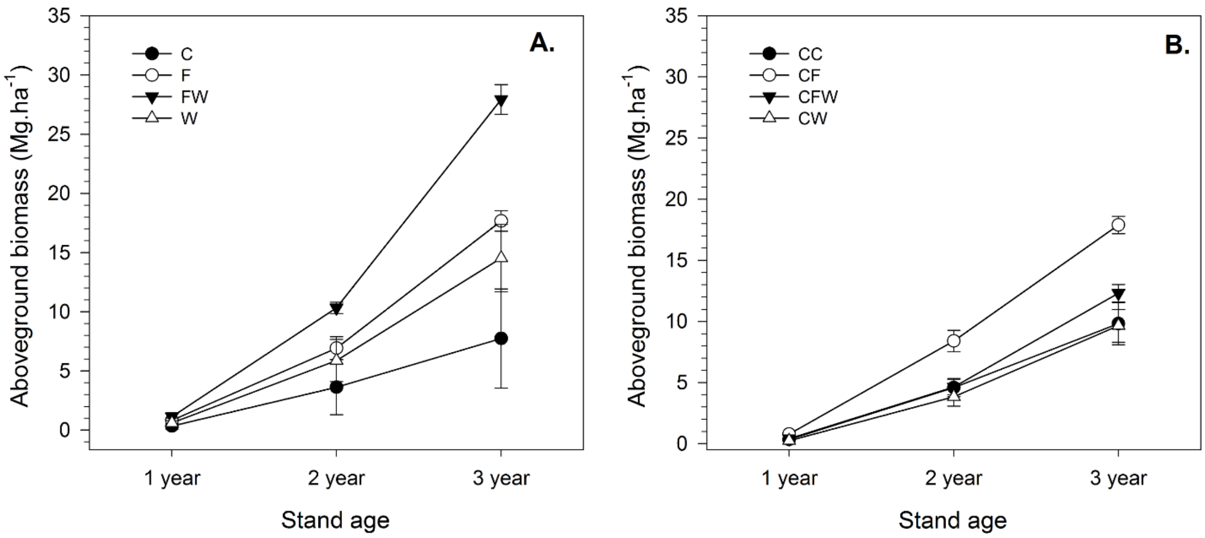

Figure 1--Total aboveground biomass accumulation for second rotation loblolly pine stands growing in (A) the actively managed retreated, and (B) untreated carryover experiments on Spodosols in north Florida. The notations C, F, FW, and W represent, respectively, the plots that received control, fertilizer only, fertilizer + weed control, and weed control only treatments in both rotations. The notations C_C, C_F, C_{FW}, and C_W, respectively, represent the untreated carryover plots that only received treatments in the first rotation: control, fertilization only, fertilization + weed control, and weed control only treatments. Error bars represent standard deviations.

In addition, historical P movement from the E to the Bh and Bt horizons [P (mg kg^{-1}): 11.4 in 0 to 20 cm, 27.5 in 50 to 100 cm], in the absence of understory vegetation, especially for the C_{FW} treatment, may have contributed to early P limitations and reduced growth. Our results suggest that understory mulching and forest floor incorporation may alleviate the need for P fertilization during stand establishment on sites previously fertilized with P.

LITERATURE CITED

Adegbidi, H.G.; Jokela, E.J.; Comerford, N.B.; Barros, N.F. 2002. Biomass development for intensively managed loblolly pine plantations growing on spodosols in the southeastern USA. Forest Ecology and Management. 167: 91-102.

Albaugh, T.J.; Allen, H.L.; Fox, T.R. 2007. Historical patterns of forest fertilization in the southeastern United States from 1969 to 2004. Southern Journal of Applied Forestry. 31: 129-137.

Allen, H.L.; Fox, T.R.; Campbell, R.G. 2005. What is ahead for intensive pine plantation silviculture in the South? Southern Journal of Applied Forestry. 29: 62-69.

Colbert, S.R.; Jokela, E.J.; Neary, D.G. 1990. Effects of annual fertilization and sustained weed control on dry matter partitioning, leaf area, and growth efficiency of juvenile loblolly and slash pine. Forest Science. 36: 995-1014.

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: 337-347.

Jokela, E.J.; Dougherty, P.M.; Martin, T.A. 2004. Production dynamics of intensively managed loblolly pine stands in the southern United States: a synthesis of seven long-term experiments. Forest Ecology and Management. 192: 117-130.

Jokela, E.J.; Martin, T.A.; Vogel, J.G. 2010. Twenty-five years of intensive forest management with southern pines: important lessons learned. Journal of Forestry. 108: 338-347.

Powers, R.F. 1999. On the sustainable productivity of planted forests. New Forests. 17: 263-306.

USDA. 2012. USDA Economic Research Service - fertilizer use and price. http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#26727. [Date accessed: March 3, 2013].

Vogel, J.G.; Suau, L.J.; Martin, T.A.; Jokela, E.J. 2011. Long-term effects of weed control and fertilization on the carbon and nitrogen pools of a slash and loblolly pine forest in north-central Florida. Canadian Journal of Forest Research. 41: 552-567.