



Post-thinning density and fertilization affect *Pinus taeda* stand and individual tree growth



Timothy J. Albaugh^{a,*}, Thomas R. Fox^a, Rafael A. Rubilar^b, Rachel L. Cook^c, Ralph L. Amateis^a, Harold E. Burkhart^a

^a Virginia Tech Department of Forest Resources and Environmental Conservation, 228 Cheatham Hall, Blacksburg, VA 24061, United States

^b Cooperativa de Productividad Forestal. Facultad de Ciencias Forestales, Universidad de Concepción, Victoria 631, Casilla 160-C, Concepción, Chile

^c Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695-8008, United States

ARTICLE INFO

Article history:

Received 9 January 2017

Accepted 21 April 2017

Available online 28 April 2017

Keywords:

Nitrogen

Phosphorus

Increment

Loblolly pine

ABSTRACT

We installed a thinning and fertilization study at five sites in mid-rotation *Pinus taeda* L. stands in the southeastern United States to examine treatment effects on diameter growth, basal area production, and volume increment. The treatments were four levels of post-thinning stand density (247, 494, 741 and 1235 stems ha⁻¹) and two levels of fertilization (none and 224 and 28 kg ha⁻¹ of elemental nitrogen and phosphorus, respectively), applied in four replications at each site using either a randomized complete block (3 sites) or a split plot (2 sites) design. Six years after treatment, thinning significantly increased diameter and diameter increment as the residual density level decreased and increased stand basal area, stand basal area increment, stand volume and stand volume increment as residual density level increased at all sites. Fertilizer significantly increased diameter and stand basal area increments at two sites and stand volume increment at one site; these sites had low initial leaf area index, a metric commonly used to assess the potential for response to fertilization. Diameter increment increased as initial diameter class increased. Larger trees grew faster than smaller trees at all sites and for all treatments. Diameter growth decreased as initial stand basal area increased, and fertilization significantly increased diameter growth for a given level of initial stand basal area at sites where fertilization affected diameter growth. Stand volume increment increased as diameter increment increased for crop trees (largest 247 stems ha⁻¹), whereas stand volume increment decreased as diameter increment increased for all trees. The stand-scale 'cost' for greater individual-tree diameter growth was a reduction in stand volume increment in the 247 stems ha⁻¹ treatment; this reduction was 13 m³ ha⁻¹ yr⁻¹ across all sites compared with the 1235 stems ha⁻¹ treatment, whereas the individual tree diameter growth 'benefit' was 0.9 cm yr⁻¹ when comparing these same treatments. Trade-offs were quantified between individual tree size and stand growth across the thinning and fertilization levels imposed in this study, which will be useful in empirical and process-based modeling efforts for predicting thinning and fertilization responses of *P. taeda*.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Thinning and fertilization are tools that forest managers can use to manipulate resource availability and how resources are allocated to individual trees within a stand. Fertilization increases resource availability by the direct application of limiting nutrients, whereas thinning affects the allocation of existing light, mineral nutrient, and water to the residual trees. Fertilization improves

growth by increasing leaf area index in nutrient-limited stands (Albaugh et al., 1998; Vose and Allen, 1988). Thinning reduces stand-scale leaf area by removing trees, although the residual stand may benefit from having more available site resources allocated to fewer trees. Total gross stand production (removals plus mortality plus final harvest) in a thinned stand will be less than in a non-thinned stand (Burkhart and Amateis, 2012); consequently, thinning removals are often relatively light to limit the reduction in stand volume production (Smith et al., 1997). However, the diameter growth response of residual trees after thinning is typically greater with heavier thinning that leaves lower residual

* Corresponding author.

E-mail addresses: Tim_Albaugh@vt.edu (T.J. Albaugh), trfox@vt.edu (T.R. Fox), rafaelrubilar@udec.cl (R.A. Rubilar), rcook@ncsu.edu (R.L. Cook), ralph@vt.edu (R.L. Amateis), burkhart@vt.edu (H.E. Burkhart).

basal area or number of trees per hectare (Bassett, 1969; Fox and Kreh, 2003).

Ecophysiological studies of responses to thinning or to thinning and fertilization indicate that increases in individual tree leaf area and growth efficiency (growth per unit leaf area) are responsible for increases in individual tree and stand growth rates (Blevins et al., 2005; Carlyle 1998; Gillespie et al., 1994; Mitchell et al., 1996). Whereas anecdotal evidence has been available for some time (Chapman, 1942), recent results demonstrated that larger trees on nutrient limited sites grow faster than smaller trees and respond more to fertilization (Carlson et al., 2008). The mechanism for this phenomenon is greater leaf area, resulting in greater light capture and higher light use efficiency (growth per unit of absorbed light) in larger trees (Campoe et al., 2013). Leaf area can vary considerably at the same stand basal area (Albaugh et al., 2004), but little quantitative information is available on how far individual tree leaf area can decline due to low resource availability (light and/or nutrients) before responses to thinning and/or fertilization are adversely affected. Clearly, we need to better understand how light and nutrient limitations affect individual trees and their potential to respond to thinning and/or fertilization.

Thinning combined with fertilization can result in a greater diameter growth response (Sword Sayer et al., 2004). However, from a modeling perspective, relatively little data exist where thinning and fertilization are combined using modern fertilizer prescriptions similar to those presented by Fox et al. (2007) where nitrogen and phosphorus were applied at the same time in *Pinus taeda* L. stands in the southeastern United States. Typically, when 224 and 28 kg ha⁻¹ elemental nitrogen and phosphorus, respectively, are added to nutrient limited mid-rotation stands an increase in growth averaging 3.8 m³ ha⁻¹ yr⁻¹ for an 8 year period is observed (Fox et al., 2007). These prescriptions resulted in relatively recent increases in the level of fertilizer application intensity throughout the southeastern United States where prior to the availability of this information (prior to ~1990) fertilization applications in the southeastern United States were about 80,000 ha yr⁻¹, whereas after that time fertilizer applications increased up to 480,000 ha yr⁻¹ (Albaugh et al., 2007). For the most part, historical thinning response data have been generated from stands that were not fertilized. Consequently, the growth response of individual trees and stands following thinning alone in these circumstances was relatively small (Hasenauer et al., 1997). However, sites with good native site resources demonstrate good responses to thinning (Sword Sayer et al., 2004). Leaf area development in most *P. taeda* stands is limited by nutrient availability rather than light (Albaugh et al., 2006; Vose et al., 1994). Stands with high leaf area indices that are close to their productive potential do not respond to additional fertilization (Zhao et al., 2016). However, fertilization and thinning may interact in fully stocked stands on sites that do not respond to fertilization. For example, fertilization applied after thinning may be needed, even in stands with high leaf area prior to thinning, to provide readily available nutrients for the residual trees to develop the additional canopy needed to fully occupy the site.

Current intensive management practices (e.g. chemical site preparation, tillage where appropriate, herbaceous weed control, early fertilization) provide more available resources on an area basis, and these resources are better utilized by the crop species because competing vegetation is reduced to low levels. As a result, individual tree and stand growth are accelerated, and there is much less variation in individual tree size (McKeand et al., 2000; Nilsson and Allen, 2003). Given typical planting densities (1235–1730 stems ha⁻¹), excellent survival, and rapid early growth (>5 m² ha⁻¹ yr⁻¹), plantations may achieve overstocked conditions (>30 m² ha⁻¹) as early as eight years old, with density-dependent mortality potentially beginning around 40 m² ha⁻¹ of

basal area at these initial density levels (Albaugh et al., 2006). Even though differentiation into crown classes is slow, there may be benefits to focus on larger trees that have sawtimber potential, due to their anticipated higher value per unit volume or weight (Daniels, 2005) (TimberMart-South, 2016). Ultimately, managers want to maximize the net present value of discounted cash flow for their range of site, product, and price conditions. To do so, they need an understanding of individual tree and stand growth responses under different stand densities, and thinning and fertilization regimes as well as the ability to quantitatively model these types of responses. This information will allow them to find the appropriate balance between maximizing stand and individual tree growth.

Numerous questions must be answered to provide this information, including: What is the relationship between stand volume growth and stand density, and how is that relationship affected by fertilization? What is the trade-off between individual tree growth and stand growth, and how is that affected by fertilization? Are there interactions between thinning and fertilization? To begin addressing these issues, we examined these hypotheses: (1) diameter increment is independent of tree diameter class following thinning (there is a zero slope in the relationship between diameter increment and diameter size class); (2) diameter increment is independent of stand basal area following thinning and is not affected by fertilization (there is a zero slope in the relationship between diameter increment and stand basal area after thinning, and this relationship is unaffected by fertilization); and (3) the relationship between stand volume growth (volume increment) and individual tree diameter growth (diameter increment) is the same when examining all trees and crop trees (the slopes are the same for the volume increment versus diameter increment relationship when examining all trees and crop trees after thinning).

2. Methods

2.1. Experimental design

We installed a randomized complete block design (sites 1, 3 and 4) or a split-plot design (sites 2 and 5) with four replications each at five sites in the southeastern United States in *P. taeda* stands. Sites were selected from five physiographic regions with one site in each region (Table 1). Site selection criteria were: mean diameter at breast height greater than 10 cm, average dominant height between 11 and 14 m, basal area greater than 23 m² ha⁻¹, density between 988 and 1482 stems ha⁻¹, no fertilization in the last four years, trees between 10 and 15 years old, and peak leaf area index between 2 and 3. Leaf area index was determined using satellite imagery (Blinn et al., 2012). Prior to treatment and averaged across site, diameter, height, basal area, volume and density were 18.4 cm, 14.1 m, 35.4 m² ha⁻¹, 234 m³ ha⁻¹ and 1305 stems ha⁻¹, respectively (Table 2).

The treatments were fertilization (none or 224 and 28 kg ha⁻¹ of elemental nitrogen and phosphorus, respectively) and thinning (247, 494, 741 and 1235 residual stems ha⁻¹). For the split-plot design, fertilization was the main-plot treatment and thinning was the split-plot treatment resulting in 8 main plots (4 blocks × 2 fertilizer treatments) with 4 subplots (thinning levels) within each main plot. Randomized complete block sites had 32 plots (4 blocks × 2 fertilizer treatments × 4 thinning levels). Each plot consisted of a measurement plot centered inside a larger treatment plot to prevent confounding of treatments. At split-plot sites, treatment plot sizes were 0.16, 0.20, 0.22, and 0.31 ha plot⁻¹ for the 1235, 741, 494 and 247 stems ha⁻¹ treatments, respectively. Treatment plot sizes at randomized complete block sites were 0.20, 0.24, 0.28, and 0.38 ha plot⁻¹ for the 1235, 741, 494 and

Download English Version:

<https://daneshyari.com/en/article/4759430>

Download Persian Version:

<https://daneshyari.com/article/4759430>

[Daneshyari.com](https://daneshyari.com)