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Growth of young loblolly pine trees following pruning

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ABSTRACT

Pruning loblolly pine trees is sometimes practiced to improve wood quality even though reduced growth following treatment may occur. Two experiments were established in February 2000 in the Piedmont region of Virginia, USA, to examine the impact of timing and intensity of pruning on subsequent growth of young loblolly pine trees. Results of one study indicated that there is a window of opportunity during the early portion of stand development where up to 50% of the live crown length can be removed without a significant loss of long-term height or diameter growth. Within a year following pruning at ages 3, 6 and 9 (all pruning treatments occurred prior to crown closure), crown mass had been restored and growth comparable to an unpruned control resumed. By age 11 there were no significant differences in cumulative height or dbh of any of the one-lift pruning treatments and the control. Findings from a second study planted at closer spacings where pruning treatments occurred at crown closure (age 6) showed that pruning some of the trees in a loblolly pine plantation does not result in a loss of long-term height or diameter growth or crown dominance for the pruned trees as compared to their unpruned neighbors. For both studies, growth reductions following pruning were small and transitory.

1. Introduction

As part of an overall forest plantation management strategy, pruning treatments may be applied to enhance wood quality by increasing the amount of knot-free wood thus increasing value from harvested trees. However, the sudden removal of live branches can reduce growth (Alcorn et al., 2008). Thus, management strategies that seek to promote both wood quantity through increased growth and wood quality by removing live crown must weigh the positive impact of pruning on wood quality against any negative effects of such pruning on growth.

The impact on growth due to removal of live branches has been well documented for many plantation-grown species of pine. For example, Karani (1978) reported that growth of *Pinus patula* Schl. and Cham. was reduced when more than 25% of the live crown was removed, and at densities greater than 750 trees ha^{-1} even the 25% treatment resulted in a significant loss of height. For Sugi (*Cryptomeria japonica* Don) the growth reduction occurred at around 30% (Dakin, 1982). For slash pine (*Pinus elliottii*), up to 50% reduction of live crown length produced little growth response (Bennett, 1955) for densities of 478 and 1076 trees ha^{-1}. Young and Kramer (1952) studied growth response of three levels of pruning to specified crown ratios of 50%, 35% and 20% of loblolly pine (*Pinus taeda* L.). They found no effect of pruning on height growth, but diameter and cross-sectional area of the stem was affected by the pruning treatments. For pruning to crown ratios of 52%, 41% and 37%, Burton (1981) found similar results. At these pruning intensities, there was no impact on height growth to a 15 cm top diameter and only the higher levels of pruning experienced a reduction in diameter growth.

From these cases, and others, some common findings emerge. First, there is some level of crown reduction up to which growth is little affected. This critical level varies by species (Pinkard and Beadle, 1998) and in some cases may be influenced by stand density (Karani, 1978).

Second, the impact on diameter growth is considerably more than height growth. Pine trees subjected to artificial pruning will respond by favoring height growth at the expense of diameter growth, presumably to maintain dominance and crown position in the stand while rebuilding photosynthetic capacity.

Third, while pruning can affect both height and diameter growth, the effect is often limited and temporary. Sutton and Crowe (1975) reported that a removal of 20–35% of the live crown reduced growth of *Pinus radiata* D. Don but the response was only for one year following pruning. For *Eucalyptus grandis* Hill ex Maiden, removal of 40–50% of the live crown resulted in a growth reduction for the following two years (Lückhoff, 1967). For *E. grandis*, Bredenkamp et al. (1980) reported that removing 50% of the live crown length reduced growth but did not impact dominance. As long as height growth is not diminished to such a degree that a tree loses its dominant position in the canopy then the effects of pruning will be minimal.

For loblolly pine, one of the most important wood producing species in the southern US, information about growth response to pruning is needed if managers are going to consider implementing

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pruning treatments in intensively managed plantations. The purpose of this report is to present growth results from two designed pruning experiments for intensively managed young loblolly pine trees.

2. The studies

In February 2000, two sites in the Piedmont of Virginia (Appomattox and Patrick Counties) were identified as being suitable for establishment of two pruning studies. Both sites were cutover areas, one of which was burned following harvest. The first pruning experiment, called the "early tree pruning" (ETP) study, examines whether timing of pruning during the first 10 years of stand development and prior to crown closure has a significant and persistent effect on height and diameter growth. Initial results for one of the four pruning treatments of this study were presented by Amateis and Burkhart (2006). The second experiment, called the "some tree pruning" (STP) study, examines the impact of pruning intensity on tree growth and specifically whether it is feasible to prune only some of the trees in a loblolly pine plantation. Some preliminary results for this study were presented by Amateis and Burkhart (2010).

Five treatment plots were randomly assigned within each of four replicates of each study at each site. The planting stock used for both studies was genetically improved 1–0 loblolly pine seedlings. Early silvicultural treatments included herbaceous and woody competition control through the first two years following planting. One fertilization treatment of 225 kg ha^{-1} of elemental nitrogen and 22 kg ha^{-1} of elemental phosphorus were applied at age 2 to all plots of both studies. Branches removed in the pruning operation were cut flush with the stem with lopping shears or pruning saws attached to poles and left on the plots where they fell.

After 11 years, percent survival on a plot basis for the 40 plots of the ETP study averaged 91% (range 75–100%). For the 40 plots of the STP study the mean percent survival was 94 (range 81–100%). Aside from a few relatively minor ice, snow and wind events that broke off tops and branches from some trees, the studies have thrived.

2.1. Early tree pruning (ETP) study

The five treatments for the ETP study included (1) control (unpruned), (2) removing half the live crown length at age 3, (3) removing half the live crown length at age 6, (4) removing half the live crown length at age 9, (5) removing half the live crown length at ages 3, 6 and 9. Square treatment plots of six rows with six trees per row were established at a spacing of 3 m by 3 m; the interior 16 trees were measurement trees. Pruning treatments were applied during the dormant months between the third and fourth, the sixth and seventh, and the ninth and tenth growing seasons. All pruning treatments occurred prior to crown closure.

2.2. Some tree pruning (STP) study

The five treatments for the STP study included (1) control (unpruned), (2) removing one quarter of the live crown length on all trees, (3) removing half the live crown length on all trees, (4) removing one quarter of the live crown length on half the trees, and (5) removing half the live crown length on half the trees. Square treatment plots of eight rows with eight trees per row were established at a spacing of 1.8 m by 1.8 m; the interior 36 trees were measurement trees. For treatments (4) and (5), the choice of which trees to prune was made systematically: tree 1 in row 1 was determined randomly to be pruned or not pruned and then every odd-numbered tree in the plot received the same treatment as tree 1. The even-numbered trees in the plot received the other treatment. Thus, following treatment, the four closest neighbors to each pruned tree were unpruned trees and the four closest neighbors to each unpruned tree were pruned trees. Pruning treatments occurred during the dormant months between the sixth and seventh growing seasons. At time of treatment, crowns had just closed and lower branches were beginning to senesce.

Both studies were measured annually from age 3 during the dormant season. Variables collected on each tree included dbh, height to live crown, total height and two measures of crown width at 90° to each other. Tables 1 and 2 present summary statistics at time of treatment application for the ETP and STP studies, respectively.

3. Methods

Analysis of variance methods in a mixed modeling context were employed to compare the means of specific tree characteristics on the treatment plots to those of the control plot. Dunnett's test (Dunnett, 1955) for multiple comparisons was used to test for differences between treatment plots and the control plot. Individual comparisons (p-values) are adjusted to contain the experiment-wise error rate at 0.05.

3.1. ETP study

A model was specified to examine the growth of three tree characteristics from treatment initiation through age 11:

$$Y_{ijlk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + r(\beta)_{il} + \tau(r)_{li} + \varepsilon_{ijlk} \quad (1)$$

where Y_{ijlk} is the periodic annual increment (PAI) on the ith treatment plot (i = 1–5) at the jth location (j = 1–2) in the lth replication (l = 1–4) for the kth tree (k = 1–16) in each treatment plot for each of three characteristics: diameter growth, height growth, or lateral crown width growth; μ is the mean, τ is the treatment effect, β is the location effect, r is replicate and ε is the error term. Treatment and location were considered fixed effects; replicate within location and plot within replicate were considered random effects. Results from applying model (1) to the pre-treatment cumulative age 3 data indicated no significant differences in dbh, height or crown width. That is, immediately prior to entering the period of the study when treatments would be applied, there were no significant differences in height, dbh or mean crown width among the plots.

3.2. STP study

In order to address the question of how pruning intensity affects growth, two models were used. Model (1) was employed to examine the main plot-level treatment effects on diameter growth, height growth and lateral crown width expansion. A second model was specified to examine the within plot treatment effects for the two treatment plots where half the trees were pruned and half remained unpruned:

$$Y_{ijlmk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + r(\beta)_{il} + \tau(r)_{li} + \gamma_m(\tau_i) + \varepsilon_{ijlmk} \quad (2)$$

where $\gamma_m(\tau_i)$ is the subgroup of pruned or unpruned trees nested within the treatment plot; all other variables are as previously defined except that the number of trees in each treatment plot is 36 (k = 1–36). Treatment, location and subgroup were treated as fixed effects and replicate within location and plot within replicate were treated as random effects. At the end of the sixth growing season immediately prior to treatment application, there were no significant differences in height, dbh or crown width among the plots.