Long-term responses in the growth and defense of loblolly pine to changes in carbon and nutrient availability

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Introduction

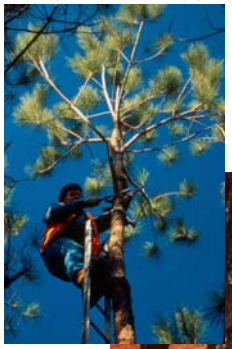
- Silvicultural practices such as thinning and fertilization influence the availability of carbon and nutrients for whole-tree physiological processes.
- Changes in resource availability influence tree growth and defense.
- Understanding tree responses to such environmental changes can aid in devising silviculture practices that enhance tree growth and resistance against pests.
- The growth differentiation balance hypothesis (GDBH) and optimal allocation theory are leading alternative models for understanding phenotypic changes in plant growth and defense.

Methods

- Factorial manipulation in 1993 of the availability of carbon and nutrients to loblolly pine in the Kisatchie National Forest of Louisiana.
  1. Manipulation of carbon acquisition potential by thinning around some trees, pruning the live crown of other trees to 50%, and leaving some trees as controls.
  2. Half of the trees in each crown treatment were fertilized (NPK)
- Measurement of growth, constitutive resin defenses, and inducible resin defenses in short term (1-3 years) and long term (13 years later).

Theoretical predictions

- Thinning enhances, and pruning reduces, whole plant carbon acquisition and therefore enhances growth and/or defense.
- Fertilization eases nutrient limitations on growth, which shifts carbon allocation towards toward growth, and therefore reduces carbon for resin defenses (GDBH).
- In the longer term, trees will adjust their resource acquisition such that their resin defenses tend to return to that of unmanipulated trees (optimal allocation theory).



Clockwise from left: pruning operation in 1993; SPB battling pitch tube; Dünya Öne with a study tree after depletion wounding in year 13 of study; Peter L. Lorio, Jr. measuring the pruned branches from one tree.

Growth

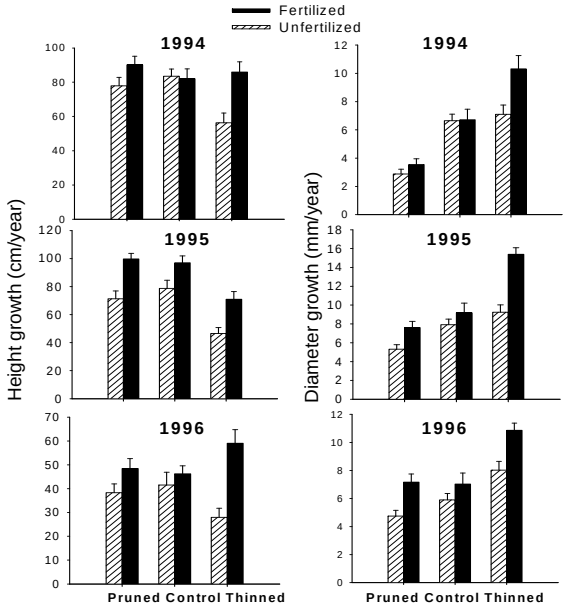


Figure 1. Both thinning and fertilization increased height and diameter growth, especially in the short term.

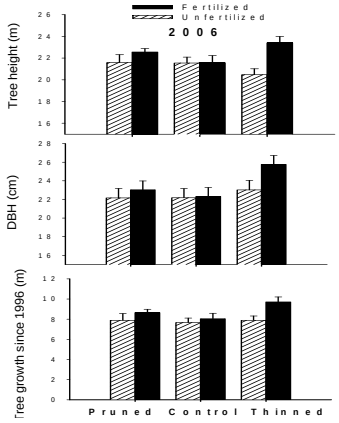


Figure 2. Effects of thinning on height and diameter growth were persistent in the long-term.

Defense

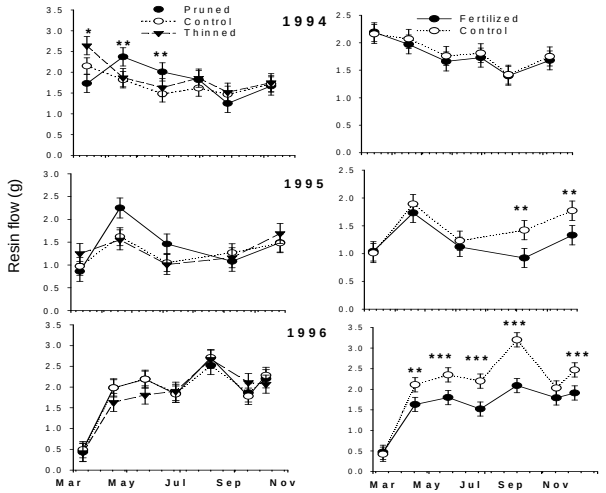
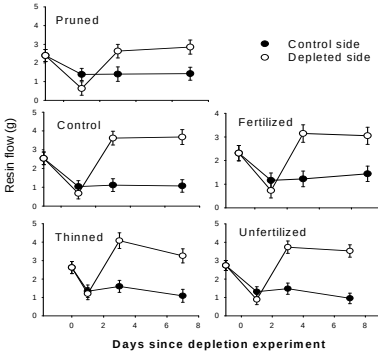


Figure 3. In the short term (3 years), increased growth from fertilization was associated with reduced resin defenses (as predicted by growth-differentiation balance hypothesis), but crown manipulations had little or no effect on resin defenses. Asterisks indicate significant differences among treatments * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.



In the long term, effects of fertilization on resin flow disappeared (as predicted by optimal allocation theory), and there were still no effects of crown manipulations on constitutive resin flow. However, previous thinning enhanced the capacity of trees for rapidly inducible synthesis of resin following depletion of constitutive resin.

Figure 4. Crown manipulations 13 years previously influenced the extent to which resin flow was depleted by standardized wounding. The day after resin depletion treatments (day 1), the resin flow (±SE) from thinned trees was only reduced by 27 ± 6 %, compared to 47 ± 6 and 51 ± 6 for control and pruned trees ($F_{2,72} = 4.45$, $p = 0.015$).

Conclusions

- Apparently, long-term increases in carbon acquisition potential, as occurs in thinned stands, can enhance the efficacy of inducible resin defenses.
- The high susceptibility to bark beetles of overstocked pine stands could be partly a result of low capacity for inducible resin defenses during the early stages of beetle attacks.
- This suggests that silvicultural thinning can reduce long term risks from the southern pine beetle by enhancing tree defenses.

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