Root Growth Potential of Loblolly Pine Seedlings After Defoliation To Mimic Browsing Damage

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Abstract

Defoliation of recently planted pine seedlings by mammalian herbivores and insects can hinder seedling establishment. The extent of browsing damage is often reported using aboveground tissue assessments. The effect on root growth belowground from the removal of photosynthetic tissue, however, may also contribute to poor seedling establishment and growth. Loblolly pine (*Pinus taeda* L.) seedlings were subjected to five defoliation treatments to mimic a range of browsing damage. Their root systems were then suspended in aerated aquariums for 28 days to determine root growth potential (RGP) and root-collar diameter (RCD) growth. Removing all foliage resulted in very low RGP and negative RCD growth. Removal of the bottom half, top half, and side foliage from seedlings resulted in some root production but significantly less than seedlings with no foliage removed. This study demonstrates the need for current photosynthate to support root development and also shows the potential growth and vigor reductions depending on browsing severity.

Introduction

In areas of the South where cattle ranged in proximity to pine (*Pinus* sp.) seedling outplanting sites, foraging and trampling were an issue for seedling growth and survival (Boyer 1967). Today, with less impact from free-ranging cattle, pine seedling growth and survival are often affected by herbivore browsing, such as by deer (*Odocoileus* sp.) (Burney and Jacobs 2010) and rabbits (Leporidae family) (Burns 1961). In many cases, even insects such as the pine sawfly (*Neodiprion* sp.), for example, can severely defoliate seedlings after outplanting (Raffa et al. 1998). Seedling damage can range from partial browsing of the foliage and branches to a complete removal of the shoot (stem, branches, and foliage) near the ground. Such damage could cause seedling mortality or the seedling to be stunted in growth after the shoot is able to somewhat recover and grow new flushes of foliage. As a result, the return on investment that was initially calculated for a reforested site may be reduced if seedlings require re-planting or become of less merchantable quality. Graham et al. (2010) recommend being strategic when re-foresting an area by considering the land use of animals to minimize the potential of seedling damage.

Shelton and Cain (2002) evaluated the response of 1-year-old loblolly pine (*Pinus taeda* L.) seedlings to simulated browsing and reported that when clipped below the cotyledon, all seedlings in the trial died because of the lack of a dormant bud. In the same trial, when loblolly pine seedlings were clipped above the cotyledons in February (dormant season) and in April, seedling survival was above 95 percent and height growth was good at both clipping times, especially in the dormant season clipping (Shelton and Cain 2002). In another trial, when 50 percent or 75 percent of the terminal shoot was removed from western redcedar (Thuja plicata Donn.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings, controlled-release fertilizer applications assisted in the initiation of height growth and recovery from the damage (Burney and Jacobs 2010).

Seedling outplanting success and subsequent recovery from browse damage is often assessed using aboveground responses such as height growth. Another important factor to outplanting success is a seedling's ability to produce new roots immediately following outplanting or browse damage to enable access to water and nutrients in the soil. Nursery managers try to produce seedlings with large, fibrous root systems to give seedlings the best chance for survival after outplanting. The larger root systems are thought to establish the seedling more rapidly by exploring a larger volume of soil for resources while utilizing stored photosynthates (carbohydrate molecules produced from photosynthesis that are transported throughout the plant) to build new root tissue. However, larger root systems do not always translate to better survival, as seedlings are dependent, not as much on stored photosynthates in the roots, but on the amount of new photosynthates produced in the existing foliage (Larsen et al. 1989). Seedlings that have endured defoliation by insects and mammalian herbivores may have reduced photosynthetic capacity, and subsequently, a reduced ability to produce new roots.

Seedling root growth potential (RGP) is a measure of new root growth when a seedling is placed in a favorable environment to produce new roots. This measure may give some indication of seedling vigor and potential performance after outplanting and is often used to evaluate nursery treatments or to compare genetic quality (Ritchie and Dunlap 1980). The objective of this trial was to determine the RGP of loblolly pine seedlings after foliage was removed from the main stem to simulate a range of indiscriminate browsing. The null hypothesis of the trial was that foliar removal would have no effect on new root production when placed in a hydroponic system for 28 days.

Materials and Methods

Bareroot loblolly pine seedlings from a half-sib source were grown under standard operational practices at the Louisiana State nursery (Columbia, LA), lifted in February 2014, and placed in cooler storage at Louisiana Tech University (Ruston, LA) on February 21. On February 27, seedlings were subjected to five defoliation treatments designed to mimic browsing damage: (1) complete removal of all needles, (2) removal of the top 50 percent of needles along the main stem, (3) removal of the bottom 50 percent of needles along the main stem, (4) removal of 100 percent of needles along one side of the main stem, and (5) no defoliation (control) (figure 1). No woody tissue was removed in any of the treatments.

Immediately following defoliation treatments, loblolly pine seedlings were randomized and placed in aerated 10-gal (37.9-L) aquariums and covered with a wooden top that enabled seedling roots to be suspended in water (hydroponic system) (figure 2). Prior to the study, the aquariums were spray-painted black to prevent light penetration and algal growth. Each of the 14 aquariums (experimental units) held 24 seedlings with a total of 336 seedlings in the trial. Four seedlings per treatment were represented in each aquarium, with the exception of the side removal treatment, which had eight seedlings per aquarium. The aquariums were arranged in a randomized complete block design on two greenhouse benches.

Figure 1. The defoliation treatments in this study consisted of: (a) complete removal of foliage, (b) top 50 percent of foliage removed, (c) bottom 50 percent of foliage removed, (d) one complete side of foliage removed, and (e) no foliage removed (control). (Photos by Paul Jackson, 2014)

Seedlings were measured after 28 days in the hydroponic system. The number of new white roots greater than 0.25 in (0.63 cm) was counted on each seedling to quantify RGP (figures 3 and 4). In addition, the root-collar diameter (RCD) of each seedling was measured before being placed in the aquariums and again after the 28-day period to determine growth. Analysis of variance was conducted using a General Linear Model and multiple comparisons of means were conducted using Duncan's Multiple Range Test using statistical analysis software (9th ed., SAS Institute, Cary, NC).

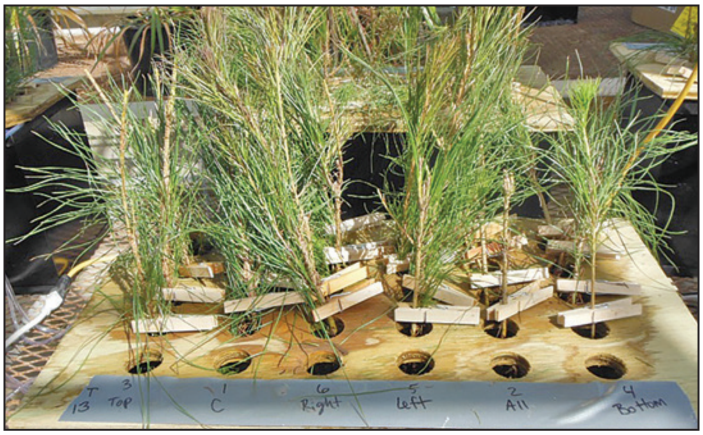

Figure 2. Seedlings from all six defoliation treatments were kept in a hydroponic system for 28 days. (Photo by Paul Jackson, 2014)

Results and Discussion

Root Growth Potential

Root production was significantly influenced by foliar removal treatments to mimic browse damage (figure 5). Removing all of the needles from the seedlings resulted in very low RGP, with a total of 19 new roots produced from all 56 seedlings combined. Removing needles from the top half, bottom half, and the side of seedlings resulted in significantly lower RGP compared with control seedlings (figure 5).

New root growth immediately following outplanting encourages more rapid uptake of water and nutrients, which in turn, increases seedling field establishment (Ritchie and Dunlap 1980). In this trial, very few new roots were produced when all foliage was removed from seedlings. Our findings are similar to those with longleaf pine (*Pinus palustris* Mill.), in which no new roots were produced when all foliage was removed, and intermediate root growth was observed with various amounts of foliage removed (South et al. 2011).

Figure 3. To determine root growth potential in each treatment, new white roots were counted after 28 days in the hydroponic system. (Photo by Paul Jackson, 2014)

Figure 4. An example of new white root growth after 28 days in the hydroponic system. (Photo by Paul Jackson, 2014)

These results confirm that southern pines rely on photosynthetic activity from current foliage to produce root tissue. The fact that any roots were produced at all in the absence of green foliage could be attributed to the woody portions of the stem and young branches remaining intact on the seedlings. The woody tissue may have provided enough stored photosynthates to generate the 19 roots counted on 11 of the 56 seedlings subjected to 100 percent foliar removal.

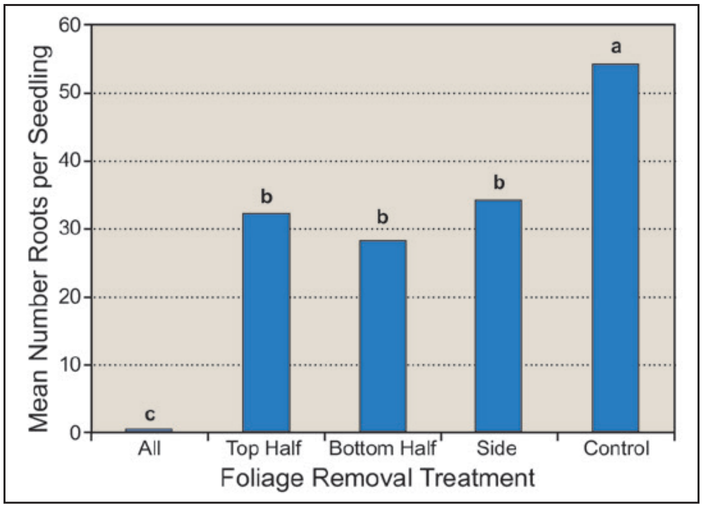

Figure 5. Mean number of new white roots (root growth potential) on loblolly pine seedlings subjected to varying levels of foliage removal to mimic browsing damage after 28 days in a hydroponic system. Means with the same letter are not significantly different based on Duncan's Multiple Range Test. Least significant difference = 16 roots; P > F = 0.0001.

Root-Collar Diameter

Removal of foliage from the entire seedling, the top half, or the bottom half resulted in significantly less RCD growth compared to the control seedlings (figure 6, table 1). In fact, the RCD growth of seedlings subjected to complete foliage removal was negative (figure 6, table 1). This may be the first report of loblolly pine RCD shrinking in a hydroponic RGP trial. Slash pine has exhibited similar RCD shrinkage in a hydroponic trial after being inoculated with the water mold *Pythium* then subjected to 3 weeks of cold storage (Jackson et al. 2012). Barnett (1984) reported a reduction in RCD 1 year after outplanting with container-grown longleaf pine seedlings that were clipped to 5 cm (1.9 in) in the nursery. Without foliage available to carry out photosynthesis, it appears that RCD growth, along with RGP, will be compromised in cases where severe browsing results in total foliar loss. The top and bottom half defoliation treatments also had reductions in RCD compared to control seedlings. This type of browsing damage could directly impact estimated economic gains for a reforested site, as a larger RCD has been correlated to more growth in the field (South et al. 1985).

Future Research Direction and Considerations

The defoliation treatments in this trial were intended to mimic indiscriminate browsing by herbivores and possible removal by insect populations. That is why treatments involving the removal of the top half, bottom half, and side foliage were used in this trial. Researchers that investigate effects from defoliating seedlings usually do so with removal of some percentage of the main stem, moving from the terminal bud downward to the hypocotyl area of the stem, as seen with loblolly pine (Shelton and Cain 2002; South 1998). Therefore, future trials that intend to mimic browsing and test RGP may consider also removing the woody portions in some way, as browsing from animals such as deer could sever the entire stem at the ground level to halfway up the seedling. Many different types of wildlife have a number of different browsing habits.

Table 1. Mean root-collar diameter of loblolly pine seedlings when placed in the hydroponic system (Day 1) and when removed from the hydroponic system (Day 28). Growth differences are shown in figure 6.

Foliage removal treatment	Root-collar diameter (mm)	
	Day 1	Day 28
None (control)	4.81	5.11
100 percent	4.97	4.88
Top 50 percent	5.08	5.09
Bottom 50 percent	4.26	4.35
Side removed	4.94	5.11

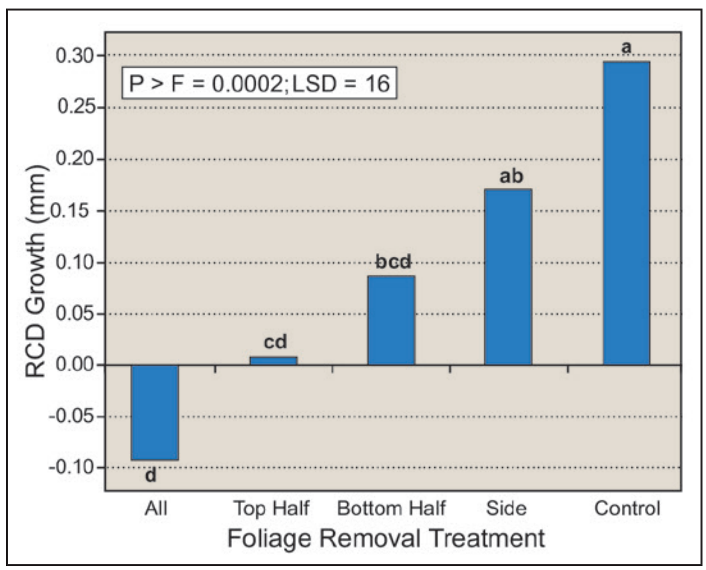

Figure 6 . Mean root-collar diameter growth of loblolly pine seedlings subjected to varying levels of foliage removal to mimic browsing damage after 28 days in a hydroponic system. Means with the same letter are not significantly different based on Duncan's Multiple Range Test. Least significant difference = 0.16 mm; P > F = 0.0002.

It is clear that the amount of foliage present to photosynthesize can determine seedling RGP after outplanting. The location of foliar removal may not serve as a determinant of how seedling RGP or RCD respond. With full foliar removal, however, seedling vigor is severely compromised and can result in no RGP or RCD growth. Seedling response to browsing damage is hard to estimate without testing a range of species, genetic qualities, defoliation treatments, seedling sizes, and outplanting sites. Seedling responses also hinge on seedling quality, which encompass all of these aforementioned factors.

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