OPTIMAL SEEDBED REQUIREMENTS FOR REGENERATING TABLE MOUNTAIN PINE

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Abstract—High-intensity, stand replacement fires have been recommended to regenerate stands of Table Mountain pine *(Pinus pungens* Lamb.) because its seeds require mineral soil to germinate and seedlings are intolerant of shade. Recent prescribed fires have resulted in poor regeneration, even though crown fires created seedbeds with abundant insolation and thin duff. This study examined regeneration success over a range of duff depth and shading in a greenhouse. Root lengths were compared over a range of duff depths. Table Mountain Pine seeds germinated and seedlings survived on seedbeds with abundant insolation and thin duff. However, stem density was significantly higher under moderate shade and on duff up to 4 in. thick. Seedling roots were able to penetrate duff depths up to 4 in. These findings suggest that prescribed fires of sufficient intensity to eliminate shade and expose mineral soil are unnecessary to regenerate Table Mountain pine.

INTRODUCTION

Fire has existed in the Southern Appalachians for thousands of years, ignited both by humans and by lightning. Humans altered the role of lightning by burning outside of the natural fire season of summer. Pyne and others (1996) described the South as "a biotic putty constantly molded and reshaped but kept malleable by chronic burning." Fire exclusion in the modern Southern Appalachians is a result of policies in place on Federal lands for the last 7 to 8 decades and may explain the decline in many plant communities, including Table Mountain pine (*Pinus pungens* Lamb.) (Waldrop and Brose 1999).

Table Mountain pine grows on steep ridge tops and south-facing slopes of the Appalachian Mountains. It ranges from central Pennsylvania to northeastern Georgia. Typically it is found on xeric sites with rocky soils where only a few hardy species are able to survive the harsh environment. Today oaks encroach on these stands, primarily chestnut oak (*Quercus prinus* L.), and hickories. Serotinous cones and thick bark indicate that Table Mountain pine is a fire-adapted species, which needs fire to regenerate.

Past studies indicate that microhabitat plays an important role in seedling survival. Williams and Johnson (1992) noted that seedling emergence and survival was lower on deep litter. Zobel (1969) indicated that extreme fire aids Table Mountain pine reproduction because it destroys competing vegetation and the litter layer. His research suggested that severe fire is necessary for successful Table Mountain pine regeneration. Severe fires kill canopy trees and undergrowth and expose mineral soil (Zobel 1969). Waldrop and Brose (1999) reported opposing results from a study done in northeastern Georgia. They found that the highest fire intensities produced the lowest density of seedlings.

This study compared different duff depth and shade level combinations to determine the best microhabitat for survival. It also determined duff depth and shade level effects on germination, height growth, root development, soil moisture, and survival.

METHODS

The study was conducted in a greenhouse at Clemson University in Clemson, SC, using a split-plot randomized complete block design. The main plot effect was shade, and the subplot effect was duff depth. Shade levels were 0, 38, 52, and 98 percent and duff depths were 0, 2, and 4 in. Each of the three replications consisted of 4 sets of 24 pots. Each set of 24 pots was randomly assigned a shade level treatment while each pot was randomly assigned a duff depth treatment. This pattern resulted in eight subsamples for each duff depth within each set of 24 pots.

Rectangular PVC boxes were constructed and commercial grade shade cloth was sewn to dimensions to slip over the PVC boxes. These boxes were then placed over each set of 24 pots. Mineral soil and duff (O layer) was gathered from an area that had been burned a few weeks prior on the Andrew Pickens Ranger District of the Sumter National Forest in South Carolina. Soil was placed in 6-in. square pots and either 2 or 4 in. of duff was layered on top of the mineral soil.

Seeds used in the study were gathered from three mature, healthy Table Mountain pines in close proximity on the Tallulah Ranger District in northeast Georgia. Seeds were gathered by cutting the trees down and clipping closed cones from the branches. Cones were then heated at 85 °C for about 20 minutes or until the cones began to open. After the cones cooled and the seeds were shaken out, seed viability was tested in the laboratory. Twenty seeds were placed in five petri dishes lined with moistened paper.

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Citation for proceedings: Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

Table 1—Soil moisture by duff depth and shade level

Treatment level	Soil moisture[a] July	August
Duff depth (in.)		
0	2.64a	0.89a
2	3.33ab	2.05b
4	4.10b	2.87c
Shade level		
0	.57a	.30a
Low	1.97b	.62a
Medium	4.06c	2.25b
High	6.83d	4.57c

[a] Means followed by the same letter within a treatment group are not significantly different at the 0.05 level.

Three replications, 18 days each, indicated a 50-percent germination rate.

The greenhouse study began on May 4, 1999, when 25 seeds were placed in each pot. Pots were watered initially and thereafter watering closely followed the rainfall pattern of the first growing season after a prescribed burn in a Table Mountain pine stand in northeastern Georgia (Waldrop and Brose 1999). Rainfall data came from a nearby weather station in Clayton, GA. Watering occurred twice a week during June, once a week in July, and every 10 days in August.

Soil moisture, germination, seedling height, root length, and seedling survival were measured from May 18, 1999, to September 13, 1999. Soil moisture was measured in each pot in July and August. A soil moisture meter was placed in each pot. The moisture was measured on a scale of 0 to 10 where 0 showed no moisture and 10 was fully saturated soil. Seedling germination and survival were measured weekly. New germinants and dead seedlings were counted and recorded for each pot. Seedling height and root length were measured after 3 months and the tallest seedling in each pot was measured. Roots were extracted from the soil, washed, and measured. Total root length and the length of root in mineral soil by duff depth were recorded.

RESULTS AND DISCUSSION

Soil Moisture

Soil moisture was measured to determine the effect of duff depth and shade level as ambient temperature increased and watering became less frequent. In July and August, soil moisture was higher with increased shade and duff (table 1). Soil moisture in July showed a significant difference among all four shade levels. In August there was no significant difference in the 0 and low shade levels, suggesting that medium and high shade levels retain soil moisture by reducing evapotranspiration.

Among duff treatments, in both July and August, soil moisture was highest in 2 and 4 in. of duff. In July the only significant difference in soil moisture was between 0 and 4 in. In August all duff depths were significantly different, suggesting the duff acted as mulch, holding moisture longer. Among all 12 treatment levels (4 shade levels by 3 duff depths) soil moisture was highest under high shade with 4 in. of duff.

Germination

Germination rates ranged from 63 to 71 percent (table 2). There was no statistical difference in percent germination on different duff depths or under different shade levels. Frequent watering during the germination period allowed abundant germination for all treatment combinations.

Seedling Height

Seedling height varied little among duff depths, ranging from 3.5 to 3.8 in. (table 3). Although the range in seedling heights was small, those on 4 in. of duff were significantly taller than those on 0 duff and 2 in. of duff.

Shade level had a more pronounced effect on growth, with seedling heights ranging from 3.0 in. under high shade to 4.1 in. under medium shade. Seedlings grown under low and medium shade were significantly taller than those grown under 0 and high shade. Under high shade, seedlings were probably not getting enough sunlight, although available moisture was plentiful. Zero shade provided plenty of sunlight but lower soil moisture and likely reduced height growth. The optimum combination of shade and duff for height growth was low to medium shade with either 2 or 4 in. of duff. This combination provided enough sunlight without drying the soil.

Table 2—Mean germination by duff depth and shade level

Treatment level	Mean germination[a]
	Percent
Duff depth (in.)	
0	70.7a
2	68.5a
4	63.3a
Shade level	
0	62.6a
Low	67.3a
Medium	69.7a
High	70.6a

[a] Means followed by the same letter within a treatment group are not significantly different at the 0.05 level.

Table 3—Seedling height by duff depth and shade level

Treatment level	Seedling height[a]
	Inches
Duff depth (in.)	
0	3.5a
2	3.6a
4	3.8b
Shade level	
0	3.5a
Low	3.9b
Medium	4.1b
High	3.0c

[a] Means followed by the same letter within a treatment group are not significantly different at the 0.05 level.

Table 4—Root in mineral soil by duff depth and shade level

Treatment level	Root length in soil[a]	Total root length
	- - - - *Inches* - - - -	
Duff depth (in.)		
0	4.4a	4.4
2	3.9b	5.9
4	3.8b	7.8
Shade level		
0	6.0a	
Low	5.3b	
Medium	3.5c	
High	1.3d	

[a] Means followed by the same letter within a treatment group are not significantly different at the 0.05 level.

Root Length

Total root length increased from 4.4 to 7.8 in. as duff depth increased (table 4). This pattern suggests that duff depth partially enhanced root growth as roots grew to reach mineral soil. Past research suggested that postfire duff must be thin so that roots could reach mineral soil (Waldrop and Brose 1999, Williams and Johnson 1992). In this study, however, roots penetrated even the thickest duff (4 in.), and there was no difference in root length in mineral soil for 2 or 4 in. of duff (table 4). Root length in mineral soil averaged 3.9 in.

Root length in mineral soil by shade level was significantly different for all four shade levels. As the shade level decreased, root length increased. Seedlings under high shade were probably allocating greater energy to height growth to reach sunlight and less energy to root growth. The longest roots in mineral soil, 6 in., were in 0 shade.

Survival

Survival was significantly greater in duff depths of 2 and 4 in. as compared to 0 duff; however, there was no significant difference between the 2- and 4-in. treatments with 25 percent survival (table 5). Among shade treatments, medium shade had significantly greater survival with more than double any other shade level. All shade levels with either 2 or 4 in. of duff had greater survival than with 0 duff (fig. 1). Again, duff acts as a mulch by retaining soil moisture. Survival was second highest under high shade (15.9 percent). In 0 and low shade, seedlings were getting plenty of sunlight, but the lack of shade caused soil to dry. The best survival was with medium shade and either 2 or 4 in. of duff. Duff depth did not seem to matter as long as some duff was in place.

CONCLUSIONS

Zobel (1969) stated that regeneration persisted in areas where an intense fire had killed canopy trees and almost all the understory. Seedlings persisted especially where erosion had occurred. Therefore, Zobel (1969) suggested that a severe fire is necessary to successfully regenerate Table Mountain pine when there is a well-developed shrub layer. This study may contradict Zobel's findings, suggesting that Table Mountain pine seedlings are able to tolerate more sunlight and duff depth than he reported.

This study showed that medium shade with either 2 or 4 in. of duff was the best treatment combination for successful survival. Medium shade slows moisture loss through evapotranspiration while allowing enough sunlight for successful survival. Seedling roots can penetrate duff up to 4 in., while duff acts as mulch retaining mineral soil moisture for a longer period.

This study indicates that successful regeneration can be achieved with lower intensity and severity fires than once thought. Lower intensity and severity burning produces less risk for loss of control and leaves more duff and litter intact, thereby reducing the chance of erosion occurring on these steep ridge-top slopes. Most importantly, burning at lower fire intensities and severities increases the burning window. High intensity and severity fires are difficult to

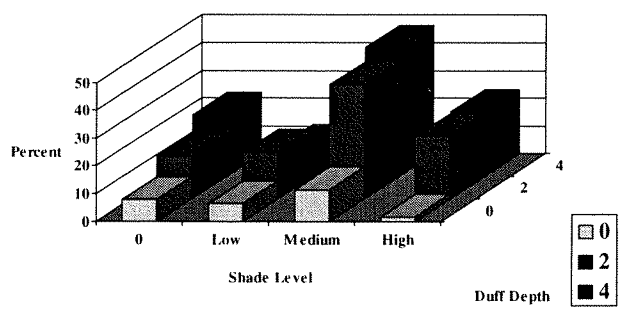

Figure 1—Seedling survival for all combinations of duff depth and shade level.

Table 5—Percent survival by duff depth and shade level

Treatment level	Survival[a]
	Percent
Duff depth (in.)	
0	6.8a
2	24.0b
4	25.5b
Shade level	
0	15.0a
Low	11.3a
Medium	33.0b
High	15.9a

[a] Means followed by the same letter within a treatment group are not significantly different at the 0.05 level.

accomplish because of a limited number of suitable burning days each year.

ACKNOWLEDGMENTS

The authors thank the Clemson University Department of Forest Resources for greenhouse space and the Department of Plant Pathology and Physiology for technical assistance. The U.S. Department of the Interior/U.S. Department of Agriculture, Forest Service Interagency Joint Fire Science Program awarded partial funding for this project.

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