Pine Regeneration Following Wildland Fire

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Abstract—*Pine regeneration following wildland fire continues to be a serious problem across the western and southeastern U.S. Frequency of large wildfires has increased over the last several decades and restoration of these burned areas is a major problem confronting land managers. Prescribed fires are used primarily to reduce heavy fuel loads and secondarily to reduce competition or prepare sites for natural or planted pine regeneration. In 1983, an experiment was initiated near the Fort Valley Experimental Forest to evaluate the growth of ponderosa pine (*Pinus ponderosa[1]*) seedlings planted after a severe wildfire. This study evaluated different herbaceous species effects on survival and growth of ponderosa pine seedlings. The study reported that competition from nonnative grass species (*Dactylis glomerata *and* Agropyron desertorum*) significantly reduced water and nitrogen availability and pine seedling growth; whereas, native grasses (*Bouteloua gracilis *and* Sitanion hystrix*) had no effect on soil resources or pines. In southern Appalachia, pine regeneration success after wildland fire varies depending on fire severity and growing season precipitation. After a high intensity, moderate severity fire on dry southern Appalachian ridges, pitch pine (*Pinus rigida*) seedling germination was high (3,000 seedlings/ha); however, most pine seedlings did not survive beyond the first year due to unusually low precipitation late in the growing season. Even in these mountains that normally receive high precipitation, drought can reduce pine seedling growth and induce mortality. More often, light and nitrogen are the limiting resources to pine seedling growth, and sprouting hardwoods are more competitive than herbaceous species with the regenerating pines. Further studies in southern Appalachia suggest that successful regeneration of pine (e.g.,* Pinus strobus, P. echinata, *or* P. rigida*) after prescribed fire will not be achieved without planting pine seedlings and reducing fast growing hardwood competitors.*

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[1] Plant species nomenclature follows http://plants.usda.gov/

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Introduction

Early ecologists (Haasis 1921, 1923, Pearson 1923) were investigating methods to secure natural regeneration of western yellow pine (*Pinus ponderosa*) since the establishment of Fort Valley Experimental Forest headquarters at Flagstaff in 1908. Restoration of native pine communities continues to be a focus of land managers, particularly following wildland fire (wildfire or prescribed fire) (Hardy and Arno 1996). In this paper, we compare pine regeneration efforts in the Southwest (based on a study by Elliott and White [1987]) to efforts in southern Appalachia (Clinton et al. 1993, Elliott and Vose 1993, Clinton et al. 1997, Elliott et al. 1999, Elliott et al. 2002, Elliott and Vose 2005). Both regions attempt to restore pine forests that have experienced a combination of drought, bark beetle (mountain pine beetle [MPB, *Dendroctonus ponderosae* Hopkins] (Jenkins et al. 2008) or southern pine beetle [SPB, *Dendroctonus frontalis* Zimmermann]), and wildland fire.

Pine Regeneration in the Southwest

In the Southwest, ponderosa pine (*Pinus ponderosa*) forests occur between 1830 to 2590 m (6000 to 8500 ft) in elevation and are semi-arid with ~50 cm (20 inches) of precipitation per year. Historically, natural pine regeneration and overstory recruitment were highly episodic; related to both optimal climate conditions for seed production, seedling germination and growth and longer intervals between surface fires, which allowed seedlings and saplings to reach a stage where they were relatively immune from subsequent burns (White 1985, Grissino-Mayer and Swetnam 2000). On severely burned sites, however, successful regeneration of natural and planted pine was limited by drought and competition with grasses (Korstian and Coile 1938, White 1985, Elliott and White 1987) and at times frost heaving and grazing (Haasis 1923, Korstian 1925).

More than 25 years ago, Elliott and White (1987) studied the effects of competition from nonnative grasses on planted ponderosa pine, a problem that continues to plague forest managers today (Hunter et al. 2006). The results from that early study are still relevant and thus, it may be beneficial to re-examine those findings; and it is timely since that work was influenced by the Fort Valley Experimental Forest research program. In June 1982, a wildfire occurred about 30 km (19 miles) north of the Fort Valley Experimental Forest headquarters, latitude 35° 27', longitude 111° 45', at an elevation of 2290 m (7500 ft). The 20 ha (49 ac) fire was severe, eliminating virtually all plant species. Standing dead trees were left with the exception of larger trees (>30.5 cm [12 in] dbh), which were removed in a salvage logging operation. Ponderosa pine seedlings (2-0 bare root stock) were planted in April 1983 and competitor species were seeded in July 1983, after summer rains had started.

Pine seedlings planted with natural vegetation or native grasses were significantly larger (Figure 1) and had significantly higher soil moisture and plant water potentials than pine seedlings planted with nonnative grasses or forbs (Table 1). *Bouteloua gracilis*, a late-season C4 native grass, was a less efficient competitor for soil moisture due in part to its shallow root system and late season growth and thus does not compete excessively for soil moisture during the early season drought

Table 1. Ponderosa pine predawn xylem water potential (Ψ) and extractable soil nitrogen (0-5 and 5-15 cm soil depths) comparison among various grass species, two growing seasons after a severe wildfire.

		Extractable soil nitrogen (Sept 1984)			
		NO_3-N (mg/l)		NH_4-N (mg/l)	
Treatment	**Ψ (- MPa)**	**0-5 cm**	**5-15 cm**	**0-5 cm**	**5-15 cm**
Bouteloua gracilis	0.54 b	1.60 a	2.68 a	1.96 a	2.40 a
Dactylis glomerata	1.32 a	0.18 b	0.12 b	2.88 b	3.32 b
Agropyron desertorum	1.55 a				
Control (denuded)	0.48 b	4.37 a	3.07 a	2.14 a	2.38 a
Natural vegetation[a]	0.56 b				

[a] Natural vegetation consisted of squirreltail (*Sitanion hystrix* [Nutt.]), mountain muhly (*Muhlenbergia montana* [Nutt] Hitch.), Arizona fescue (*Festuca arizonica* Vasey), lupine (*Lupinus* spp.), and others.

Average values in a column followed by different letters are significantly ($p \leq 0.05$) different according to a nonparametric equivalent to Tukey's multiple comparison test (Dixon 1983). Taken from Elliott and White (1987).

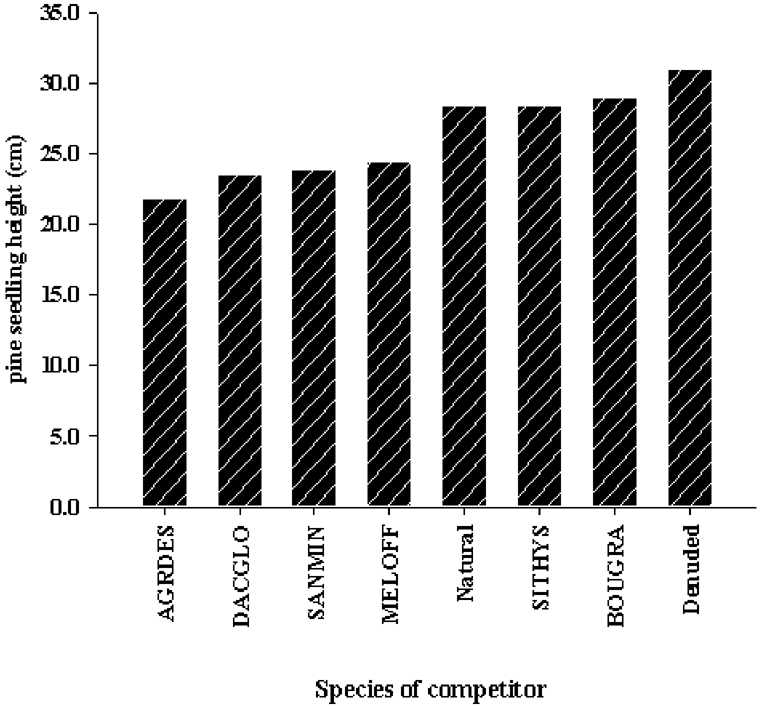

Figure 1. Average ponderosa pine seedling height (cm) on competitor plots at the end of the second growing season after planting a severely burned wildfire site in northern Arizona. Species codes: AGRDES, *Agropyron desertorum* (Fisch.) Schult. (crested wheatgrass); DACGLO, *Dactylis glomerata* L. (orchardgrass); SANMIN, *Sanguisorba minor* Scop. (small burnet); MELOFF, *Melilotus officinalis* (L.) Lam. (yellow sweet clover); SITHYS, *Sitanion hystrix* (Nutt.) J.G. Smith (squirreltail) BOUGRA, *Bouteloua gracilis* ((H.B.K.) Lag ex Steud (blue grama). 'Natural' plots were allowed to become established with any post-fire species, and 'Denuded' plots were periodically weeded to remove all competing vegetation. Single competitor plots were weeded periodically to remove any species other than those assigned to that plot. Average values followed by different letters are significantly different ($p<0.05$) according to Duncan's Multiple Range Test (Dixon 1983).

period. In contrast, pine seedlings growing with *Dactylis glomerata* or *Agropyron desertorum*, early-season C3 nonnative grasses, were smaller (Figure 1) and had lower plant water potentials (Table 1) during periods of low precipitation and low soil moisture. From this research (Elliott and White 1987), it would appear that native species are a good choice for re-vegetating sites after wildfire, particularly if those sites will be planted with ponderosa pine.

The trade-off, of course, is whether the late-season native species will occupy severely burned areas fast enough to control erosion and water runoff (Robichaud et al. 2000; Robichaud 2005). More recent studies have shown that native periennial forbs, such as yarrow (*Achillea millifolium*) and fireweed (*Chamerion angustifolium*), are more effective for increasing plant cover and reducing bare soil cover (Peterson et al. 2007). However, it is not known how competitive these forbs would be with natural or planted pine seedlings. Thus, the balance between restoring ponderosa pine and reducing erosion by rapidly revegetating severely burned sites continues to be a management dilemma in the southwest (Hunter et al. 2006).

Pine Regeneration in Southern Appalachia

In the southern Appalachian mountains, where annual precipitation is >150 cm (60 in), the ecoregion is described as 'sub-tropical mountains' (Bailey 1995). Mixed pine-hardwoods occupy the driest sites (i.e., upper slopes and ridges) where yellow pines [pitch (*Pinus rigida*), Virginia (*P. virginiana*), Table Mountain (*P. pungens*), and/or shortleaf (*P. echinata*)] are mixed with oaks [scarlet (*Quercus coccinea*), chestnut (*Q. montana*), and white (*Q. alba*)] and other hardwoods [red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*)]. Over the past century, pine-hardwoods have been on a trajectory of increased pine overstory mortality, a lack of tree regeneration, loss of ground layer herbs and grasses (Elliott et al. 1999,Vose and Swank 1993, Vose 2000), and expansion of mountain laurel (*Kalmia latifolia*) (Dobbs 1998). The most recent SPB outbreak (1999-2002) resulted in extensive and widespread pine mortality.

Forest managers prescribe fire as a silvicultural treatment in pine-hardwood forests (http://www.fs.fed.us/fire; http://www.nature.nps.gov/firemanagement) to reduce fuel load, to restore diversity and productivity (Clinton et al. 1993, Clinton and Vose 2000), and to promote regeneration of native pines and oaks (Vose 2000). Fire reduces mountain laurel and delays its growth (Clinton et al. 1993), encourages oaks and other tree species including pines to sprout (Elliott et al. 2004), and provides a seedbed for native pine germination and establishment (Elliott et al. 1999, Waldrop et al. 2000).

Fire research in southern Appalachia has investigated the effects of wildland fire on ecosystem processes such as net primary production, nutrient and carbon cycling, and vegetation dynamics (http://www.srs.fs.usda.gov/coweeta). Part of this program is to assess restoration of pine-hardwoods (Clinton and Vose 2000) by evaluating the competitive environment of planted and naturally regenerating pine (Elliott and Vose 1995, Elliott et al. 2002). On ridge sites, where fire intensity is highest, stand-replacing fires can consume understory vegetation and ignite crowns. Pitch pine and Table Mountain pine seedling germination may be high (Waldrop et al. 2000). However, pine seedlings may not survive beyond the first year (Figure 2) when precipitation in late summer is below the long-term average (Elliott et al. 1999).

Other fire studies have focused on restoration of shortleaf pine/bluestem grass communities (Hubbard et al. 2004). Prescribed burn treatments were intended to reduce competition; promote regeneration of shortleaf pine; and promote a diverse ground flora including native bluestem grasses (*Andropogon gyrans*, *A. gerardii*, and *Schizachyrium scoparium*) (Elliott and Vose 2005). While some undesirable species were reduced (Figure 3), hardwoods and blueberries (*Vaccinium* spp.) were more abundant, and shortleaf pine and bluestem grass did not regenerate (Figure 3). Elliott and Vose (2005) concluded that more aggressive treatments would be necessary to restore shortleaf pine and native bluestem grass on these sites.

Another study was designed [http://www.firescience.gov/JFSP_Search/Vose] with collaboration from the Cherokee National Forest, Tennessee to restore shortleaf pine/bluestem grass in forests heavily impacted by SPB induced tree mortality. Following burn treatments (March 2006), shortleaf pine seedlings were hand planted (~ 270 seedlings/ha [110 seedlings/acre]) and native bluestem grass seeds were broadcast spread. Survival of planted pine averaged 75% the first growing season; whereas, establishment of bluestem grass did not occur until the second growing season. Preliminary results suggest that planting shortleaf pine and seeding bluestem grass could accelerate the recovery of these forests.

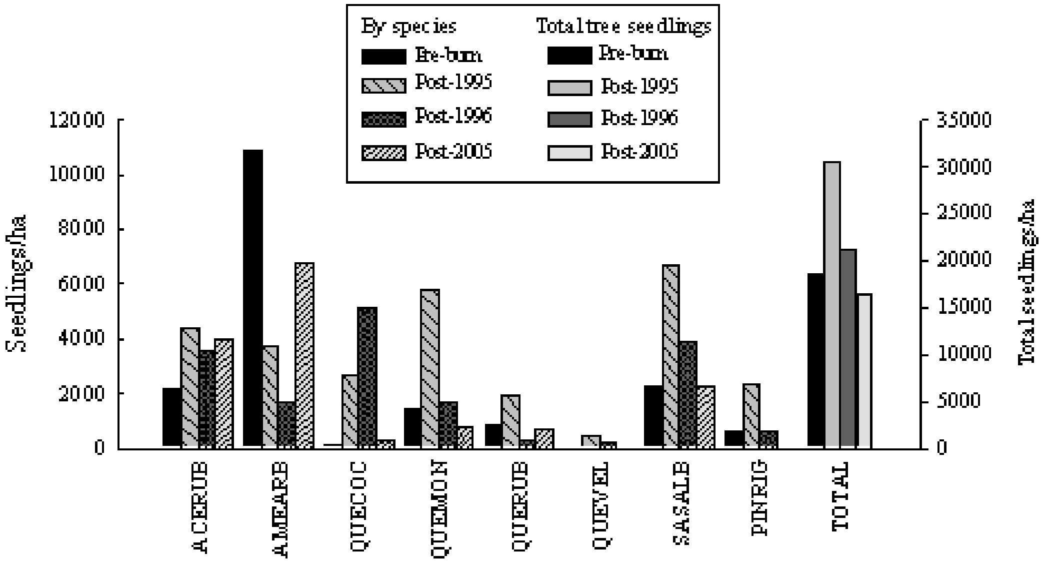

Figure 2. Changes in number of tree seedlings after prescribed fire in the Wine Spring Creek watershed, western North Carolina; pre-burn (1994) and the first (1995), second (1996) and tenth (2005) growing seasons post-burn. Species codes: ACERUB, *Acer rubrum*; AMEARB, *Amelanchier arborea*; QUECOC, *Quercus coccinea*; QUEMON, *Quercus montana*; QUERUB, *Quercus rubra*; QUEVEL, *Quercus velutina*; ROBPSE, *Robinia pseudoacacia*; SASALB, *Sassafras albidum*; PINRIG, *Pinus rigida*. Species nomenclature follows Gleason and Cronquist (1991).

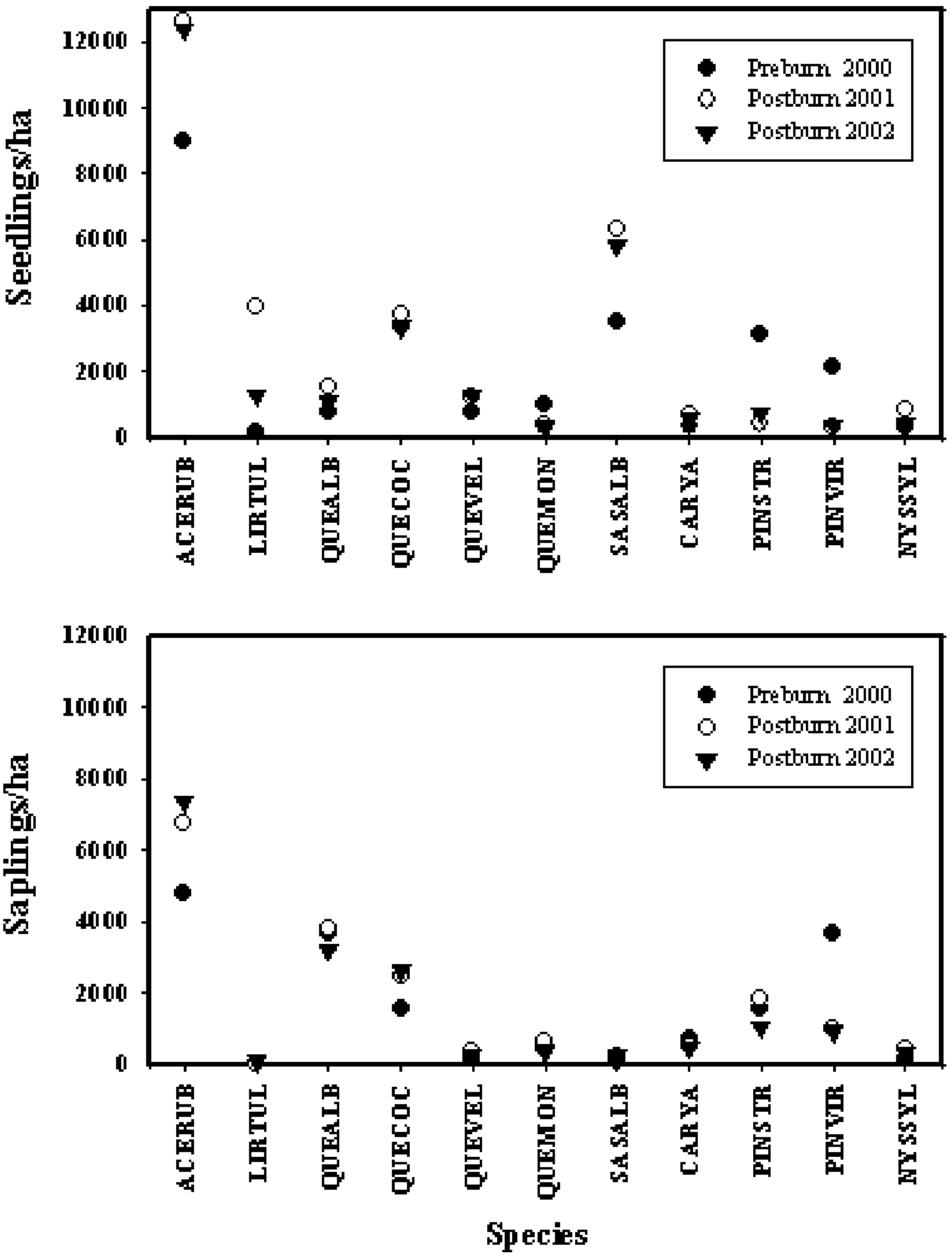

Figure 3. Changes in number of tree seedlings (<0.5 m height) and saplings (>0.5 m height, <5.0 cm dbh) after prescribed fire in the Conasauga River Watershed, eastern Tennessee and north Georgia: pre-burn (2000) and the first (2001) and second (2002) growing seasons post-burn. Species codes: ACERUB, *Acer rubrum*; LIRTUL, *Liriodendron tulipifera*; QUEALB, *Quercus alba*; QUECOC, *Quercus coccinea*; QUEVEL, *Quercus velutina*; QUEMON, *Quercus montana*; SASALB, *Sassafras albidum*; CARYA, *Carya* spp.; PINSTR, *Pinus strobus*; PINVIR, *Pinus virginiana*; NYSSYL, *Nyssa sylvatica*. Species nomenclature follows Gleason and Cronquist (1991).

Summary

Costly and dramatic post-fire rehabilitation (i.e. erosion control) efforts, such as those used in the western states, are not required in southern Appalachia. Even after severe fire, recovery rates of Appalachian forests are much faster than southwestern forests due to rapid vegetative re-growth. However, this re-growth may not have the desired species composition that restores native pines or oaks to the pine-hardwood forest. Thus, restoring ecosystems after wildland fire by establishing pine regeneration can be problematic in both the southwest and the southern Appalachians. In the Southwest, pine regeneration is often limited by competition from seeded nonnative grasses and the most limiting resource is water. In southern Appalachia, pine regeneration is also limited by competition, but the most aggressive competitors are fast-growing hardwood sprouts. Even though water can limit establishment of pine seedlings, the most limiting resource to pine seedling growth is light.

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