RESTORATION PLANTING OF PITCH AND SHORTLEAF PINES AFTER CLEARCUTTING A MIXED HARDWOOD STAND ON A RIDGE SITE IN THE SOUTHERN APPALACHIANS: LESSONS LEARNED AFTER 13 YEARS

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ABSTRACT

Southern yellow pines (*Pinus* spp.) are not regenerating in formerly mixed hardwood—pine stands on low elevation ridges in the Southern Appalachians, resulting in loss of biodiversity. The purpose of this study was to evaluate clearcutting and planting as a regeneration method for restoring a pine component in a mixed hardwood stand on a ridge site. The study objective was to test for differences of stocking, diameter breast height (d.b.h.), and basal area between pitch (*P. rigida*) and shortleaf (*P. echinata*) pines at crown closure, 13 years after planting. One year after clearcut harvesting the mature mixed oak (*Quercus montana*, *Q. coccinea*) stand, 1-0 bare-root seedlings were bar planted 1.83 m apart in rows spaced 2.44 m (2,220 trees/ha) in four, 0.05 ha plots. All pine and hardwood reproduction ≥0.1 cm was inventoried by d.b.h. class on 5, 1/1000 ha sample subplots on each plot. The regenerated stand basal area of 9.56 m^2/ha was distributed among yellow pines 13 percent, oaks 17 percent, yellow-poplar (*Liriodendron tulipifera*) and other shade intolerant species (29 percent), red maple (*Acer rubrum*) and other shade tolerant species 37 percent and mountain laurel (*Kalmia latifolia*) 4 percent. There were no differences in reproduction between the two pine species. The most surprising result of this study was the dominance of yellow-poplar reproduction on the dry, southwest facing ridge summit, a species that was absent in the preharvest stand. The surviving dominant and codominant pines, which tended to occur in scattered small groups of two-to-five trees, will likely be a continuing canopy component of the maturing stand. Preliminary results from this study suggest that clearcutting small patches of mixed hardwoods and planting yellow pine seedlings provides resource managers with a low-cost option for restoring habitat biodiversity on dry, oak-dominated sites.

INTRODUCTION

Within the predominantly, hardwood dominated oak-hickory (*Quercus-Carya*) forests of the Southern Appalachian Mountains, vegetative communities on low-to-moderate elevation (<1060 m) dry ridges typically include a minor component of several species of southern yellow pines (*Pinus* spp.), particularly shortleaf pine (Harmon 1982, Jenkins 2007) (fig. 1). Periodic wildland fire was previously a common disturbance on these sites, which created conditions favorable for natural reproduction of pines (Barden and Woods1976, DeVivo 1991, Welsch 1999). The combination of fire suppression during the 1900s and periodic outbreaks of the endemic southern pine beetle (*Dendroctonus frontalis*) has resulted in composition changes from mixed hardwood-pine communities to predominantly hardwood dominated stands in the Southern Appalachians and throughout the interior uplands of the Southeastern United States (Guldin and Black 2018). The associated reduction of biodiversity resulting from loss of yellow pines affects habitat for birds and mammals (Eddleman and others 2007, Masters 2007), including Indiana bats (*Myotis sodalis*) (O'Keefe and Loeb 2017).

Restoration of pines as a minor component of hardwood communities in the Southern Appalachians has typically involved prescribed burning to create conditions favorable for natural reproduction (Elliott and others 2012, Vose and others 1999). Prescribed burning for natural reproduction has not been effective because low intensity, controlled fires do not reduce leaf litter on the forest floor sufficiently for establishment of seedlings or reduce shade from hardwoods (Elliott and others 1997, Elliott and Vose 2005). Direct seeding to supplement natural production by onsite trees is usually not successful because of predation by birds and rodents (Barnett 2014). Planting seedlings following harvests can be successful for pine restoration, but intensive site preparation and competition control of advance hardwood reproduction is usually necessary for establishment of well stocked stands for commercial management (Clabo and Clatterbuck 2020). However, on sites where the objective is

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Figure 1—A remnant group of mature pitch and shortleaf pines surrounded by mixed oaks on the ridge crest opposite the study area at Boyd Gap, Bent Creek Experimental Forest. A 124-year-old shortleaf pine in this group likely indicates the most recent date of a stand replacing fire. Natural yellow pine reproduction is absent in the stand but abundant in grasses on the south-facing road bank. The three yellow circles indicate resprouting shortleaf pine saplings following periodic cutting of vegetation on the right-of-way beside Boyd Branch Road. The two white arrows identify eastern white pine saplings that have regenerated in the stand (USDA Forest Service photo by W. Henry McNab).

to establish a component of pines in the new stand, rather than a high density for management, a minimal level of site preparation may be adequate, such as herbicide treatment of cut stumps of readily sprouting species, including red maple (*Acer rubrum*) and sourwood (*Oxydendrum arboretum*) (Kochenderfer and others 2012, Zedaker and others 1987). Clabo and Clatterbuck (2015) reported increased growth of loblolly pine seedlings planted after clearcutting and prescribed burning a hardwood site in eastern Tennessee. In the North Carolina Piedmont, restoration of shortleaf pine on an upland hardwood site was successful by planting following site preparation by prescribed burning (Schnake and others 2021). Information is lacking, however, for restoration of yellow pines on hardwood sites that have not been burned.

The purpose of this study was to determine the potential for ecological restoration of yellow pines by planting seedlings on a clearcut mixed hardwood site with minimal site preparation. The objective was to compare performance of pitch and shortleaf pine. This is the first report of results from this long-term study of pine restoration.

METHODS

Study Site

The study was installed at Boyd Gap (35.4915o N, -82.6383o W) in the Bent Creek Experimental Forest, in the Southern Appalachian Mountains of western North Carolina. Annual temperature averages 12.5 oC; precipitation averages 1200 mm and is uniformly distributed among seasons. The 0.57-ha study site was the southwest-facing slope of a broad

Table 1—Mean preharvest basal area and 13 years postharvest stem density (stem den.), basal area (BA), and quadratic mean diameter at breast height (qdbh) by species in the restoration study area

Species	Shade tolerance	Preharvest	Postharvest				
		BA	Stem den.	(SD)	BA	(SD)	qdbh
		m²/ha	*n/ha*		*m²/ha*		*cm*
S. yellow pine	Intolerant	0	400	(598)	1.284	(2.233)	6.4
Yellow-poplar	Intolerant	0	2,300	(2,736)	2.094	(2.549)	3.4
Oaks[a]	Intolerant	17.45	4,550	(2,104)	1.596	(1.176)	2.1
Sassafras	Intolerant	0.46	700	(1,129)	0.310	(0.731)	2.4
Minor species[b]	Intolerant	0	500	(560)	0.362	(0.488)	3.0
Black gum	Tolerant	0.46	1,750	(1,410)	1.183	(2.237)	2.9
Red maple	Tolerant	3.21	4,200	(3,592)	1.800	(3.1815)	2.3
Sourwood	Tolerant	3.21	350	(933)	0.542	(1.974)	4.4
Mountain laurel	Tolerant	1.84	4,600	(5,355)	0.394	(0.520)	1.0
All species	NA	26.63	19,350	(2,538)	9.565	(1.672)	2.5

SD = standard deviation; NA = not applicable.

[a] Oak species were primarily chestnut and scarlet.

[b] Minor species: black cherry, American chestnut, serviceberry, black birch.

ridge crest at 775 m elevation. Soils are deep (>100 cm) and predominantly Ultisols of the Evard-Cowee complex. The preharvest canopy of the of the study site was dominated by two species of shade-intolerant oaks: chestnut and scarlet (table 1). The midstory consisted primarily of red maple, black gum (*Nyssa sylvatica*), and sourwood. Also present were sassafras (*Sassafras albiden*) and occasional sprouts of American chestnut (*Castanea dentata*). Mountain laurel (*Kalmia latifolia*), a shade-tolerant evergreen shrub common on xeric sites, dominated the understory. The single remaining mature shortleaf pine (approximately 30 cm d.b.h.) had died from unknown causes and was windthrown in 2004. Site index (50-year base age) estimated from a nearby 124-year-old shortleaf pine in the stand shown in figure 1, was 17.4 m.

This site occupies the ecotone between landscapes typically occupied by two species of southern yellow pine species: shortleaf pine on gentle slopes of lower elevations up to 900 m and pitch pine on steeper slopes of higher elevations to about 1370 m. Forest composition of the study site was typical of xeric oak-pine communities on mid-elevation ridges that have been maintained historically by periodic disturbance from low-intensity wildland fires (Elliott and Vose 2005). There was no evidence of timber harvest although historical records suggest the area was likely used as a woodlot and had been burned periodically to promote browsing for livestock before 1900, when the tract was purchased by George Vanderbilt as part of his Pisgah Forest properties (Nesbitt 1941). The presence of a dense, tall (>3 m) shrub layer of mountain laurel is an indication of the absence of recent fire, probably before acquisition by the Forest Service, U.S. Department of Agriculture, for the Pisgah National Forest in 1914.

Study Design and Field Data

Timber on the study site was harvested in fall 2005. The merchantable parts of tree stems were skidded to a log deck next to a logging road outside of the study area. Large branches of unmerchantable treetops were cut in place to increase ground contact and promote decomposition. All residual trees and shrubs larger than 2.54 cm d.b.h. were cut. Cut stumps of undesirable species were sprayed with a 50:50 ratio of triclopyr amine and water. Undesirable species included red maple, sourwood, black gum, sassafras, and mountain laurel. Basal sprouting from stumps of these species can occupy a large proportion of growing space soon after harvest (Fei and Steiner 2009). Herbicide treatment of cut stumps was a method of site preparation commonly used by national forests for low-impact site preparation (Kochenderfer and others 2012).

The study site within the larger harvested area consisted of two, 0.10-ha blocks, which extended parallel with the ridge crest across the upper slope position and down to the middle slope. Each 0.10-ha block (approximately 36 m x 28 m) was subdivided into two 0.05-ha treatment plots. Study treatments consisted of planting (spring 2007) each plot with unimproved 1-0 seedlings of either pitch pine or shortleaf pine from state nurseries in Tennessee and North Carolina, respectively. Seedlings were bar-planted 1.83 m apart in rows extending down slope across contours; rows were spaced 2.44 m apart for an average of 2,220 seedlings/ha. Control (unplanted) plots were not established because the objective

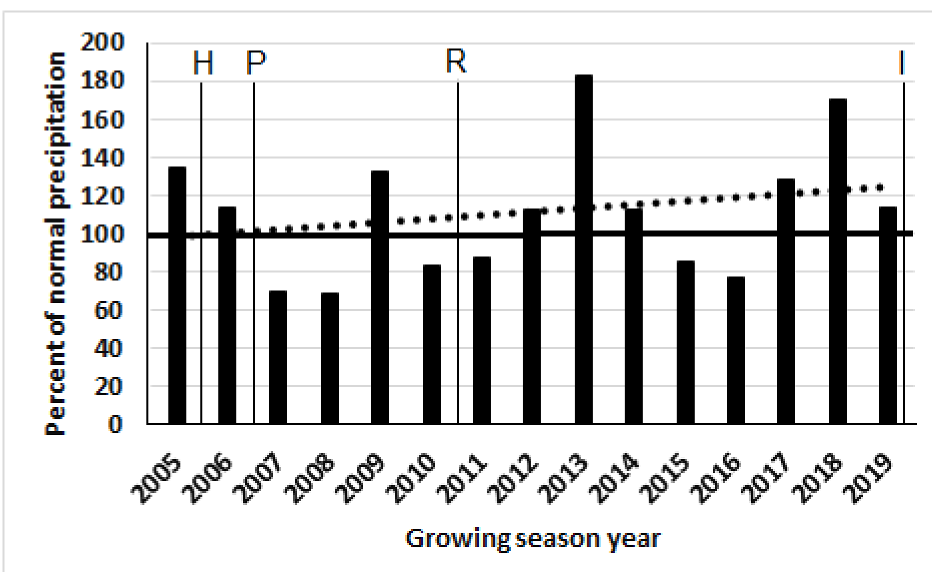

Figure 2—Growing season (April–September) precipitation during the 13 years of the study displayed as percentage of normal (613.7 mm) recorded at the Asheville Regional Airport, about 8 km southeast of the study area. The horizontal solid line represents 100 percent of normal growing season precipitation; the dotted line represents the trend of growing season precipitation during the study period. The letters H, P, R, and I represent harvest, planting, release, and inventory events occurring during the study, respectively.

was to compare performance of two species of pine seedlings. Mean second-year survival of each pine species was >95 percent. In May 2011, both pine species were released from competition using streamline basal spray application of 20-percent triclopyr ester herbicide mixed with mineral oil.

Pine and hardwood reproduction were inventoried in fall 2019, on five systematically located, circular 0.001-ha sample subplots in each treatment plot. Tree and shrub (mountain laurel) stems ≥1.37 m tall were inventoried by species and d.b.h. and recorded in approximately 2-cm classes (<0.5 cm, 0.6–1.9 cm, 2.0–3.9 cm, etc.). The first size class was subdivided primarily to better describe stand structure associated with mountain laurel, which consisted entirely of small stems. Calculated response variables were basal area and quadratic mean d.b.h. (qd.b.h.). Mean stocking of sample plots by ≥1 pine tree was calculated for each species. Pine survival percent by species was based on a potential planting density of 2,220 seedlings per ha. The 30-year normal (1980–2010) and measured growing season (April–September) precipitation were obtained from the National Oceanic and Atmospheric Administration (NOAA) site at the Asheville Regional Airport (35.4361° N, -82.5083° W; 660 m elevation), located about 8 km southeast of the study area (fig. 2).

Data Analysis

Treatment response variables were stem density and basal area and their relative values as a percentage of total tree basal area in each sample plot. All sample plots were stocked with hardwoods, but pines were missing from more than half of the sample plots, resulting in negatively skewed data for analysis. Shapiro-Wilks tests confirmed non-normal distributions for all treatment response variables. Therefore, the non-parametric Kruskal-Wallis one-way ANOVA was used for analysis of treatment (pine species) differences.

Version 3.5.1 of R was used for data analysis (R Core Team 2020); significance was determined at the α = 0.05 level.

RESULTS AND DISCUSSION

Basal area composition of the preharvest stand was distributed as 66 percent in the canopy consisting of two oak species (scarlet and chestnut); 26 percent in the shade-tolerant midstory of black gum, red maple and sourwood; and 8 percent in the mountain laurel shrub layer (table 1). Thirteen years postharvest, basal area was distributed as 17 percent oaks, 37 percent midstory species, and 4 percent shrubs. Basal area of new species in the postharvest stand included 13 percent southern yellow pines and 22 percent yellow-poplar. The sapling reproduction stem density was dominated by oaks, red maple, and mountain laurel. Composition changes following the clearcut harvest, particularly for yellow-poplar, were similar to results reported elsewhere in the Southern Appalachians (Elliott and others 1997, Shure and others 2006).

Stem density of the even-aged pine and hardwood reproduction in the study area followed a negative exponential relationship (fig. 3). The majority of stems in the smallest qd.b.h. class (0.1–0.5 cm) were mountain laurel, followed by red maple and chestnut oak (table 2). Except for the planted pines, species with the largest mean qd.b.h. were stump sprouts of shade-tolerant species, particularly black gum and sourwood. Chestnut oak, yellow-poplar, and red maple stems were abundant across all qd.b.h. size classes. Although mean basal area in the study area was less than reported by Elliott and others (1997) on a more mesic site, the size class distribution and composition of stems were similar.

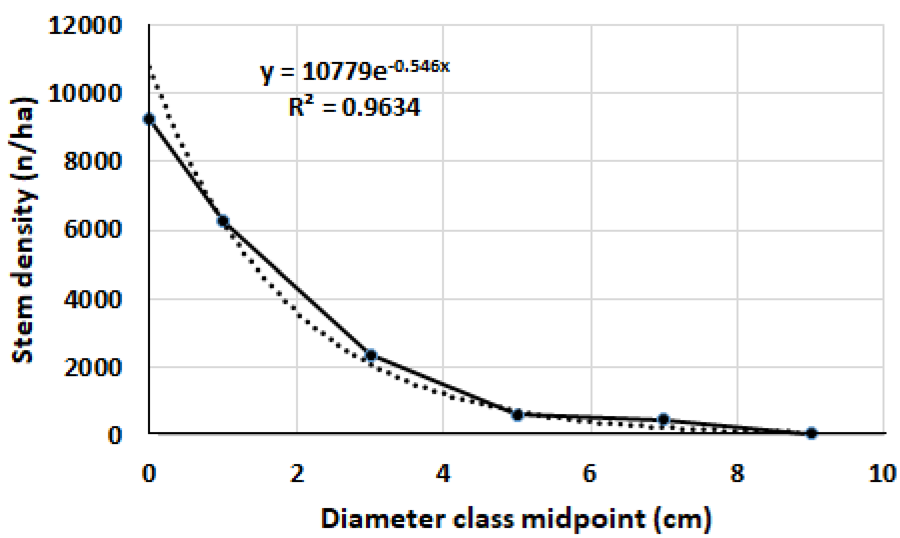

Figure 3—A negative exponential model describes the relationship between stem density and diameter at breast height (d.b.h.) class midpoints of pine and hardwood reproduction inventoried in the study site 13 years after planting.

Table 2—Stem density of reproduction by species and diameter at breast height (d.b.h.) classes 13 years postharvest

Species	Stem density (*n/ha*)						
	d.b.h. class (*cm*)						
	0.1-0.5	0.6-1.9	2.0-3.9	4.0-5.9	6.0-7.9	8.0-9.9	Total
Pitch pine	0	0	50	50	50	0	150
Shortleaf pine	0	0	50	100	100	0	250
Chestnut oak	1650	1100	150	50	100	0	3050
Scarlet oak	350	450	50	0	0	0	850
Minor oaks[a]	300	300	50	0	0	0	650
Yellow poplar	250	1000	800	200	50	0	2300
Sassafras	150	400	150	0	0	0	700
Minor intolerants[b]	200	100	150	50	0	0	500
Red maple	1750	1750	550	100	50	0	4200
Black gum	700	700	250	0	50	50	1750
Sourwood	50	100	100	50	50	0	350
Mountain laurel	3850	750	0	0	0	0	4600
All species	9250	6650	2350	600	450	50	19350

[a]Minor oak species: black, northern red, white.

[b]Minor intolerant species: black birch, American chestnut, serviceberry, black cherry.

Table 3—Mean (standard deviation [SD]) stand characteristics of pine reproduction by species and probability (P) that the difference is significant 13 years after planting

Pine reproduction	Pitch pine		Shortleaf pine		P
	Mean (SD)		Mean (SD)		
Sample subplot stocking (%)	30	(48.3)	40	(51.6)	0.65
Stem density (n/ha)	300	(483.0)	500	(707.1)	0.47
Relative stem density (%)[a]	1.615	(2.6)	2.451	(3.6)	0.56
Stem basal area (m^2/ha)	0.897	(1.7)	1.672	(2.7)	0.45
Relative stem basal area (%)[a]	6.551	(11.7)	15.448	(22.3)	0.28

[a]Pine relative density and basal area calculated as percentage of total (pine and hardwood) stem density and basal area.

Analysis of variance indicated no difference between the two blocks for pitch pine stem density (P=0.51) and basal area (P=0.37) or shortleaf pine density (P=0.81) and basal area (P=0.64) (data not shown). Sample data for the two plots of each block were then merged for species comparisons. Stocking percent of the sample plots did not differ (P=0.65) between pitch (30 percent) and shortleaf pine (40 percent) (table 3). Also, there was no significant differences between pitch and shortleaf pines for density (P=0.56), relative density (P=0.56), basal area (P=0.45), or relative basal area (P=0.28). Survival after 13 years was low for each pine species: 13.5 percent for pitch pine and 22.58 percent for shortleaf. Competition as the stand aged was the likely cause for the low survival (Baker and others 1996, Shelton and Murphy 1992). Growing season precipitation was below average for the 2 years after planting (fig. 2), but the high early survival of both pine species during that period (>95 percent) suggests viable seedlings were planted. The subsequent low survival of pitch seedlings (from a Tennessee nursery) as the stand aged may be a result of environmental differences between the seed source provenance and the planting site (Leland and others 2016).

Two naturally established pine saplings were observed in the study area, a pitch pine (d.b.h. 12 cm) and a shortleaf pine (d.b.h. 10.5 cm). The seed source for both saplings was likely a small group of mature, mixed-pine species approximately 50 m north of the study site (fig. 1). These two trees originated from wind disseminated seeds that germinated on disturbed soil soon after logging and therefore were a year older than the planted seedlings, which were established one growing season following harvest. These two volunteer trees, which were dominant in comparison with surrounding hardwoods and larger than the planted pines, demonstrate the growth potential of natural pine reproduction in competition with hardwoods on dry ridge sites.

The low survival (approximately 20 percent) of planted pines on my study sites was similar to the 23-percent survival reported by Clabo and Clatterbuck (2015) on clearcut, unburned sites with similar species composition in eastern Tennessee. In that study, however, survival of planted pines was nearly two times higher on burned plots. In central North Carolina, Schnake and others 2021 reported good 5-year survival of shortleaf following clearcut and burning for site preparation. Phillips and Abercrombie (1987), in the Piedmont of South Carolina, reported high survival and growth of shortleaf pines following prescribed burning of logging debris. Based on results from studies elsewhere, survival of pines in my study would probably have been higher if the area had been prescribed burned for site preparation.

Except for scattered chestnut oak and black gum stump sprouts, yellow-poplar was visually the tallest hardwood species in the sample plots, which made it the primary competitor with both the pines and other hardwoods, including red maple. Domination of the regenerated stand by yellow-poplar was a surprising result because it was absent before the harvest and is a mesophytic species that logically should not flourish on the dry southwest slope of the study area. Generally higher-than-average years of growing season precipitation during the period of study probably compensated for the dry characteristics of the site (fig. 2). The high density of yellow-poplar reproduction probably originated from the seed bank (Clark and Boyce 1964) when the forest floor litter was disturbed during logging (Beck and Della-Bianca 1981). Above average precipitation after harvest (2005) likely aided germination of yellow-poplar seeds and establishment of seedlings. Source of the stored seeds was likely from mature trees on the backside (northeast facing) slope of the ridge crest study area. Wind disseminated yellow-poplar seeds can be transported up to 100 m from the mother tree (Engle 1960). About half of the surviving pine species were visually equal or taller than the surrounding hardwoods and will probably remain a canopy component as the stand ages. Although yellow-poplar could be a lasting component of this stand on a dry site, it will likely undergo self-thinning during periods of drought (Hilt 1985). Prescribed burning can reduce stem density of juvenile yellow poplar (Barnes and VanLear 1998), but as the stand matures, wildland fire could be more harmful to oaks, particularly scarlet oak (*Q. coccinea*), than to yellow-poplar (Brose and VanLear 1999, Nelson and others 1933), probably because of differences in bark thickness (Hare 1965).

The pattern of pine survival resulting from the row planting could be a factor influencing variation of their size, which ranged from 2 to 8 cm d.b.h. In the only sample subplot where two planted shortleaf pines were inventoried, their d.b.h. differed by 3 cm. The smaller of the two inventoried pines was solitary, but the other (larger) was near several other planted pines outside of the sample plot boundary, which collectively formed a small group of crown-touching trees. All pines in the group appeared larger than other nearby pines occurring singly. Casual observations elsewhere in the study area revealed a similar apparent greater size of trees in groups compared to those occurring as single trees surrounded by hardwoods. Detailed study appears warranted of this apparent size difference associated with intraspecific competition among pines in groups.

CONCLUSION

Reduction of wildland fire in the Southern Appalachians during the early 1900s has resulted in a lack of southern yellow pine reproduction and increasing loss of tree species diversity in mixed hardwood stands on dry ridges. Results from this study show that a conifer component can be restored on dry ridge sites by clearcut harvesting small patches (<0.5 ha) in mixed hardwood stands and planting pitch or shortleaf pines. Although herbicide was used for site preparation to reduce sprouting of undesirable species in this study, it may not be necessary if the objective is to establish a minor component of yellow pines for biodiversity rather than a high density of pines for management.

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