INDIVIDUAL TREE RELEASE AND ENRICHMENT PLANTING IN YOUNG NATURAL UPLAND HARDWOODS

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Abstract—Individual naturally regenerated trees of red oak, white oak, and yellow poplar in upland North Carolina Piedmont hardwood stands aged 1 to 13 were treated with mechanical clearing, herbicide of competition, and fertilization. These treatments produced significant changes in height and diameter growth 2 to 3 years posttreatment. Generally, height growth was negatively impacted by mechanical release alone, but diameter growth was enhanced by most treatments. Height growth partly compensated when mechanical release was coupled with herbicides or fertilization or both. On similar sites, with stands at age 1, red and white oak 1-0 bareroot seedlings were enrichment planted with weed mats and fertilization, and height and basal-diameter increment studied after 3 years. These seedlings planted into natural regeneration survived well and responded positively in height and basal-diameter increment growth. Implications of the findings for promoting desirable stocking of preferred species in even-aged natural hardwood systems are discussed.

INTRODUCTION

Regenerating rapidly growing natural hardwood timber stands of preferred species has become a substantial forestry challenge across Eastern North American uplands. In many situations, existing (preharvest) stands do not contain sufficient numbers or size or both of preferred advance regeneration such as oaks (*Quercus* spp.), to foster desirable species composition in the new stand. When desired species are present in sufficient numbers in the new stands, their growth is often slow and mortality high due to intense competition from herbaceous vegetation and from less preferred trees such as red maple (*Acer rubrum*), yellow-poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*) and sweetgum (*Liquidambar styraciflua*). These and other issues, and the underlying ecological constraints in regenerating desirable species, have and continue to be broadly addressed (Allen and Marquis 1970, Downs 1946, Hilt and Dale 1980, Johnson and others 1997, Kellison and others 1988, Loftis and McGee 1993, McGee and Loftis 1992, Newton and Robison 2001, Romagosa and Robison 2003, Schuler and Robison 2001).

In many situations, the challenge of regenerating fast-growing stands of desirable species has been addressed through the development of plantation systems. In Eastern North American hardwoods, this has not proved to be a robust solution, due in large part to problems associated with weed/competition control. Furthermore, the genetic improvement of hardwoods has lagged, making plantations of hardwoods with poor growth rates and ineffective broadscale weed control doubly unattractive. For oaks in particular, genetic improvement has been very slow owing to relatively long juvenile periods, episodic seed crops, and abundant seed predators. Improvement is also costly, especially when adequate competition management options do not exist to help recoup the investments in genetic improvement.

In this study, we report on two postharvest techniques to affect species composition and growth rates in naturally regenerating hardwood stands. We have addressed these possibilities in young stands, ranging from 1 to 13 years, in order to discover new ways to (1) promote desirable natural regeneration regardless of composition and competition issues and (2) insert small planting stock into regenerating stands to enrich species composition. The former approach is analogous to crop-tree release, but in very young stands before natural processes have promoted individual stems into obvious crop-tree candidates (= "*crop tree release before they can be identified as crop trees*"). The later approach is an attempt to develop a plantation system on an individual tree basis within the broader context of a naturally regenerating stand (= "*an individual tree plantation, one tree at a time*").

METHODS

Individual Tree-Release Study

In 1998 on the North Carolina State University, Department of Forestry's Hill Demonstration Forest (Durham County) in the Piedmont region, three upland hardwood stands on similar sites, regenerated by clearcutting 6, 8 and 13 years previously, were selected. The two dominate species in the 6-year-old stand [mean height 3.3 feet, density 13,499 trees per acre (TPA)] were yellow poplar, then red oaks, and mixed others; in the 8-year-old stand (mean height 7.0 feet, density 15,200 TPA) dominants were yellow poplar, mixed other, and then red oaks; in the 13-year-old stand (mean height 13.8 feet, density 5,305 TPA) dominants were mixed others, then yellow poplar and red oaks.

About 70 non-stump-sprout-origin trees of northern red (*Quercus rubra*) or black oak (*Q. velutina*), white oak (*Q. alba*), and yellow poplar, in a dominant/codominant position, were identified on about a 20 foot by 20 foot grid (ca. 210 trees per site). Approximately equal numbers of trees of each species were randomly treated as:

1. Control
2. Mechanical = clearing of competition in 6-foot radius in Year 1 (1998)

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3. Mechanical + Chemical Year 1 = clearing (Year 1) + Garlon on cut stumps in Year 2
4. Mechanical + Chemical Year 2 = clearing (Year 1) + Oust and Accord on competition in Year 2
5. Mechanical + Chemical Year 1 + Fertilization = clearing (Year 1) + Garlon (Year 1) + Fertilization (Yr 2) with DAP at 10 ounces per tree (90 N, 100 P, pounds per acre equivalent).

Tree height and d.b.h. were recorded in midsummer 1998, height remeasured after the 2000 growing season (2.5-year increment), and d.b.h. remeasured after the 2001 growing season (3.5-year increment).

Enrichment Planting and Release Study

One site each on the NC State University Department of Forestry's Hill Demonstration Forest and Schenck Memorial Forest (Wake County), both in the NC Piedmont, were identified and salvage-clearcut harvested during winter 1996-97 following damage from Hurricane Fran (Sept. 6, 1996). Stands naturally regenerated to mixed pine-hardwood. Into the two sites, a total of 216, 1-0 bareroot seedlings of northern red oak and white oak from a Georgia State nursery and the same number from a Virginia State nursery were shovel planted in February 1998 (864 trees total). Additionally, across the two sites, a total of 76 naturally regenerated seedling or seedling-sprout origin mixed oaks were identified for the study. Approximately equal numbers of all these tree types were randomly treated as:

1. Control
2. Fertilized = Fertilization with 1.75 ounces DAP per Tree in Year 1 (1998)
3. Weed Mat = 3 foot x 3 foot "Vis Pore" Weed Mat around Tree in Year 1
4. Fertilized + Weed Mat = Fertilizer + Weed Mat as above in Year 1.

Immediately after planting the height and basal diameter (BD) of each tree were measured and remeasured during winter 2000-01 (3-year increment). For both studies, blocking effects were not significant. For the enrichment planting study, site effects were not significant, and each tree was considered an individual-tree plot for statistical analysis by ANOVA (Analytical Software 2000). ANOVA P values less than 0.10 were considered significant, and those between 0.1 and 0.20 were considered indicative of a potentially substantive/emerging response in these early results.

RESULTS AND DISCUSSION

Findings in this study suggest that individual tree release and treatment of naturally regenerated red oaks, white oaks, and yellow poplar at ages 6, 8 and 13 years on these Piedmont sites, resulted in significant growth rate changes after 2 to 3 years (table 1). In nearly every case, the height growth of these trees was slowed by mechanical release but partly compensated for in red oak and yellow poplar when mechanical release was supplemented with chemical competition control or fertilization or both. This finding suggests that the relaxation of above ground crowding and competition for sunlight reduced the rate of height growth required to maintain canopy dominance. However, reductions in below ground competition (due to the chemical release treatments), or the improvement of microsite fertility (fertilization) or both, maintained height growth.

Unlike height growth, diameter growth was generally accelerated by the various treatments, for all species (table 1). These early responses suggest that tree-diameter growth alone can be enhanced by simple mechanical clearing around individual trees within dense, regenerating stands. However, this simple release in the absence of below ground competition control or fertility enhancement or both also resulted in slowed height growth. Although it is too early to determine the rotation-length impact of slowed height growth, if it is long-lived, then it would put these trees at a distinct size disadvantage despite any short-term increase in diameter growth. As canopy closure occurs and released trees respond with accelerated height growth, then the loss may be negated. Coupling mechanical release with chemical or fertility treatments or both appears to promote diameter growth and compensate in part for the reduction in height growth.

Enrichment planting of red and white oaks on these Piedmont sites was successful, with survival after 3 years greater than 90 percent among the red and white oaks across all treatments. Where height growth of enrichment-planted red and white oak seedlings responded significantly to the treatments, it was enhanced variably by the weed mats and fertilization and the combination of these treatments (table 2). Similar results were found for basal diameter-growth response of the planted seedlings. When significant, the data from these early measurements suggest that the weed mat effect may be greater than the fertilizer effect. The naturally regenerated mixed oak species, which were treated similarly to the enrichment-planted seedlings, responded more consistently than planted trees (table 2). It was the fertilization treatment that enhanced both height and BD growth of these natural oaks. These small natural trees, despite being of similar size to the planted seedlings at the start of the study, grew considerably more than the planted trees. This may be a reflection of their preadaptation to the site, or the fact that some substantial portion of these arose from advance regeneration, or both.

The putatively 1-year-old naturally regenerated oaks released at the same time as the enrichment-planted seedlings (table 2) are in essence a young age class of the study results reported in table 1. Together, these results suggest that naturally regenerated oak stems, at ages 1 to 13, can be made to grow more quickly with appropriate treatments. Treatments may vary with tree age. Other workers have reported similar findings (Allen and Marquis 1970, Beck 1977, Church 1955, Della-Bianca 1975, Hilt and Dale 1980, Lamson and others 1990, Smith and Lamson 1983). This approach to "crop tree release before individuals can be identified as crop trees" may hold substantial promise for altering species composition and growth rates of select stems in naturally regenerated hardwoods. Current research encourages the presence of a sizeable amount of advance regeneration oaks in order to ensure adequate oak stocking following overstory harvest

Table 1—Mean incremental growth response of individually released stems (non-stump-sprout origin) in young Piedmont natural hardwoods following clearcut regeneration at Hill Forest, NC

Treatments, and ANOVA *P*-value	Stand age when treatments were applied: 2–5-year-height increment 6	8	13	3–5-year-d.b.h. increment 6	8	13
	- - - - - - - - *feet* - - - - - - - -			- - - - - - - *inches* - - - - - - -		
Red oak						
Control	3.4	3.2	4.0	0.39	0.38	0.48
Mechanical	2.8	2.3	3.7	0.53	0.44	0.65
Mech. + Yr 1 chemical	2.7	2.0	4.1	0.54	0.49	0.69
Mech. + Yr 2 chemical	2.3	2.9	4.1	0.55	0.63	0.67
Mech. + Yr 1 chem. + fert.	3.3	2.2	2.6	0.78	0.47	0.66
ANOVA *P*-value ≤	0.1	NS	NS	0.05	0.1	0.1
White oak						
Control	3.9	4.0	3.1	0.53	0.46	0.48
Mechanical	2.8	2.8	4.1	0.66	0.58	0.67
Mech. + Yr 1 chemical	2.8	2.2	2.8	0.72	0.64	0.58
Mech. + Yr 2 chemical	2.7	3.2	3.0	0.75	0.72	0.69
Mech. + Yr 1 chem. + fert.	3.3	2.8	2.8	0.8	0.68	0.72
ANOVA *P*-value ≤	0.05	0.05	NS	0.1	0.1	NS
Yellow poplar						
Control	3.0	4.0	4.3	0.28	0.46	0.45
Mechanical	2.6	2.6	2.6	0.46	0.50	0.48
Mech. + Yr 1 chemical	2.6	2.7	5.3	0.56	0.54	0.72
Mech. + Yr 2 chemical	2.8	3.8	4.0	0.48	0.54	0.54
Mech. + Yr 1 chem. + fert.	2.6	3.2	3.2	0.43	0.57	0.49
ANOVA *P*-value ≤	NS	0.1	0.1	0.05	NS	NS

NS = not significant.

Table 2—Mean 3-year (1998–2000) incremental growth response of planted (February 1998) bareroot seedlings and individually released naturally regenerated mixed-oak seedling or seedling sprout stems or both in young Piedmont natural hardwoods following clearcut regeneration (winter 1996/1997); Hill and Schenck Forests, NC

Treatment, *P*-value	Seedling species and source: 3-year height increment GA RO	VA RO	GA WO	VA WO	OS NO	3-year basal diameter increment GA RO	VA RO	GA WO	VA WO	OS NO
	- - - - - - - - - - - - - - -					*inches* - - - - - - - - - - - - - - -				
Control	4.7	8.7	15.7	9.1	35.0	0.090	0.118	0.228	0.094	0.464
Fertilized	4.7	12.6	16.9	11.8	41.7	0.114	0.134	0.150	0.067	0.681
Weed mat.	10.6	11.0	19.7	11.4	27.6	0.165	0.106	0.193	0.102	0.472
Fert. + mat.	8.7	13.4	18.5	13.0	43.3	0.169	0.113	0.181	0.169	0.776
P-value ≤	0.2	NS	0.1	NS	0.2	0.1	NS	NS	0.05	0.05

GA = Georgia; VA= Virginia; OS = on site; RO = red oak; WO = white oak; NA = natural oaks; NS = not significant.

and to lessen the impact of self-thinning in the subsequent stand (Barnes and Van Lear 1998; Brose and others 1999; Johnson 1993; Kelty 1988; Loftis 1990a, 1990b). Individual tree release of select stems following harvest may facilitate adequate preferred species stocking as well as, or more efficiently than, the advance regeneration approach. Whereas the latter calls for very many oak regenerants per acre prior to overstory removal, the postharvest approach described here, if substantiated, would require only a few hundred (or fewer) stems per acre to ensure adequate representation of oaks in the next harvest.

Results reported here from the enrichment planting study suggest that the species composition of naturally regenerated stands can be enhanced or altered. However, these results are too preliminary to determine if the enrichment-planted trees will thrive and survive through the rotation. This approach may provide a means to not only direct species composition but also to deploy genetically improved individuals (Schlarbaum and others 1997) and thereby create "an individual tree plantation, one tree at a time."

Both the individual tree-release and enrichment-planting approaches may require supplementary treatments at regular intervals to sustain them in the canopy. The likelihood that these approaches could be economically viable (Dutrow 1980), remains unknown. However, recent economic modeling suggests that silvicultural interventions in young natural hardwood stands may be attractive due to productivity enhancements and improved species composition (Siry and others, in press).

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