Virginia Department of Forestry

Forest Research Review

April 2008

The New Kent location of the longleaf provenance test at age two. Native Virginia source seedlings are in the foreground.

In this issue...

VDOF Research Program

Jerre Creighton, research program manager

Wayne Bowman, research forester

Onesphore Bitoki, tree improvement forester

It's been a busy six months since our last publication. In October, we helped to host the conference "Northern Limits – Restoring the Longleaf Pine Ecosystem in Virginia" in Wakefield. Also in October, we completed collection of our loblolly pine second generation improved seed crop from the orchard in Milledgeville, GA. The best 20 families produced in excess of 3,200 bushels of cones that yielded more than 6,000 pounds of seed for the future seedling crops from our Garland Gray Nursery. With help from the Forest Nutrition Cooperative, we began installation in December of a study of loblolly pine response to varying intensities of mid-rotation thinning in combination with fertilization. Before tree growth resumes in the spring, we will also remeasure VDOF's mid-rotation fertilizer tests, as well as a MeadWestvaco density and fertilization trial. And just this week, we installed multiple locations of a study to look at the effects of new insecticides for controlling tipmoth in young loblolly pine.

In this issue, you'll find summaries of recent information gathered from tests of clonal loblolly pine plantations; performance in Virginia of loblolly and longleaf pine from various geographic seed sources; early effects of biosolid applications on loblolly pine growth; growth of loblolly pine seedlings interplanted in understocked one-year-old plantations, and responses of southern red oak to crop tree release and fertilization. And we're introducing a new feature highlighting the results of our collaborations with research cooperatives. We'll take time in each issue to summarize recent reports from the various cooperatives in which VDOF is a member, including the Tree Improvement, Forest Nutrition, and Growth and Yield cooperatives. We hope you'll find the information interesting and useful.

Please let us know if you have any questions or comments, and be sure to visit our Web site at http://www.dof.virginia.gov/research/publications.shtml to browse through all the publications, fact sheets and analytical tools from the VDOF Research Program during its more than 53-year history.

As always, please feel free to contact the research program staff with any questions or suggestions you may have:

Jerre Creighton, research program manager, Central Office

(434) 977-6555; jerre.creighton@dof.virginia.gov

Wayne Bowman, research forester, Appomattox-Buckingham State Forest

(434) 983-2175; wayne.bowman@dof.virginia.gov

Onesphore Bitoki, tree improvement forester, New Kent Forestry Center

(804) 966-2201; ones.bitoki@dof.virginia.gov

www.dof.virginia.gov

Research Cooperatives

The Department of Forestry maintains memberships in three important research cooperatives: the Tree Improvement Program at NC State University; the Forest Nutrition Cooperative at Virginia Tech and NC State, and the Growth and Yield Cooperative at Virginia Tech. Each of these cooperatives leverages the collective resources of numerous member agencies, institutions and industries to focus on important areas of forestry research. And each of them publishes its results frequently and maintains member Web sites with reports, presentations, training aids and/or models. This month, we summarize results from two recent publications – one from the growth and yield co-op and one from the forest nutrition co-op. For complete text of these and many other co-op publications or other co-op products, VDOF personnel can find more information under Forest Research Publications on the VDOF Intranet.

Does row orientation affect the growth of loblolly pine plantations? Ralph L. Amateis and Harold E. Burkhart. Loblolly Pine Growth and Yield Research Cooperative Report No. 150, Nov. 2007.

Decisions made at establishment affect the growth and development of forest plantations. Among the most important of these decisions are the initial density and the inter-tree and inter-row spacing. Much is known about the impact of density and spacing on pine plantation growth. In some row crops, a north-south row orientation has been found to be advantageous. But relatively little is known about the effect of row orientation on forest plantation growth.

This analysis was based on data from a set of loblolly pine spacing trials established in 1983 at four site-prepared areas in the Piedmont and Coastal Plain of Virginia and North Carolina. [One of these locations is on the Appomattox-Buckingham State Forest.] Analysis of covariance methods were applied to the long-term data and showed that the orientation of rows with regard to a particular azimuth direction had no significant impact on either basal area or dominant height growth through age 20. Results were consistent for a wide range of planting densities, spacings and across a range of ages that included very young ages prior to crown closure. These results suggest that the selection of row orientation at plantation establishment can be made based on criteria other than growth.

Nutrient by Stand Density Trial in the Piedmont of Virginia. Colleen Carlson and Tom Fox. Forest Nutrition Cooperative Research Note No. 27, Oct. 2007.

In 2006, VDOF and Virginia Tech agreed to collaborate on the future measurement, maintenance and reporting of a nutrient x density trial established by MeadWestvaco in Buckingham County in 1998. This report examines the data collected through 2007. The trial is designed as a factorial with three levels of nutrition: a low-nutrient regime where the site index (base age 25 – SI_{25}) is expected to be 55 feet; an intermediate regime fertilized at a rate meeting the nutrient requirements of a stand with a SI_{25} of 70, and high-nutrient regime fertilized at a rate equivalent to a SI_{25} of 80 and two levels of stand density (363 trees per acre and 726 trees per acre) replicated three times. Fertilizer applications were made in 1999, 2000, 2001 and 2007.

Treatments did not affect survival or height during the first nine years of the trial. At age nine, the lower stand density had increased diameter (averaged across all nutrition treatments) by 0.93 inches. The intermediate- and high-nutrition levels increased diameter (averaged over both stand density treatments) by 0.21 and 0.35 inches, respectively, compared to the low-nutrient level. Intraspecific competition started to play a role when the trees were approximately five years old with the diameter growth being negatively affected by the higher stand density from this time onwards. The higher planting density responded to a greater extent to the nutrient applications with a linear increase in basal area with increasing level of nutrient addition. At the lower planting density, the two levels of nutrient addition improved the basal area over the controls but to the same extent. Basal areas in the higher stand density treatment ranged from 92.9 to 107.2 $ft.^2$/acre and will require a thinning within the next couple of years to prevent density dependent mortality. However, projected tree sizes within the next two years indicate that thinning will not be economical even within the 726 trees per acre treatment, as merchantable volumes range from 356 to 726 $ft.^3$/acre depending on the fertilization regime.

Comparing Early Survival and Growth of Varietal and Open-Pollinated Loblolly Pine Seedlings

Ones Bitoki, tree improvement forester

Traditionally, the VDOF has grown seedlings from seed collected in open-pollinated seed orchards. In recent years, a growing number of seedlings has been produced by a technology called somatic embryogenesis. Open-pollinated seedlings vary genetically because they have a random mix of parents. Using somatic embryogenesis, large numbers of genetically-identical seedlings can be grown from individual seed embryos from a known parent tree. Theoretically, these "varietal" seedlings will be more uniform in growth or other desirable characteristics, leading to much greater overall stand productivity and performance.

In 2007, the Virginia Department of Forestry (in partnership with ArborGen) established a trial comparing two ArborGen clones with the VDOF nursery's first- and second-generation seedlings. Three objectives of the trial stand out: 1) to make a direct comparison of clonal seedlings derived from somatic embryogenesis to our traditional open-pollinated seedlings; 2) to test the adaptability of the two ArborGen varieties in the New Kent area, and 3) to provide a demonstration site of varietal forestry possibilities in Virginia.

A randomized complete block design with four replications of 49-tree plots was installed in February of 2007. In June 2007, survival was counted for all planted seedlings, and in December 2007, we measured total height and survival. Survival did not change from June to December, so the December results are shown in Figure 1. The varietal seedlings have tended to survive better than the open-pollinated seedlings. In height (Figure 2), there were highly significant differences in growth for the different seedlings. The two varieties have grown faster than the two Virginia sources after one growing season. In addition, variety 34 grew significantly more than variety 769.

At this early age, it is prudent not to make any decisive inference. However, we notice an early growth advantage of the two varieties (Figure 3). Variety 34 grows faster and is more uniform compared to the other sources with a coefficient of variation of 29 percent. Variety 769 has a high coefficient of variation, 53 percent. Virginia first and second generation have coefficient of variation of 30 and 40 percent, respectively. Given the better survival after the first growing season coupled with faster growth, the varietal seedlings have a high potential if the trends remain. However, the ArborGen seedlings were noticeably larger than the VDOF seedlings when planted, so we will want to follow performance over time to see how these early results hold up. In addition, these are the very first varieties selected by ArborGen in 2005; they now have more than 30 varieties selected and in further trials or just coming out of the lab.

We will continue to monitor this trial and observe whether the early results continue or change. The early results suggest that significant growth and uniformity gains may be possible from planting varieties, and that there are potentially big differences among varieties. Tests within Virginia would be needed to determine which are best suited here.

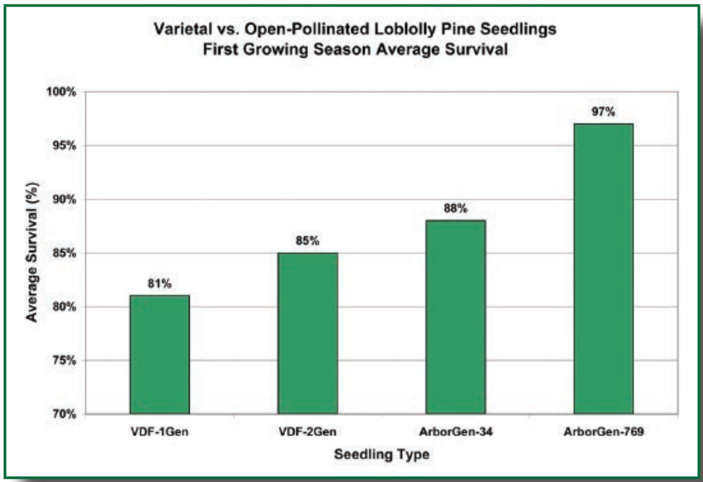

Figure 1. First-season survival of the varietal forestry study.

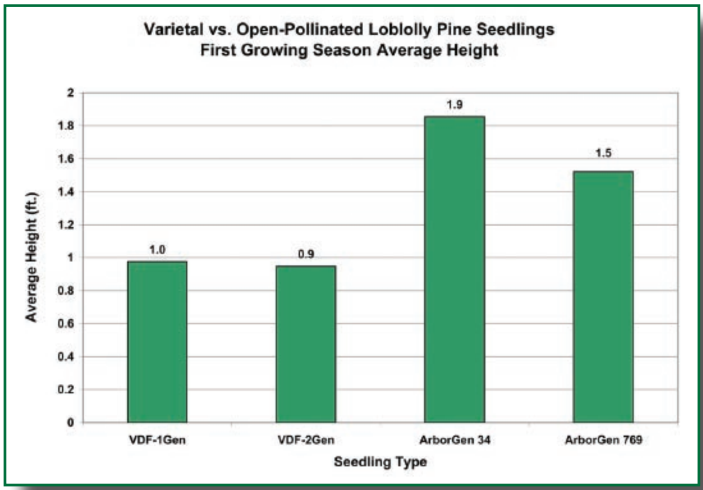

Figure 2. First-season height growth of the varietal forestry study.

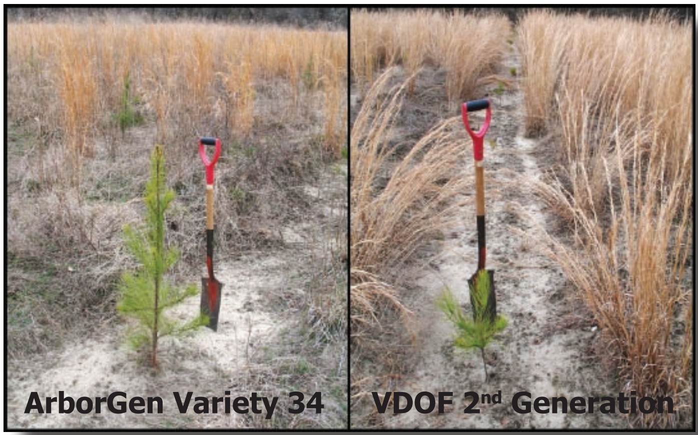

Figure 3. Somatic embryogenesis variety 34 (left) compared with VDOF second generation seed orchard mix after one growing season.

Performance of North Carolina and South Carolina Loblolly Pine Families in Virginia

John Scrivani, director of resource information

It is thought to be well known in loblolly tree breeding circles that the fastest growing loblolly pines are found in the coastal regions of the Carolinas. It is also well known that moving a loblolly seed source more than 100 miles north increases risk of poor adaptability, with a potential for growth and survival losses. Of particular concern is the likelihood of insufficient cold-hardiness in these more southern sources.

In 1993, the Chesapeake Forest Product Company established a test to determine if fast-growing, elite loblolly pine families from North and South Carolina can survive and grow in Virginia. For each of three provenances, Virginia, North Carolina and South Carolina, sixteen second-generation, open-pollinated families were used in the tests. Three test locations were planted - Coastal Virginia (King and Queen County), Piedmont Virginia (Cumberland County) and Eastern Shore Maryland (Worcester County).

Chesapeake measured the two Virginia test plots at age six and reported the results. At that age, the South Carolina sources performed poorly at the Piedmont site, but all provenances survived and grew equally well at the Coastal Plain site. A slight advantage in stem straightness was noted for the Virginia source at both locations.

After Chesapeake exited the forestry business, it gave VDOF access to the plots and data for this study. We measured the two Virginia locations at age 12 and the Eastern Shore Maryland test at age 10. The results generally confirmed the earlier results. The Virginia source families, on average, had better stem straightness than both Carolina sources (statistical significance $P<0.001$) for all three tests combined. A significant interaction was found for both height and volume with test location. In other words, the relative performance of the different sources depended on where they were planted.

At the Coastal Plain and Eastern Shore tests, the height and volume for the three sources were not different. Based on trials outside of Virginia, volume gain for these South Carolina, North Carolina and Virginia sources compared to unimproved Virginia loblolly should have been 32 percent, 12 percent and 2 percent respectively. These comparisons are based on predicted performance gains for the North Carolina Coastal Plain (the region in which the most performance ratings were available across provenance) from the Performance Rating System (PRS) of the North Carolina State University Cooperative Tree Improvement Program.

In the Piedmont test (Figure 4), significant differences for height and volume were found. The Virginia and North Carolina sources outperformed the South Carolina source for both height and volume ($P<0.001$ for both traits). These results indicate that South Carolina sources are poorly adapted for the Piedmont of Virginia. It was observed that the performance among the North Carolina families was more variable than among either the Virginia or South Carolina families. This suggests that some of the North Carolina families may be better adapted to the Virginia Piedmont than others. However, this observation was not subjected to a statistical test.

Looking at performance ratings for volume provided by the North Carolina State University Tree Improvement Cooperative, one could conclude that the South and North Carolina families should outperform Virginia families. Since this was not observed, we conclude that performance ratings from other regions do not predict performance in Virginia plantings. We looked at the statistical correlations between volume performance in the tests and volume performance ratings (Table 1). The Virginia and North Carolina PRS ratings were positively and significantly correlated only with the family performance in the Coastal Plain test. Eastern Shore test performance was essentially uncorrelated, and Piedmont test performance by family was somewhat negatively correlated with PRS ratings. This suggests that the top performers in the Carolina Coastal Plain may be the least adapted to the Piedmont.

Figure 4. Recent photos of loblolly pine (now age 15) from Virginia (left) and South Carolina (right) sources at the Piedmont site in Cumberland County, VA.

In summary, we can conclude that the outstanding performance of Carolina Coastal Plain source loblolly families tend to "regress" to the same performance levels found in the Virginia source families when planted in Virginia, and exhibit somewhat less stem straightness.

Table 1. Correlation Coefficients between Test Performance and PRS Ratings.

Location	PRS - Virginia	PRS - NC Coastal	PRS - NC Piedmont	PRS - SC Coastal
Coastal Plain	0.574**	0.508**	0.508**	0.247
Eastern Shore Test	0.197	-0.064	0.099	-0.088
Piedmont Test	-0.223	-0.465**	-0.200	-0.275
** P > 0.001				

Both Carolina sources seem reasonably well adapted to the Virginia Coastal Plain, but the South Carolina source is not well adapted to the Virginia Piedmont. Performance ratings available from coastal tests may be used to select top families for deployment in the Coastal Plain but provide little or no guidance to performance in the Virginia Piedmont or Maryland Eastern Shore.

Longleaf Pine Establishment and Provenance Studies

Nathan Lojewski, longleaf pine restoration forester

In the August 2006 issue of the Forest Research Review, we presented data from our establishment study at the New Kent Forestry Center and informed you about a provenance study which was undertaken at Sandy Point State Forest, and the New Kent and Garland Gray Forestry Centers. In this issue, we have an update on the establishment study and the first data from our provenance study.

The establishment study, which was designed to test the effects of site preparation, planting depth and herbicide treatment on early growth, was re-measured this fall after three growing seasons. Previously, we found that scalping, shallow planting depth (i.e. with ½ inch or more of the plug exposed) and light to moderate herbicide application (Oustar at 8-12 oz./acre) were the most effective treatment to maximize growth and minimize mortality.

Our data after three years (Table 2) confirm these findings and reveal that the single most important factor in old field establishment success is scalping. We also found that higher Oustar rates (16 oz./acre) and the Arsenal x Oust tank mix (at 4 and 2 oz./acre respectively) were detrimental to seedling growth and increased mortality substantially. It should be noted that other researchers have found that the Arsenal x Oust treatment works quite well when applied in May or later, but our treatment was applied on April 13. Scalping and shallow planting led to results as good as any in the study (75 percent+ survival and roughly ⅔ of seedlings out of the grass stage). Figure 5 shows the height growth differences between treatments, the scalped, shallow-planted plots with or without 8 oz./acre of Oustar (treatments 3, 4 and 8) were superior. Treatment 2 (deep planting, i.e. planting with none of the plug exposed) produced good height growth but suffered higher seedling mortality.

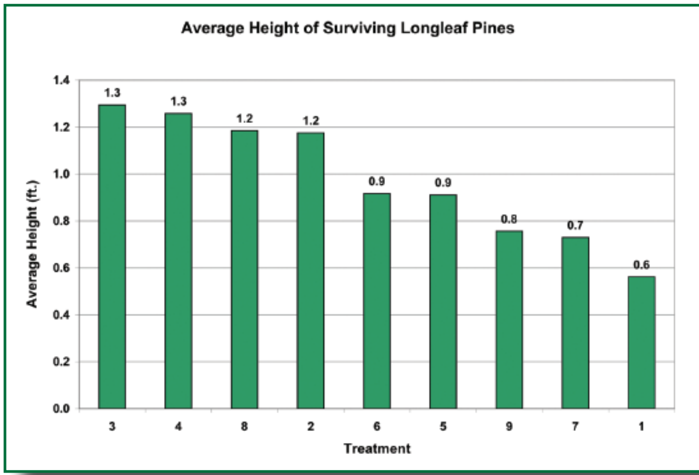

Figure 5. Average height of surviving longleaf pines on the establishment study plots after three growing seasons.

Table 2. Summary of mortality, grass stage emergence and height growth after three years at the longleaf pine establishment study at New Kent Forestry Center.

Treatment #	Scalping	Planting Depth	Source	Herbicide	Mortality %	% Out of Grass Stage	Mean Height
1	none	shallow	NC	none	62	22	0.6
2	scalp	deep	NC	none	28	36	1.2
3	scalp	shallow	NC	none	23	61	1.3
4	scalp	shallow	NC	Oustar 8	22	68	1.3
5	scalp	shallow	NC	Oustar 12	20	62	0.9
6	scalp	shallow	NC	Oustar 16	33	55	0.9
7	scalp	shallow	NC	Arsenal + Oust	67	23	0.7
8	scalp	shallow	GA Mt.	none	17	78	1.2
9	scalp	shallow	GA Coast	none	25	56	0.8

The goal of our provenance study is to test the effect of geographic seed origin from the entire range of longleaf pine on establishment success and growth and yield in Virginia. Eight different geographic sources of longleaf are being compared in 25-tree plots replicated twice at each of three locations: Garland Gray Forestry Center (in Sussex County), New Kent Forestry Center (in New Kent

County), and Sandy Point State Forest (in King William County). After two years of growth, the results are somewhat surprising. Seed collected in Southampton County from some of the few remaining native Virginia longleaf has outperformed all other seed sources (Table 3 and Figures 6 and 7) – including genetically improved North Carolina stock – in the initial stages of growth and establishment. Most dramatic are the high rate of survival and the large proportion out of the grass stage after two years for the Virginia source.

Based on these two studies, we recommend planting native Virginia seedlings if available and scalping as site preparation for old field plantings. If further herbaceous control is needed, Oustar at 8 oz./acre may provide small additional increases to early growth and establishment.

We want to express our appreciation to International Paper Forest Resources for its ongoing support in permitting us to access, preserve and collect seed from the native Virginia longleaf pines located on its South Quay property in Southampton County; to International Forest Co. for providing the seed from other states, and to the Virginia Department of Conservation and Recreation's Natural Heritage Program for its ongoing field support.

Table 3. Longleaf pine provenance study results after two years.

Source	Mortality (%)	Out of Grass Stage (%)	Average Height (ft.)
Southampton Co., VA	9.3%	48.0%	0.53
Genetically Improved Stock, NC	26.7%	27.3%	0.36
Richmond Co., NC	28.0%	18.0%	0.27
Dorchester Co., SC	22.0%	11.3%	0.32
Forest Co., MS	29.3%	11.3%	0.30
Talladega Co., AL	26.4%	15.3%	0.33
Colquitt Co., GA	21.3%	14.0%	0.28
Santa Rosa Co., FL	14.0%	15.3%	0.42

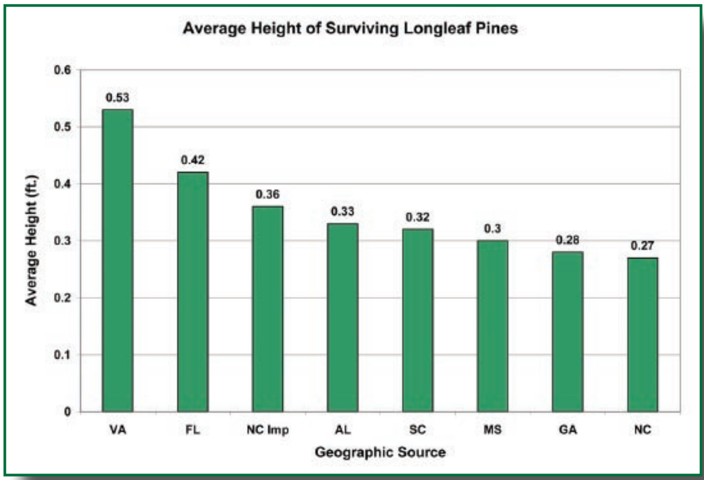

Figure 6. Average height of surviving longleaf pines on the provenance study plots after two growing seasons.

Figure 7. Seedlings at the New Kent location of the longleaf provenance test after two growing seasons, clockwise from left: native Virginia, North Carolina improved, and Mississippi sources.

Early Effects of Biosolid Applications on Growth of Thinned Mid-Rotation Loblolly Pine

Biosolids are solid or liquid materials produced from the treatment of municipal sewage sludge. About half of the biosolids produced annually in Virginia are land-applied. Historically, most of these applications have been to agricultural fields, but interest in using biosolids as fertilizers in forest stands has increased in recent years. In October of 2006, the VDOF research team installed a study to compare the effects of biosolid applications and traditional inorganic fertilizer [urea + diammonium phosphate (DAP)] on the growth of thinned mid-rotation loblolly pine.

The plots were installed in western Essex County in a recently-thinned (summer 2006) mid-rotation loblolly pine stand (Figure 8). The experimental design is a randomized complete block with four replications of four treatments (all applied in June of 2007): 1) no application; 2) urea + DAP at a rate of 200 lbs./acre of nitrogen; 3) lime-stabilized biosolid material from Arlington, VA applied at 200 lbs./acre of plant available nitrogen, and 4) biosolids at 400 lbs./acre plant available nitrogen.

Total height, crown height and diameter were measured on each tree in the tenth-acre measurement plots in the winter of 2006-2007 and again one year later (January 2008). Since the treatments were applied in June, the trees had only part of a growing season to respond. And the growing season in question was extremely dry, which probably limited growth. Even so, as Figure 9 shows, there has been an early effect of nutrition. The biosolids plots have grown about three times as much in diameter as the untreated plots, and trees on the DAP + urea treatment have grown nearly twice as much as the biosolids plots. These are very short-term data; our plan will be to continue annual measurements of this site to determine the magnitude and duration of responses.

Figure 8. One of the biosolids study plots six months after biosolid application; this plot received the equivalent of 200 pounds per acre of nitrogen.

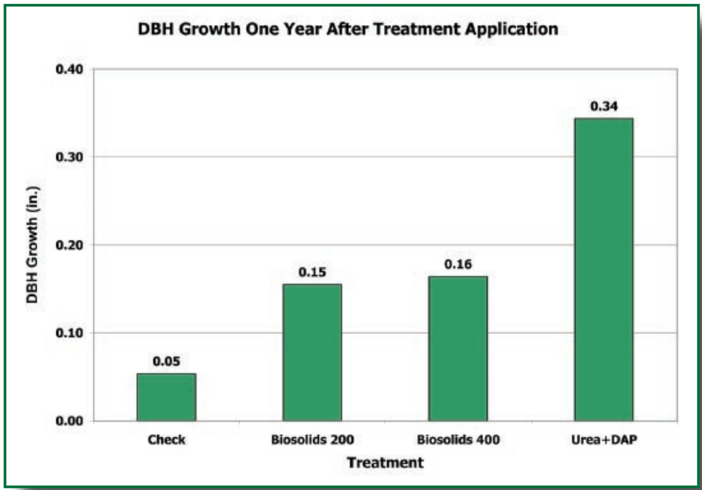

Figure 9. Average dbh growth during the 2007 growing season on the biosolids study plots.

Growth of Loblolly Pine Seedlings Interplanted in Reduced-Density One-Year-Old Stands

Questions often arise as to the value of interplanting additional seedlings into stands that have suffered early mortality or for some other reason are inadequately stocked after their first growing season. The VDOF research program published results from an old-field interplanting study in Occasional Report 53 (1980); the results showed that dead seedlings could be replaced after the first growing season with the expectation of reasonable volume growth from the interplanted trees. In 1992, Occasional Report 106 was published reporting results of interplanting on site-prepared cutover sites. As expected, in that case interplanting was unsuccessful because the interplanted seedlings had to compete not only with the surviving pines but also with hardwood competition. Both studies, however, indicated that there might be some critical minimum spacing or opening size above which interplanted seedlings could contribute to stand volume.

In recent years, as initial planting density targets have declined, it has been hypothesized that interplanting in today's stands might be more successful because an understocked stand would have wide enough openings to allow the interplants to thrive. To test that theory, we installed a study in a one-year-old loblolly plantation on the Appomattox-Buckingham State Forest. The initial planting (March 2006) was completed by a contract crew, and the interplanting was done by the research team in April 2007. All seedlings were second-generation open-pollinated seed orchard mix seedlings from the VDOF Garland Gray Nursery.

The existing stand had a surviving pine density averaging 451 trees per acre. We installed tenth-acre square plots in a randomized complete block design with four replications testing four treatments: 1) no interplanting; 2) reduce density to 300 trees per acre and interplant in empty spots; 3) reduce density to 200 trees per acre and interplant in empty spots, and 4) reduce density to 100 trees per acre and interplant in empty spots. To accomplish the density reductions, we pinflagged all surviving trees and randomly pulled up enough to reach the target density. We then replaced the trees that had been pulled up with an interplant. Examples of the original and interplanted seedlings are shown in Figure 10.

Figure 10. Original (left) and interplanted (right) seedlings from the 2007 interplanting study at time of interplanting (April 2007).

One growing season after interplanting (January 2008), we tallied survival and heights of these seedlings. The results are summarized in Table 4 and show that at least on this site in this dry growing season, the interplanted seedlings have not been successful at all (Figures 11 and 12). They average 2.5 feet or more shorter than the original seedlings and are beginning to suffer mortality. Keep in mind that these results could be a best-case scenario because the research crew was careful to interplant seedlings at exactly the same spacing as the original seedlings (i.e. in the exact spot where an original seedling was removed). In practice, operational planting crews would just plant a specified number of seedlings per acre to bring the density back to some target (in this study, 450 trees per acre) and as a result would likely have a much more patchy stand distribution.

Table 4. Comparison of heights and survival one year after interplanting in the 2007 study.

Density (trees per acre)	Average Height (ft.)		Height of Tallest Tree (ft.)		Survival (%)	
	Original Trees	Interplanted Trees	Original Trees	Interplanted Trees	Original Trees	Interplanted Trees
450*	3.29		5.70		99	
300	3.40	0.84	7.40	1.70	97	96
200	3.36	0.74	5.50	1.80	100	97
100	3.04	0.65	5.00	1.80	100	92
* Original Stand - no interplanting						

Figure 11. Comparison of original (left) and interplanted (right) seedlings at the end of the 2007 growing season (one year after interplanting). Pinflags are each approximately 2 ft in height.

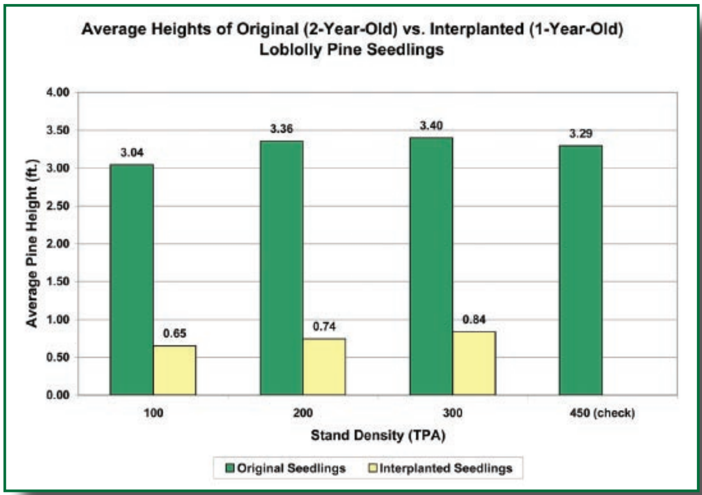

Figure 12. Average total heights of original and interplanted seedlings from the 2007 interplanting study after one growing season.

Hardwood Silviculture

Effects of Crown Touching Release and Fertilization on Growth of Southern Red Oak

On Nov. 7, 2003, we installed a test of hardwood crop tree release using Garlon 4 herbicide applied as a thinline basal spray to remove competing stems in a 12-year-old stand. The test area had been allowed to naturally regenerate in hardwoods following a clearcut harvest and prescribe burned in 1991. A total of 138 of eight stems of different species were originally released. On April 26, 2007, we selected the predominant species in the test – southern red oak – and released 23 of them again – this time with chainsaws (Figure 13). In addition, we fertilized eleven of those with 200 pounds of nitrogen plus 25 pounds of phosphorus per acre.

After one year, there has been a diameter response to the fertilization treatment. Figure 14 shows that after the fertilizer was applied, the difference in average diameter at breast height between the two groups of trees increased from 0.07 to 0.2 inches. Combined with the results we found from our white oak crop tree release study (reported in the March 2007 issue), it appears that combining crop tree release with fertilization can increase hardwood growth for at least a year, and hopefully (pending future measurements) longer.

Figure 13. A southern red oak release using a chainsaw in the spring of 2007.

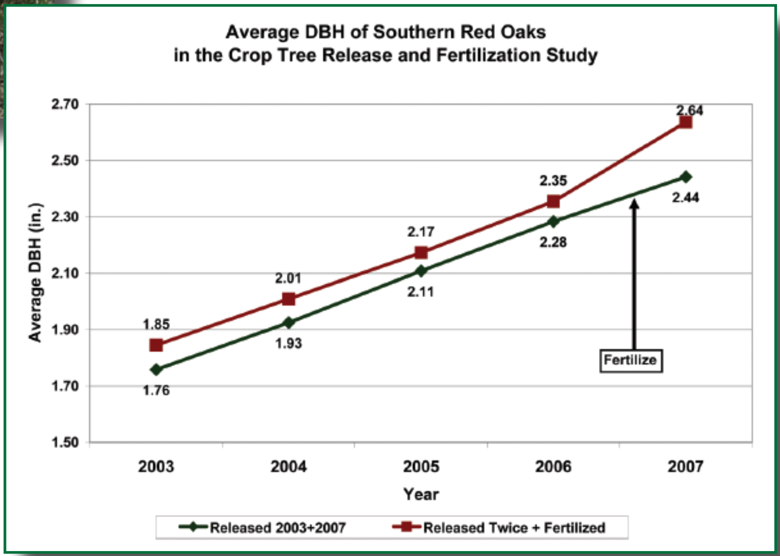

Figure 14. Average dbh of southern red oaks in the crop tree release and fertilization study.

Virginia Department of Forestry
900 Natural Resources Drive, Suite 800
Charlottesville, VA 22903