VIRGINIA DEPARTMENT OF FORESTRY

Forest Research Review

May 2011

In March 2011, we installed a study in Appomattox County to compare five different types of tree shelters for protection of northern red oak planted in riparian buffers. The test includes Tubex, Tubex Combi-tube, Acorn and Acorn Bio-shelter along with shelters constructed from four-foot woven wire.

In this issue...

VDOF Research Program

Jerre Creighton, research program manager

Onesphore Bitoki, tree improvement forester

Welcome to the spring 2011 issue of the Research Review. There have been significant changes in the VDOF Research Program since our last issue. We have initiated several new studies; received news of significant grant funding from two of our research cooperatives, and seen the departure of three of our research staff team members.

Over the last few months, we have installed six new studies – many in collaboration with colleagues from other agencies – that we will be reporting on in coming issues. These include 1) a comparison of different tree shelter types for planting northern red oak (photo on cover); 2) a shortleaf pine provenance test comparing Virginia, Missouri and Arkansas seed sources; 3) an expanded longleaf pine provenance test (in cooperation with the USDA Forest Service and NC State University) comparing 138 seed sources at 10 locations across the Southeast; 4) a comparison of water-use efficiency among the eight provenances in our 2006 longleaf pine test (also in collaboration with the USDA Forest Service); 5) a study to track the fate of nitrogen fertilizer applied to thinned loblolly pine (in collaboration with Virginia Tech and NC State Universities), and 6) a spacing study with loblolly pine of seven different genetic selections at planting densities from a few hundred to several thousand per acre.

From our research cooperatives comes news that the USDA National Institute of Food and Agriculture (NIFA) recently announced two significant research grants that VDOF will share in as a result of our memberships. First, in early January, a $14.6 million NIFA award was granted to a team led by Dr. David Neale of the University of California-Davis to sequence the loblolly pine genome. The pine germplasm to be sequenced comes from the North Carolina State University **Cooperative Tree Improvement Program** and was produced by a mating made by the Virginia Department of Forestry. Our loblolly pine selection will be the reference genome sequence of loblolly pine. And second, in February, they awarded a $20 million grant to study the effects of climate change on southern pine plantations to a consortium of universities in the South lead by the University of Florida. Virginia Tech and NC State are major partners. This is the largest grant of its kind ever awarded to productivity research in southern pine. Among other things, approximately $3 million will go to silviculture research; $3 million for genetics and genomics; $1.2 million for ecophysiology research, and $1.2 million for modeling work. The **Forest Productivity and Forest Modeling Cooperative** at Virginia Tech and NC State will receive significant funding and has a major role in the silviculture, ecophysiology and modeling portions of the grant.

The following pages contain updates on several new and ongoing loblolly pine studies we measured over the winter, including: 1) two-year results from thinning and fertilization at mid-rotation; 2) plantation density effects on long-term volume production; 3) effects of biosolid applications on growth, and 4) five-year growth response to hardwood competition control at different times. In addition, there are five-year results from the longleaf pine provenance study and six-year findings in the white oak crop tree release x fertilization test.

Visit http://www.dof.virginia.gov/research/index.shtml to browse all of the publications, fact sheets and analytical tools delivered by the VDOF Research Program.

Farewells….

In the past three months, the Research Program has seen major changes in staffing that deserve special recognition. Nearly 65 years of experience with the Department of Forestry departed as Research Forester Wayne Bowman and Tree Improvement Technician Donnie Jamerson retired and Longleaf Restoration Forester G. T. Hendrick accepted a position as the VDOF technician serving Fluvanna and Goochland counties. All three made substantial contributions to our program and will all be greatly missed.

Wayne Bowman, research forester

Wayne Bowman worked part-time with VDOF in 1974 at the Appomattox-Buckingham State Forest and began full-time employment in September 1975 as Forester A in Halifax County working on southern pine beetle control and other disease programs. In October 1976, he transferred to Portsmouth as Forester B, and a month later, due to illness of a co-worker, he moved to the Accomack County on the Eastern Shore. In July 1977, he was promoted to county forester in Appomattox County, and in May 1989, he transferred to the Appomattox-Buckingham State Forest where he was upgraded to forester supervisor in July 1992. Over the coming years, Wayne went through a few job title changes (forester supervisor / resource forester / natural resource manager I / natural resource specialist III), but remained on the State Forest – most recently as research forester – until his retirement Jan. 1, 2011. He had 35 years of service with the VDOF.

Donnie Jamerson, research specialist

Donnie Jamerson worked part-time beginning in 1983 until a year later when he was offered the full-time forestry aide position at Appomattox-Buckingham State Forest. Over the years, the job titles changed but the work within the seed orchard and State Forest system remained just as important. Donnie was responsible for the establishment and maintenance of the seed production areas that provided most of the white pine and many of the loblolly pine seedlings produced by our nurseries over the years. The orchards were always neatly mowed and healthy under Donnie's watch. At his Jan. 1, 2011 retirement – after almost 27 years of full-time employment – his job title was natural resource specialist II.

G.T. Hendrick, SPB specialist

G. T. Hendrick – the "new kid on the block" – worked as an FIA forester in southwest Virginia beginning in 2008 before starting full-time with the Department in July 2009 as the longleaf pine/southern pine bark beetle specialist stationed at the New Kent Forestry Center. On March 25, 2011, he transferred to the technician position covering Fluvanna/Goochland counties.

Thank you, Wayne, Donnie and GT, for all your excellent work and contributions to the VDOF Research, Tree Improvement and Longleaf Pine Restoration programs.

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Forest Productivity Cooperative (Virginia Tech, NC State)

Thinning and Fertilization in Mid-Rotation Loblolly Pine (Regionwide 19) – Location 195501 – Appomattox-Buckingham State Forest

A good deal of study over the years has gone into understanding loblolly pine response to thinning and fertilizer as individual treatments. But to optimize stand value, we need to understand and predict tree and stand growth responses when thinning and fertilization are combined. Foresters need help to decide how to strike the right balance between overall stand growth and individual tree growth.

A number of important questions must be answered, including: 1) How fast can individual trees grow (diameter and volume) in nutrient-rich environments where stand density is maintained at low levels through thinning?; 2) What are the relationships between individual tree growth, stand volume growth and stand density and how are those relationships affected by fertilization?; 3) What is the impact of fertilization and thinning on wood properties and stem quality?; 4) At what age can stands be thinned to low densities to maximize diameter growth and still maintain acceptable stem and wood quality?, and 5) Do we need to have different fertilization regimes based on stand density and crown conditions?

With help from the Forest Productivity Cooperative, we completed installation of one location of a test designed to answer these questions in early 2009. Five additional locations have been installed in other states across the South. Our test is in a plantation at the Appomattox-Buckingham State Forest (ABSF) that was 15 years old at the time of installation. The initial stand had 476 surviving trees and 137 square feet of basal area per acre. Treatments included an unthinned check plus plots thinned to 300, 200 and 100 trees per acre (tpa). All of these were repeated with and without fertilization (200 lb. nitrogen + 25 lb. phosphorus) and the entire eight-treatment scheme was replicated four times. All volunteer pines and competing hardwoods were removed first by cutting and later by a ground-based herbicide release treatment.

Early results after two years have just been compiled (Table 1). As we would expect, trees in thinned plots have easier access to sunlight so they are growing more in diameter and less in height than the unthinned trees. And, an interesting trend in diameter growth is already developing. After just two years, statistical tests show that there is an interaction between thinning and fertilization – the diameter response differs depending on the stand density. Notice for example (Figure 1), that the response to fertilizer is smaller (0.14 in.) in the unthinned plots than in any of the thinned plots. Over time, there is a chance that similar differences could develop among the other residual densities. This is the goal of this study – to help foresters decide what combination of thinning intensity and fertilizer will produce the optimum growth for a particular silvicultural objective.

Table 1. Diameter (dbh) and total height growth two years after thinning and fertilizer application in the Forest Productivity Cooperative Regionwide 19 study at ABSF.

Treatment	Diameter			Height		
	Growth (in.)	Response (in.)	Response (%)	Growth (ft.)	Response (ft.)	Response (%)
*476 tpa (unfertilized)	0.49			6.2		
100 tpa (unfertilized)	0.94	4.5	92	4.2	-2.0	-32
200 tpa (unfertilized)	0.68	1.9	38	6.0	-0.2	-3
300 tpa (unfertilized)	0.57	0.8	16	5.4	-0.8	-13
*476 tpa (fertilized)	0.63	1.4	28	6.2	0.0	0
100 tpa (fertilized)	1.25	7.6	154	4.6	-1.6	-26
200 tpa (fertilized)	0.95	4.5	92	5.5	-0.7	-11
300 tpa (fertilized)	0.83	3.4	68	5.8	-0.4	-6
* unthinned plots						

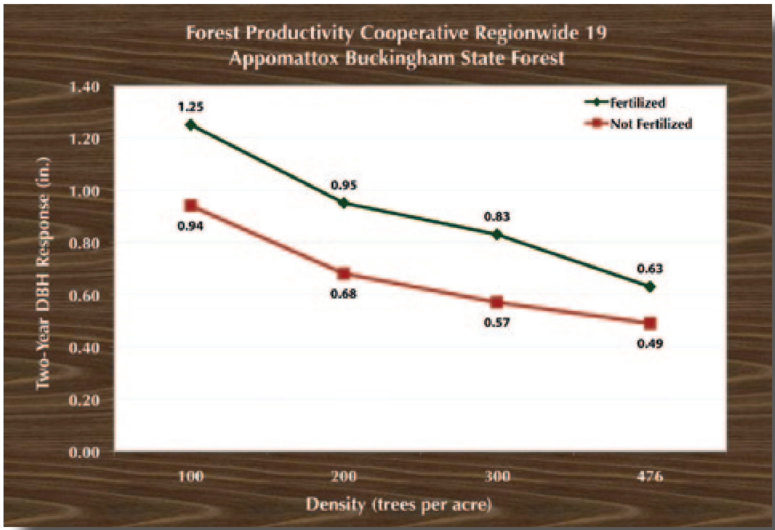

Figure 1. Diameter (dbh) growth two years after thinning and fertilizer application in the Forest Productivity Cooperative Regionwide 19 study at ABSF.

Forest Modeling Cooperative (Virginia Tech)

Rotation-Age Results from a Loblolly Pine Spacing Trial (Report No. 159, July 2010)

Cubic-foot volume yields from a 25-year-old loblolly pine spacing trial show how closely total and merchantable wood production are linked to initial spacing. Results at the close of the study indicate that 1) high-density plantations can be managed on short rotations for woody biomass production; 2) pulpwood yields can be maximized at a planting density in the neighborhood of 680 trees/acre; 3) the production of solid wood products requires lower establishment densities with as few as 300 trees/acre planted resulting in a substantial proportion of the total yield recovered as large sawtimber, and 4) a ratio of between-row to within-row planting distances of at least 3:1 does not substantially affect yield production. When considered together, results from this study suggest that no single planting density is optimal for the wide array of product objectives for which loblolly pine is managed in the South. Rather, managers must select an appropriate planting density in view of the products anticipated at harvest.

One of the most-visited locations on the Appomattox-Buckingham State Forest is our surviving replication of this test (Figure 2). Some results from that location demonstrate the overall study conclusions reported above. Figure 3 demonstrates how early production of wood fiber (albeit on smaller individual trees) for uses such as biomass or biofuels could be maximized at very high densities, while planting fewer trees per acre creates stands that can maintain their health and vigorous growth for a longer period and produce larger individual trees while doing so. Notice how, by the end of the 25-year measurement period, the ranking of the different densities has almost completely reversed (and the trend appears to be that the 303-tpa plots would soon surpass the 454-tpa stand).

In addition to total stand volume and individual tree size, planting density also dramatically affects the age at which the stand matures. One very simple way of defining rotation age holds that the biological maturity of the stand occurs when periodic annual increment (PAI) falls below the mean annual increment (MAI) – in other words, when the growth in one year is less than what the stand has been averaging over its life up to that point. Doing

Figure 2. Loblolly pine trees 28 years after planting at densities of 2,722 trees per acre (left) compared to 303 trees per acre (right). In addition to the differences in individual tree size, notice the much heavier development of hardwood regeneration on the lower-density plot.

this for the spacing study yields some pretty interesting results (Figure 4), indicating that the most-dense stands would need thinning or harvest no later than age 11-12, whereas the least-dense stand could grow for 25 years before growth falls below the threshold.

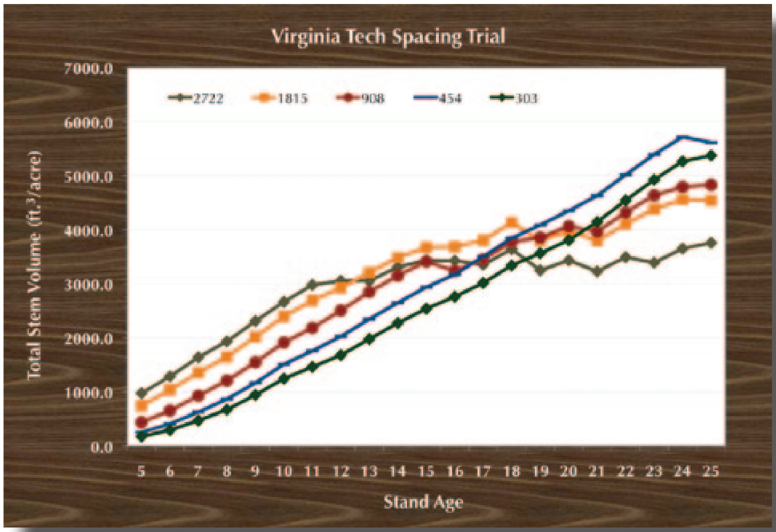

Figure 3. Total tree volume trends over a 25-year rotation of loblolly pine planted at a range of densities at Appomattox-Buckingham State Forest and never thinned.

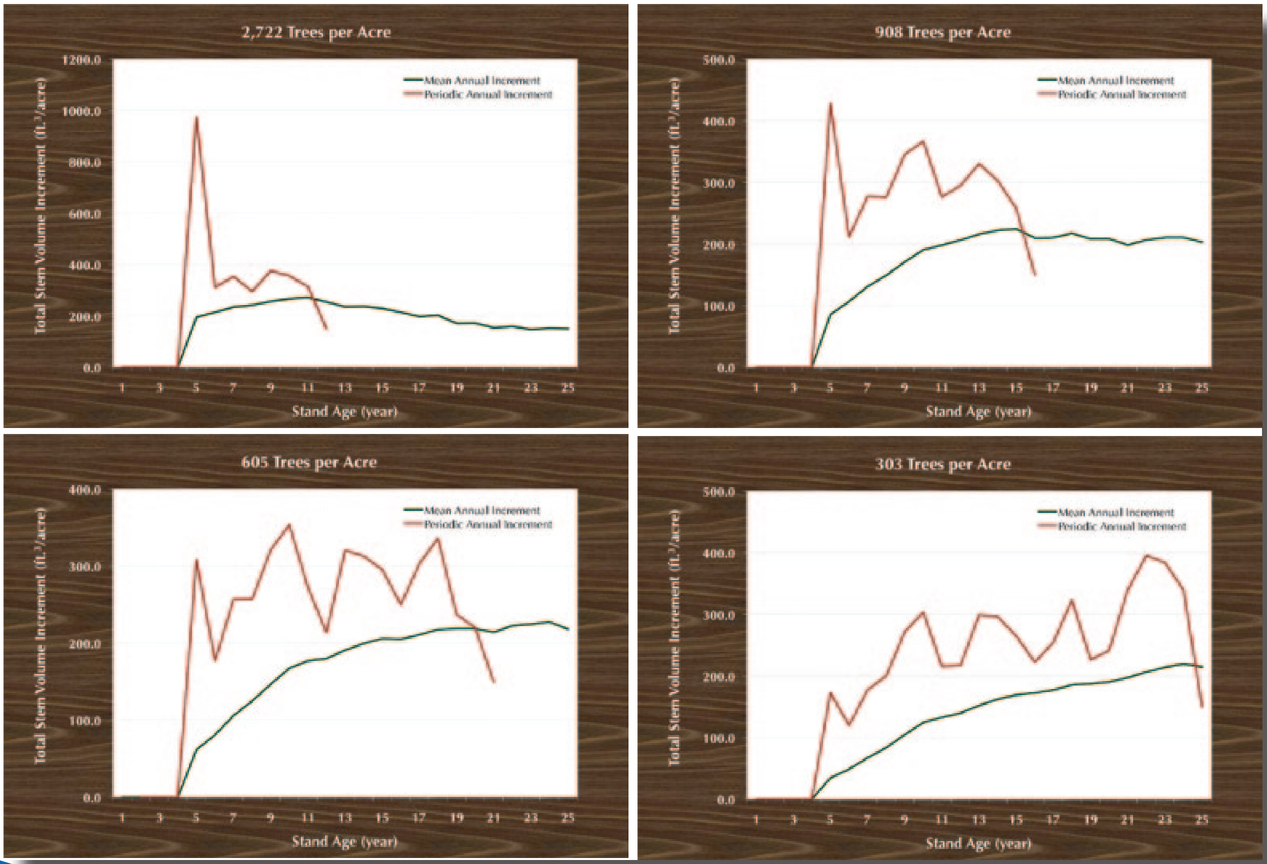

Figure 4. Estimating rotation ages for unthinned loblolly pine at various planting densities by comparing mean to periodic annual increments. Approximate rotations: 2,722 tpa – 11-12 years; 908 tpa – 15-16 years , 605 tpa – 20-21 years; 303 tpa – 24-25 years.

Comparing Biosolids to Traditional Fertilizers for Loblolly Pine

We recently completed our fourth year of data collection on the Essex County study comparing biosolid applications and traditional inorganic fertilizer (urea + diammonium phosphate (DAP)) on the growth of thinned, mid-rotation loblolly pine. Earlier reports from this study are in the October 2010, April 2009 and April 2008 editions of the Forest Research Review.

During the four years since treatment, all of the fertilizer treatments have positively affected tree growth (Table 2). Fertilized plots have produced between 53 and 70 percent more total tree volume over that time period (Figure 5). Diameter growth slowed last year (Figure 6), although all of the fertilized plots still grew better than the unfertilized control. Statistically, all three nutrient sources are producing similar diameter growth responses, and all three are significantly outgrowing the untreated plot. And the difference has been greater with each succeeding year. While the decline in growth last season could have been drought-related, we are especially interested to see what next year's measurements show.

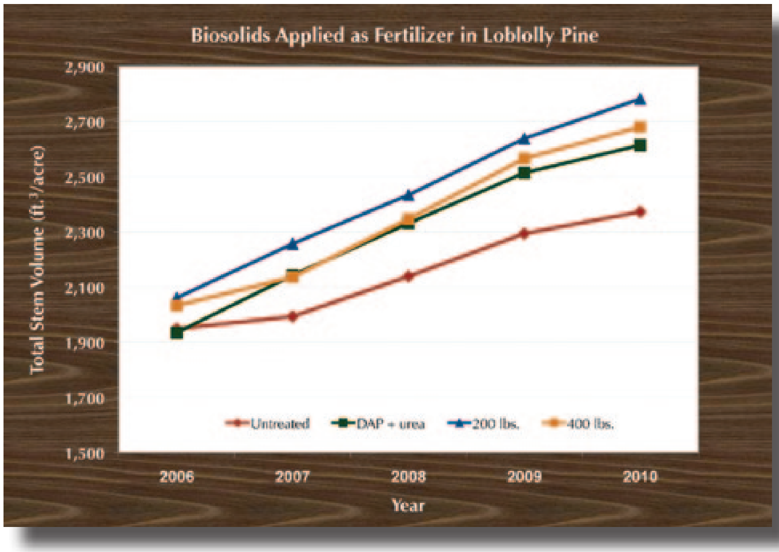

Figure 5. Total stem volume growth curves since fertilizer application in mid-2006.

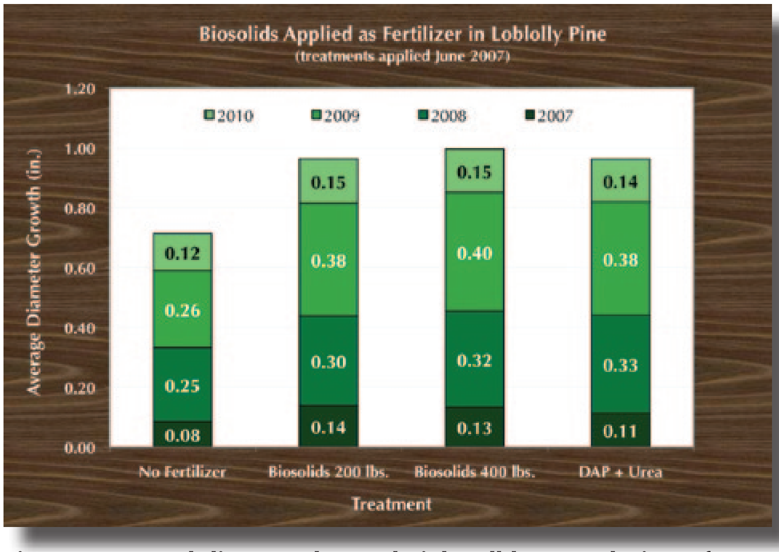

Figure 6. Annual diameter breast height (dbh) growth (in.) of loblolly pine in the study of biosolids applications.

Table 2. Summary of loblolly pine growth responses through four growing seasons following application of biosolids and inorganic fertilizer.

Treatment	DBH (in.)	DBH Growth (in.)	Height (ft.)	Height Growth (ft.)	Total Volume ($ft.^3$/acre)	Volume Growth ($ft.^3$/acre)	Volume Response (%)
Untreated	8.85	0.72	57.6	2.84	2,372	423	–
Biosolids – 200 lb. N	9.14	0.96	61.6	4.89	2,782	722	70
Biosolids – 400 lb. N	9.18	1.00	60.2	4.85	2,680	647	53
DAP + Urea	9.32	0.98	60.6	5.73	2,613	679	60

Timing of Hardwood Competition Control in Loblolly Pine – Age 5 Results

In last October's issue, we reported preliminary/partial results of a study comparing the effects of various chemical weed control strategies on loblolly pine growth. The test was installed on the Appomattox-Buckingham State Forest just east of the headquarters in stand AB-0708 of the Glover Management Unit. Hardwood competition was heavy at this site (typical of Piedmont Virginia sites).

The study is a randomized completed block design with three replications. Treatments were applied using a split-plot approach. The eight whole-plot treatments included:

- an untreated check;
- two site prep mixes [imazapyr (Chopper at 40 oz./acre) alone and with sulfometuron (Sulfometuron Max at 3 oz./acre)] at three different application times (July 23, September 3 and October 1) – a total of six treatments, and
- one chemical release treatment [imazapyr (Arsenal at 12 oz./acre applied Sept. 12, 2007].

Half of each whole plot was treated for first-season herbaceous weed control April 14, 2006 with imazapyr + sulfometuron (Arsenal at 4 oz./acre plus Oust at 2 oz./acre) and the other half received no further treatment.

The test site was burned very thoroughly just weeks before the beginning of the study. There was virtually no leaf area present at the first (July) application, and not much more by the time of the October treatments that we measured. Perhaps as a result of this intense site-prep burn, there was relatively little development of herbaceous or vine competition and, hence, there was no pine growth response to either the site-prep treatments that included Sulfometuron Max or the first-year Arsenal / Oust treatments. Therefore, the data presented here are averages of the combined data from those plots.

The results (Table 3, Figure 7) clearly show the importance of hardwood competition control and of treatment timing. The best plots in the test have trees that average 3.3 inches in diameter and 16 feet in height at age five – not bad for the Virginia Piedmont. The herbicide release at age two increased volume growth by 24 percent over no treatment, but the site prep was applied two years earlier and increased volume growth by 47 (August) to 69 (October) percent. Among the site prep treatments, development of hardwood leaf area following the burn was important. Waiting until October to apply the herbicides resulted in better hardwood control (as measured by the VDOF free-to-grow rating) and greater growth response than the application in early August immediately after the burn (Figure 8).

Table 3. Age five growth summary for loblolly pines following chemical site preparation before planting; hardwood competition control at age two, or no competition control treatment. (*Tree volume calculated as the volume of a cylinder: DBH2*Height* Survival*454 trees per acre).

Treatment	FTG Rating (1-4)	DBH (in.)	Height (ft.)	Survival (%)	Basal Area (ft.^{2}/acre)	Volume (ft.^{3}/acre)	Volume Response (ft.^{3}/acre)	Volume Response (%)
Untreated	3.0	2.06	11.99	95	11.7	170	–	–
October Site Prep	1.1	3.28	16.15	96	26.4	288	118	69
September Site Prep	1.2	3.21	15.89	93	25.4	279	109	64
August Site Prep	2.1	2.95	15.62	95	21.6	249	79	47
Age 2 Release	1.6	2.66	13.81	97	17.9	211	41	24

Figure 7. A five-year-old loblolly pine stand with no competition control (left) compared to a site-prep herbicide application for hardwood control.

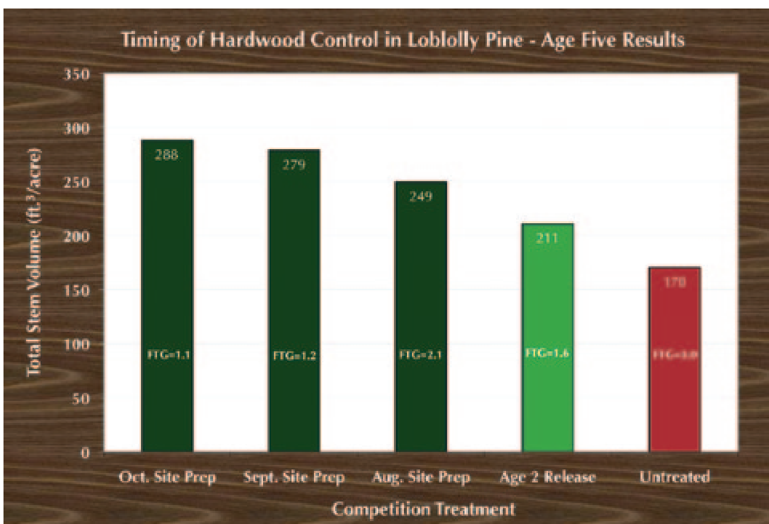

Figure 8: Age five loblolly pine volume comparison in the 2005 woody competition control study. (*Tree volume index calculated as the volume of a cylinder: DBH2*Height* Survival*454 trees per acre).

2006 Longleaf Pine Provenance Study

Our longleaf pine provenance study was planted in early 2006. The goal was 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 pine 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). We recently completed measurements and data analysis of this test at age five. Earlier results were summarized in the April 2008 issue of the Research Review.

After five years of growth, the results continue to support preservation of the northern Virginia native source. Seed collected in Southampton County from some of the few remaining native Virginia longleaf pines has outperformed all other seed sources (Table 4, Figure 9) in growth and survival. There are certainly differences among sites and replications in the performance of the various sources, but based on overall averages Virginia emerges as the top-ranked source in height, diameter, survival and emergence from the grass stage.

To carry the analysis a bit further, with help from Dr. Phil Sheridan of the Meadowview Biological Research Station, we calculated combined relative fitness rankings (for average age-five height, diameter and survival) across the three locations. The fitness scores are calculated by dividing the average for any attribute (height, dbh, etc.) for each source by the average for the top-ranked source. For example, from Table 4, the age-five height fitness score for NC orchard mix would be 5.85 divided by 6.01 or 0.973. In essence, this says that the measured height performance of the NC orchard source is 97.3 percent of the top ranked native Virginia source. The rankings for any number of attributes (height, dbh, survival, etc.) can be combined by simply multiplying them together. The results of this process are shown in Figure 10, and further document the desirability of northern source longleaf pine for planting in Virginia.

These data are not meant to suggest that other sources are not suitable or cannot succeed in Virginia. To the contrary, there are other sources – generally those from latitudes closest to Virginia, and in particular the North Carolina orchard source – that have performed well. But they do suggest that there is a difference between native Virginia and other sources that is worth preserving, and to that end, the VDOF, in collaboration with the Virginia Department of Conservation and Recreation's Natural Heritage Program, is continuing to collect as much seed and produce as many seedlings as possible from the remaining native trees for restoration projects in Virginia.

Table 4. Longleaf pine provenance study results after five years.

State	Source	Age 2 Height (ft.)	Age 3 Height (ft.)	Age 3 Percent Out of Grass Stage	Age 5 Height (ft.)	Age 5 DBH (in.)	Age 5 Survival (%)
VA	Holland #1 (Native)	0.62	1.49	81%	6.01	1.30	86%
NC	Orchard Mix	0.44	1.25	66%	5.85	1.29	73%
GA	Colquitt Co.	0.51	0.96	65%	4.86	1.21	78%
NC	Richmond Co.	0.41	1.07	56%	5.02	1.26	69%
SC	Dorchester Co.	0.44	0.97	61%	4.85	1.21	69%
AL	Talladega Co.	0.49	0.95	61%	4.63	1.14	76%
FL	Santa Rosa Co.	0.41	0.93	55%	4.85	1.14	65%
MS	Forest Co.	0.51	0.92	55%	4.55	1.15	69%

Figure 9. The New Kent location of the longleaf provenance test at age five. Native Virginia source seedlings are on the right, contrasted with Santa Rosa County, FL, seedlings on the left.

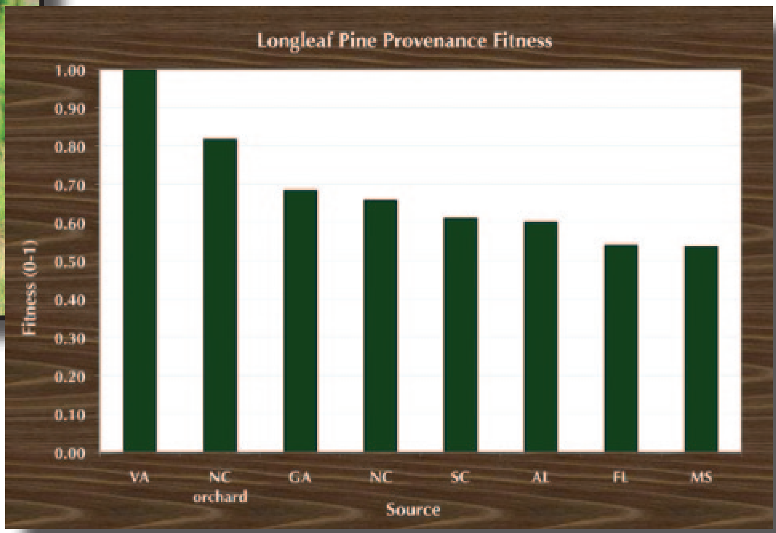

Figure 10. Combined relative fitness rankings (for average age-five height, diameter and survival) across three locations.

2005 White Oak Crop Tree Release Study – Six-Year Responses

On April 26, 2005, a study was installed in the Burnham Unit of the Appomattox-Buckingham State Forest in a 15-year-old mixed hardwood stand with the objective of evaluating the combined effects of crop tree release and fertilization on the growth of white oak. Three-tree replications were matched based on diameter breast height (dbh) and total height. Two of the three were selected at random for release (by felling all surrounding trees touching their canopy), and one of those two was then randomly selected to be fertilized at a rate of 200 lb. nitrogen plus 50 lb. phosphorus per acre over a tree-centered 10-ft.-radius circle. Earlier results were reported in the February 2007 and March 2010 editions of the Research Review.

After the end of the 2010 growing season, the trees were re-measured for dbh and total height (Table 5). An example of the differences in tree appearance after six years is in Figure 11. Height growth continues to be modest and statistically not affected by treatment. Diameter growth, meanwhile, was improved significantly with release (by 56 percent) and even more with the addition of fertilizer (by 70 percent). An additional learning from these plots is that larger trees respond more to the treatments than smaller trees; Figure 12 shows the relationship between initial dbh at the start of this test plotted on the x-axis and six-year dbh growth on the y-axis. As the trend line indicates, the best strategy with crop tree release of white oak is to release the largest, healthiest trees.

Table 5. Summary of white oak growth response through six years following crop tree release and fertilization treatments.

Treatment	2010		6-Year Growth	
	DBH (in.)	Height (ft.)	DBH (in.)	Height (ft.)
Untreated	4.15	36.75	1.04	10.79
Released	4.74	34.98	1.62	8.67
Released and Fertilized	4.89	36.31	1.77	9.71

Figure 11. Lower stem (bottom) and canopy (top) photos of 21-year-old white oaks that have been released in April 2005 and again in April 2011 (left) and never released (right).

Hardwood Silviculture, continued

The response to the added fertilizer has begun to diminish; beginning in the third year after treatment, fertilized trees have not grown any faster than those that were only released (Figure 13). As a result, the same treatments (crop tree release with or without 200 lb./acre plus 50 lb. P fertilizer) were re-applied in April 2011 to the same trees that received them six years ago. We look forward to continuing measurements of these plots to determine whether we can further boost the growth of these trees.

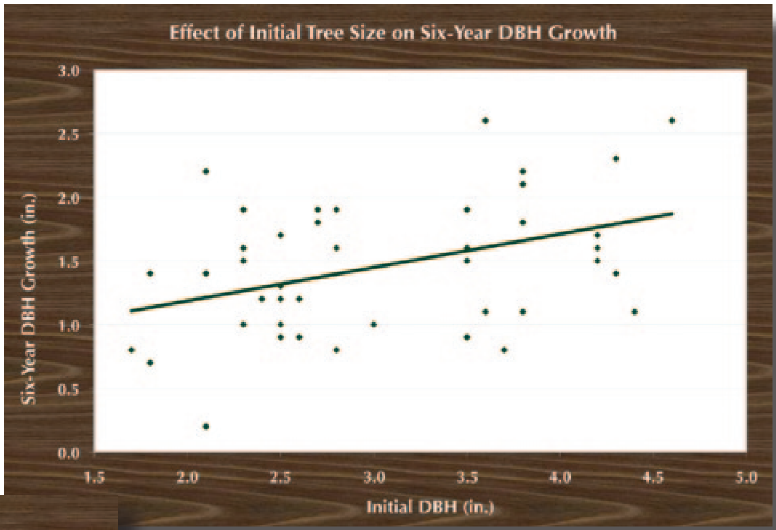

Figure 12. Relationship between initial tree size (dbh) and six-year dbh growth.

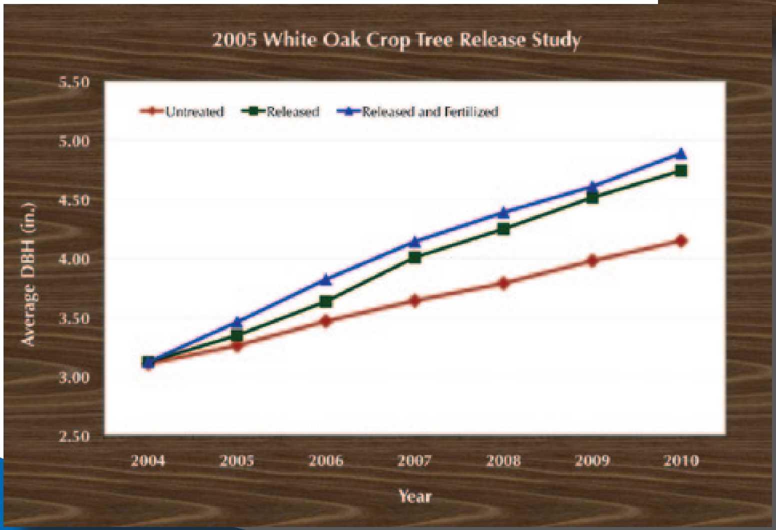

Figure 13. DBH growth curves over six years following crop tree release and fertilization in white oak.

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