FOREST RESEARCH REVIEW

August 2012

One location of the PineMap (Pine Integrated Network: Education, Mitigation and Adaptation Project) study, funded by a USDA National Institute of Food and Agriculture grant to a team of scientists from 11 southeastern land grant universities (coordinated by the University of Florida), was installed at Appomattox-Buckingham State Forest during the winter of 2011-2012.

IN THIS ISSUE...

VDOF Research Program

Jerre Creighton, research program manager

Onesphore Bitoki, tree improvement forester

It's time for the 2012 issue of the Virginia Department of Forestry Research Review. You may notice that it's been a while since the last issue; this is because we have decided to scale back our publication schedule from two publications per year to one. We feel we can still cover new results and study updates effectively while cutting costs and more efficiently using our limited resources. When important new topics or reports become available between issues, we will be issuing (via email and the web) occasional reports, fact sheets or information sheets as appropriate, so be on the lookout for those.

Over the last year, we have installed several new studies. One will examine alternative deployment strategies and planting configurations for new loblolly pine offerings from our tree improvement program. We are looking at ways to grow products for different markets (solid wood, pulpwood and biomass/biofuel) in the same plantation by planting at different densities in alternating rows to be harvested at different ages. We are also collaborating with Virginia Tech and NC State scientists to establish a hybrid poplar yield study and a cold-hardy eucalyptus planting. And, of course, the establishment of the PineMap study described in the last issue has recently been completed (cover photo), and we will be collecting data on the response of loblolly pine to differences in nutrient and moisture (i.e. rainfall) availability.

In the current issue, you will find summaries of recent efforts from the Forest Modeling and Forest Productivity Research Cooperatives (on loblolly pine pruning and fertilization effects at different planting densities, respectively), as well as updates on VDOF projects studying genetic sources of loblolly pine for use in Virginia; application of biosolids as fertilizer for loblolly pine; first-year performance of different provenances of shortleaf pine; interplanting loblolly pine after high first-year mortality; alternative types of tree shelters for protecting planted hardwoods, and responses of white oak and southern red oak to crop tree release and fertilization.

Feel free to visit www.dof.virginia.gov to browse all of the publications, fact sheets and analytical tools delivered by the VDOF Research Program. Contact us if you have questions, comments or suggestions.

Cover Photo: The work at Appomattox-Buckingham has been led by Andy Laviner under the direction of Dr. Tom Fox from Virginia Tech and will monitor the responses of loblolly pine to simulated drought and fertilizer additions over the next five years. The plot shown here simulates drought by preventing roughly one-third of the precipitation from reaching the forest floor.

Forest Modeling Cooperative (Virginia Tech)

Effects of Pruning on Young Loblolly Pine Plantations

(Amateis, R.L. and H.E. Burkhart. 2011. Growth of young loblolly pine trees following pruning. For. Ecol. Manag. 262: 2338-2343.)

Pruning can enhance wood quality – and hence stand value – by increasing the amount of knot-free wood in loblolly pine (*Pinus taeda* L). But the sudden removal of live branches decreases the leaf area available for photosynthesis, which could negatively affect growth. It is important to evaluate the impact of pruning on wood quality and the negative effects on growth rates before deciding to prune.

Two pruning experiments were established in February 2000 at each of two sites – one in Appomattox County and the other in Patrick County – in the Virginia Piedmont. The Appomattox location is on the Appomattox-Buckingham State Forest. The first experiment – called the "early tree pruning" or "ETP" study – looks for effects of the timing of pruning during the first 10 years of stand development in plots planted at a 10 x 10 foot spacing. The five treatments included: 1) the unpruned control; 2) removing 50 percent of the live crown at age three; 3) removing 50 percent of the live crown at age six; 4) removing 50 percent of the live crown at age nine, or 5) removing 50 percent of the live crown at ages three, six and nine. The second – called the "some tree pruning" or "STP" study – looks at the impacts of pruning intensity at crown closure (age six) – treating a portion of the trees compared to all trees in a stand planted at a 6 x 6 foot spacing (Figure 1). Again, five treatments were tested: 1) the unpruned control; 2) removing 25 percent of the crown on all trees; 3) removing 50 percent of the crown on all trees; 4) removing 25 percent of the live crown on half of the trees, or 5) removing 50 percent of the live crown on half of the trees.

The important results are consistent and straightforward (Table 1):

- For a single pruning at any of these young ages, the effect on height growth was small and temporary. Even at very young ages with severe pruning, there was little impact on height growth.

Figure 1. Plots with no pruning (left) and pruning of all trees to 50 percent of crown height (right) 12 growing seasons after planting on the STP study.

- Diameter growth was reduced for a year or two following single heavy pruning treatments, but by age 11, there was less than a half inch difference. Where pruning was later or less severe, the difference was even shorter-lived and smaller. Trees appeared to briefly shift allocation of resources to crown development and height growth at the expense of diameter.
- Three pruning treatments (at age 3, 6 and 9) had a larger negative effect on growth than single pruning operations.
- A light pruning, removing 25 percent of the live crown, had no impact on subsequent height, dbh or crown growth.
- When half the trees were heavily pruned, the growth at plot level was not reduced and the growth of the pruned trees was not hindered by the unpruned neighbors.

In conclusion, pruning up to half of the live crown in young loblolly pines does not reduce subsequent growth. This is the case in trees pruned before (conditions similar to lower density stands) or after (conditions similar to more dense plantings) crown closure. It is possible to select specific trees to prune while leaving others unpruned without affecting subsequent tree or stand development. Wood quality can be improved through pruning without compromising rapid tree or stand growth rates gained from improved genetics or intensive management.

continued on page 4

Table 1. Age 11 results from the "ETP" (early tree pruning) study and "STP" (some tree pruning) study.

ETP Study – All Pruned 50% of Live Crown	
Pruning Treatment	DBH Growth (in.)
None	6.63
Age 3	6.43
Age 6	6.14
Age 9	6.24
Ages 3, 6 & 9	5.50
STP Study – All Pruned at Age 6	
Pruning Treatment	DBH Growth (in.)
None	2.08
25%, all trees	2.06
50%, all trees	1.88
25%, half of trees	2.07
unpruned trees	2.09
pruned trees	2.06
50%, half of trees	2.01
unpruned trees	2.16
pruned trees	1.87

Forest Productivity Cooperative (Virginia Tech, NC State)

Combined Effects of Planting Density and Nutrient Additions on the Growth of Loblolly Pine Through Mid-Rotation (age 14). Data summary and analysis by Colleen Carlson at Virginia Tech.

In 2006, VDOF and the Forest Productivity Cooperative staff at Virginia Tech agreed to collaborate on the continued measurement, maintenance and reporting of a nutrient x density trial established by MeadWestvaco in Buckingham County in 1998. We last reported on the results in the April 2008 issue of the review.

This report summarizes the data collected through 2011 (Table 2). The trial is designed as a factorial with three target levels of site index (SI_{25}) (a low nutrient regime where the 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 have not affected survival or tree height during the first 14 years of the trial. Average survival and height across the test are 96 percent and 44 feet, respectively. Diameter, however, has been significantly influenced by nutrition (since age 4) and density (since age 5). The lower stand density has increased diameter (averaged across all three nutrition treatments) by 1.7 inches (more than 26 percent) and the intermediate and high nutrition levels have increased diameter (averaged over both stand density treatments) by 0.3 and 0.6 inches, respectively, compared to the lowest nutrient

Table 2. Summary of individual tree and stand level data through age 14.

Measurement	Nutrient Availability / Planting Density					
	Low (SI_{25}=55)		Intermediate (SI_{25}=70)		High (SI_{25}=80)	
	363 tpa	726 tpa	363 tpa	726 tpa	363 tpa	726 tpa
Height (ft.)	44	43	44	43	44	44
DBH (in.)	7.9	6.3	8.3	6.6	8.5	6.8
Crown Length (ft.)	26	21	26	20	26	20
Basal Area (sq. ft./acre)	118.4	155.8	130.4	163.5	136.0	176.7
Total Volume (cu. ft./acre)	1874	2444	2105	2574	2170	2818

level (Figure 2). These differences in individual tree dbh growth are likely a result of the considerably larger crowns (28 percent greater crown length, on average) of trees at the lower planting density.

On a stand level, of course, total volume productivity remains greater where there are more trees. Compared to the low planting density, the 726 trees per acre plots contain nearly 30 percent more basal area and volume. Over time, the basal area curves for the two densities continue to diverge. But depending on the target rotation age (i.e. on the product mix objective) for the stand and market conditions, the dollar value of the lower density stand could begin to surpass that of the high-density planting.

Figure 2. 726 trees per acre at low fertility (left) compared to 363 tpa with high fertility (right).

Tree Improvement

Comparing Varietal and Open-Pollinated Loblolly Pine Seedlings

by Onesphore Bitoki, Tree Improvement Forester

For more than five decades, tree breeders in the Southeast United States produced seed by traditional breeding methods (either open or controlled pollination). In recent years, new technologies in tree improvement, such as embryogenesis and controlled mass pollination, enabled production of new varieties and full-sibling crosses. All these different seedling types have varied adaptability, productivity and disease resistance depending on their geographic origins and where they are deployed. Study trials of these new seedlings have been established to find the best suited seedlings for the Virginia environment.

VDOF's first study of this kind was established in spring of 2007 at the New Kent Forestry Center with the collaboration of ArborGen. Preliminary results after one growing season were reported in the May 2008 issue. In 2008, we established a larger study with new material from ArborGen and CellFor at our Hockley research station in King William County. In this issue, we present updated results of the first trial at New Kent and an initial analysis of the newer trial.

The objectives and experimental design for the 2007 study were described in detail in the May 2008 issue. In summary, the objectives were to make a direct comparison of clonal and Virginia traditional open-pollinated seedlings (orchard mixes from both first- and second-generation VDOF orchards); test the adaptability of the new varieties in New Kent area, and establish a demonstration and educational site for varietal forestry possibilities in Virginia. After one growing season, we reported that there were highly significant differences in growth for the different seedlings; the fastest growers were the two ArborGen varieties with AG-34 being the best.

After four years, we conducted a survival count and measured total tree heights. The results are summarized in Table 3. Survival has decreased for all seedling types.

Table 3. Average height (feet) and survival (%) for different seedling types after first, second and fourth growing seasons in a study at New Kent Forestry Center.

Seedling Type	Height (ft.)				Survival (%)	
	Age 1	Age 2	Age 4	Growth	Age 1	Age 4
VDOF 1st Gen	0.97	2.26	5.80	4.83	81	70
VDOF 2nd Gen	0.96	2.23	6.02	5.06	85	81
Arborgen A34	1.87	3.13	6.25	4.38	88	82
Arborgen A769	1.52	2.63	6.85	5.33	97	79

This decline was due to deer damage in the second year. Analysis of height growth shows no statistically significant differences among the four seedling types. Notice that Virginia's traditional open-pollinated seedling mixes are not significantly different from varieties developed elsewhere, at least the ones we tested. Since the height growth trends and rankings (Figure 3) appear to be changing during the early years of this test, we are anxious to follow it in coming years to see how the local selections in the VDOF orchards perform compared to the newer offerings.

We established a second study at the Hockley research station in March and April of 2008 with seedlings from ArborGen and CellFor to continue searching for the best products suited for Virginia's conditions. The objectives of the study at Hockley were to demonstrate new seedling varieties and compare their adaptability and growth rate to traditional VDOF orchard mixes from our first and second generation orchards. We used a randomized complete block design with four replications of 25-tree plots.

In January 2011, we assessed the test for survival and measured total height (Table 4). Survival was excellent – ranging from 91 to 97 percent – and did not differ among seedling types. In terms of height growth (Figure 4), there were differences among seedling types with CF-L3791 ranking highest but not significantly different from the two Virginia's open-pollinated mix seedlings or AGM-51. The other two CellFor clones are at the bottom of the ranking but not different from the rest except CF-L3791. Notice that VDOF second gen and first gen are ranked third and fourth respectively in early height growth. We are pleased that the VDOF open-pollinated orchard mixes have compared favorably, and see this as an indication that our nursery's newer offerings – including only top-ranked individual families or groups of families (Virginia's Best, Elite and Premium) – should rank even higher. Tests including those offerings are planned in the near future.

Table 4. Average height (feet) and survival (%) for different seedling types after three growing seasons in a study at Hockley.

Family	Height (ft.)	Survival (%)
AGM-38	7.92	92
AGM-39	8.15	94.6
AGM-51	8.13	93
AGM-52	8.45	94.6
CF-L3791	8.90	92
CF-O6248	7.36	97
CF-Q7766	7.79	92
DOF Gen 1	8.21	91
DOF Gen 2	8.31	92

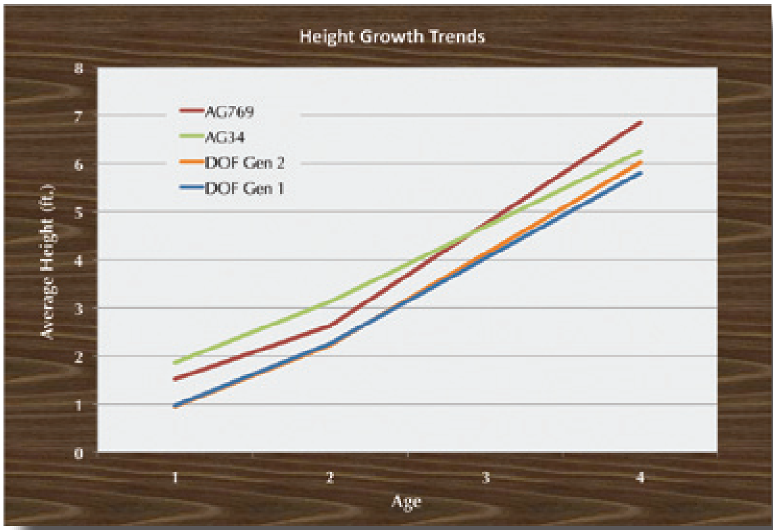

Figure 3. Height growth trends through four growing seasons of the 2007 study.

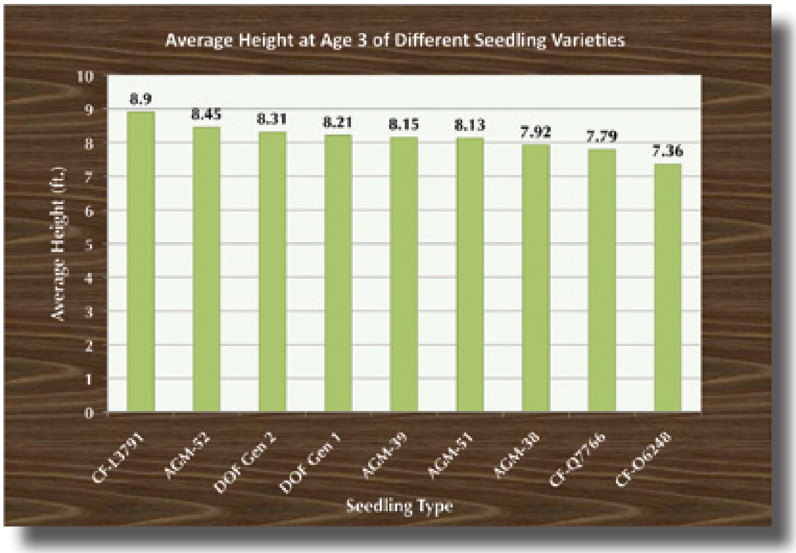

Figure 4. Average height at age three for different varieties and Virginia open-pollinated seedling study at Hockley.

Pine Silviculture

Comparing Biosolids to Traditional Fertilizers for Loblolly Pine

The use of biosolids – the solid or liquid material produced from the treatment of municipal waste water – as a source of nutrients in loblolly pines is the subject of a 2006 VDOF study. Our trial compares the effects of biosolid applications and traditional inorganic fertilizer (urea + diammonium phosphate (DAP)) on the growth of thinned mid-rotation loblolly pine. The plots are in western Essex County in a mid-rotation loblolly pine stand that was thinned the summer before fertilizer application. 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 applied at 200 lbs./acre of plant available nitrogen (PAN), and 4) biosolids at 400 lbs./acre PAN.

Tree growth parameters (total height, live crown ratio and diameter breast height (dbh)) of each tree in the tenth-acre measurement plots were measured before treatment and in each winter since. We recently completed the fifth year of data collection.

During the five years since the study was installed, all of the fertilizer treatments have positively affected tree growth (Table 5). Diameter growth slowed in 2010 (perhaps due to dry conditions) but accelerated again in 2011 (Figure 5). Fertilized plots have produced around 40 percent more total tree volume over that time period (Figure 6). Despite the fluctuations in growth rate, all of the fertilized plots have still grown better than the unfertilized control in every year. Statistically, all three nutrient sources are producing similar diameter growth responses, and all three are significantly outgrowing the untreated plot.

From these data, we can conclude that 1) nutrient additions as either biosolids or traditional inorganic fertilizer have been beneficial to tree growth, and 2) there is no evidence of any negative effects of the biosolids on loblolly pine growth or vigor.

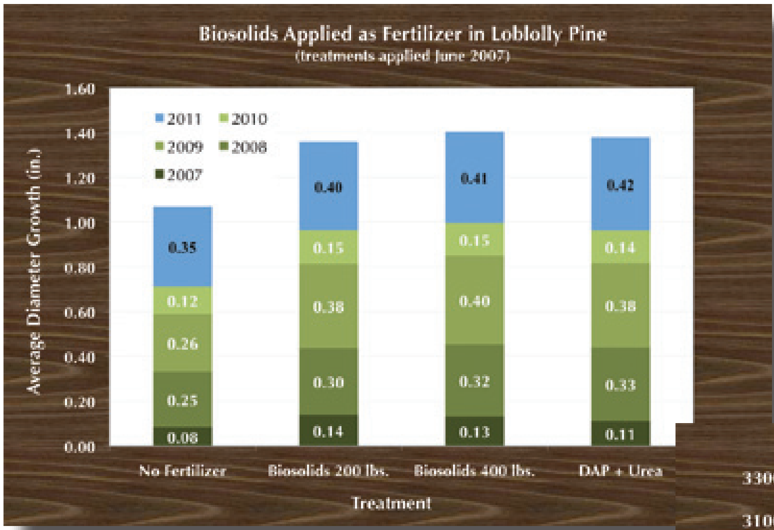

Figure 5. Annual diameter breast height (dbh) growth (in.) of loblolly pine in the study of biosolids applications.

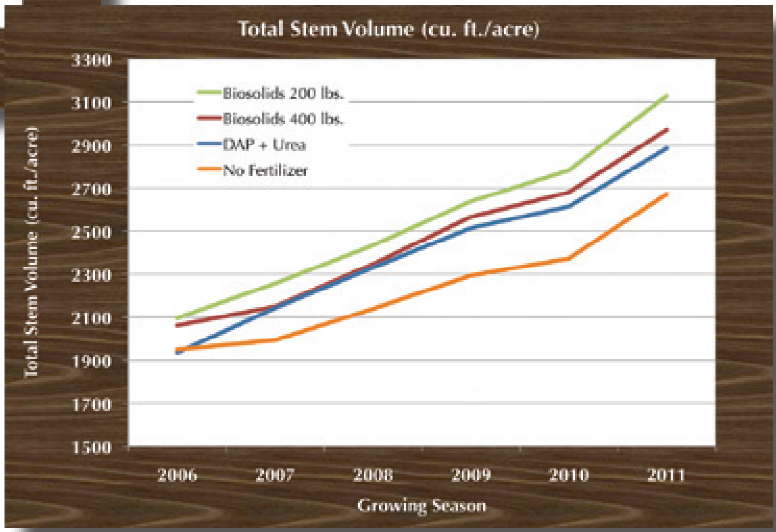

Figure 6. Total stem volume growth curves since fertilizer application in mid-2006.

Table 5. Summary of loblolly pine growth responses through five growing seasons following applications of biosolids and inorganic fertilizer.

Treatment	DBH (in.)	5-Year DBH Growth (in.)	Height (ft.)	5-Year Height Growth (ft.)	Total Volume (cu. ft./acre)	5-Year Volume Growth (cu. ft./acre)	Volume Response (%)
Untreated	9.20	1.07	59.9	7.29	2671	779	–
Biosolids-200 lbs. N	9.53	1.36	63.5	10.29	3128	1097	41%
Biosolids-400 lbs. N	9.61	1.41	61.9	10.45	2969	1076	38%
DAP + Urea	9.70	1.38	62.9	12.32	2884	1078	38%

Shortleaf Pine Provenance Test

In early 2011, we collaborated with Dr. Greg Frey and Dr. Marcus Comer of Virginia State University to install a study comparing three different geographic sources of shortleaf pine (Pinus echinata Mill): 1) Virginia; 2) Arkansas, and 3) Missouri. The seeds were collected from seed orchards containing genetic material from selected trees around each state. Our intention was to compare seedling populations commercially available to most landowners.

Seed from each source was obtained and sown at the Garland Gray Forestry Center in early 2010. The bareroot seedlings were lifted in March 2011 and planted on a 10 x 7 foot spacing (622 trees per acre) at Tucker Pond (in Greensville County, near Skippers, VA) in a randomized complete block experimental design with three replications. The old-field site was first scalped to remove the competing sod and root mat (Figure 7). Plots consisted of 49 trees in total with the interior 25 trees (0.04 acres) measured. In February 2012, survival was tallied and trees were measured for height and groundline diameter (GLD). Plot averages are presented in Table 6.

Survival was excellent through one year – averaging 98 percent – and did not differ by source; there were only five dead seedlings in the entire test. The mean diameters and heights were greatest for the Virginia seedlings, intermediate for Missouri and lowest for Arkansas. Statistical analysis showed that the diameter difference among the three sources was not significant, but there was a significant difference among the heights: the Virginia source was statistically taller than both Arkansas and Missouri, which in turn were not significantly different from each other. A volume index integrating the combined effects of survival, diameter and height is depicted in Figure 8 and gives an indication of the one-year comparison among shortleaf pine seed sources.

Figure 7. Newly-planted shortleaf pine seedlings from Arkansas, Missouri and Virginia in scalped rows at the 2011 provenance test site.

Table 6. Average height, diameter at groundline and volume index for one-year-old shortleaf pine from Arkansas, Missouri and Virginia seed sources.

Source	Survival (%)	Height (ft.)	Groundline Diameter (in.)	Volume (cu. in/acre)
Arkansas	99%	0.99	0.29	586
Missouri	97%	1.08	0.34	864
Virginia	97%	1.20	0.37	1089

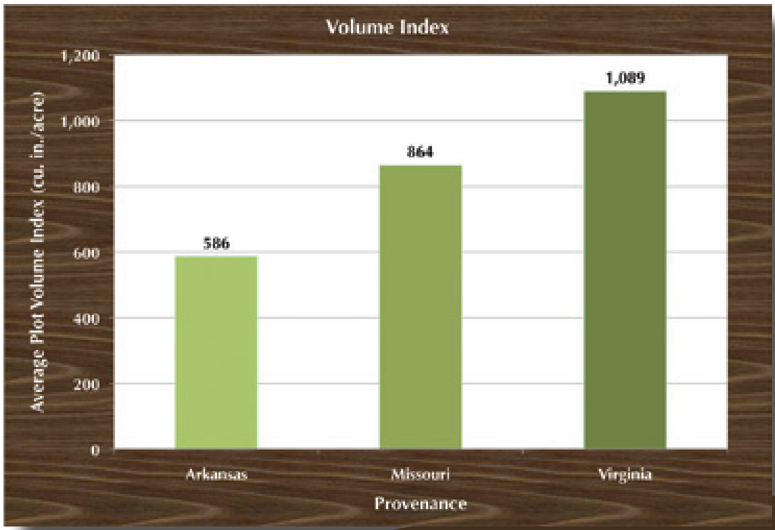

Figure 8. Volume index [(height*12) * {(diameter/2)^2}*3.14)] for Arkansas, Missouri and Virginia source shortleaf pines after one year.

Interplanting Loblolly Pine in Stands with Varying Levels of Simulated Random Mortality

In 2007, we initiated a trial to evaluate interplanting of loblolly pine seedlings in a stand on the Appomattox-Buckingham State Forest in Buckingham County established one year earlier with various levels of simulated poor survival. The study is now five years old and the original stand is age six. In 1980, VDOF Occasional Report 53 concluded that interplanting was unsuccessful in stands established at 1,200 trees per acre (tpa), but the contribution of interplanted trees to total stand volume increased with increasing row spacing. This seems to suggest that there may be a density threshold below which interplanted seedlings could succeed. Our objective in this study is to determine whether interplanting is more successful with today's lower initial planting densities (averaging 450-500 tpa), improved genetics and improved competition control.

The initial planting took place in March 2006. The study site was burned prior to planting. In March 2007, the research team installed tenth-acre square plots in a randomized complete block design with four replications testing four treatments: 1) the original stand at 450 tpa (no mortality or interplanting); and simulated mortality with a residual stand density of 2) 300 tpa; 3) 200 tpa, and 4) 100 tpa followed by interplanting of empty planting spots. Treatments 2-4 are equivalent to first-year survival of 66, 44 and 22 percent, respectively. To accomplish the density reductions, we pin flagged all surviving original trees ("originals") and randomly pulled up enough to reach the target density (simulated mortality). We then replaced the trees that had been pulled up with new 1-0 seedlings ("interplants"). All of the seedlings were from an open-pollinated orchard mix from the VDOF second-generation loblolly pine orchard. Hardwood competition on the plots was controlled using herbicides after the first growing season.

Tree heights were measured annually for the first four years after interplanting. At the end of 2011 – when the original seedlings were six years old and the interplants were five – we measured survival, height and diameter (dbh) of all trees (Table 7). There has been very little mortality on any of the plots. Survival averages more than 96 percent for the entire study (including both originals and interplants) since its inception, and there are no significant differences among the treatments.

The originals are taller and larger in diameter than the interplants on all plots, but the height growth trend over time varies depending on the level of simulated mortality (Figure 9). The height difference between the originals and interplants has diminished (i.e. the interplants are growing faster) on the plots with the highest simulated mortality since the third growing season after interplanting (2009). On the plots with 66 percent survival, the difference has continued to increase (originals growing faster) through age five.

Looking at just the originals, a relationship between survival and height growth seems to be developing; as survival rate increases, so does average tree height. On the plots with 22 percent simulated survival, the originals are growing less than in the undisturbed stand. As survival increases to 44 and 66 percent, height growth of original seedlings increases. At 44 percent survival (200 tpa) and above, intraspecific competition for light may be sufficient to drive a phototropic response, whereas, below that threshold, the trees are allocating more resources to diameter growth or crown development.

By calculating basal area and total stem volumes, we can look at the combined effects of differences in density, height and diameter. Although earlier studies at higher original planting densities indicated that interplanting would not be successful, under the conditions in this study, the interplants are contributing to a significant proportion of the stand in both basal area and volume (Figure 10). As first-year survival declines from 66 to 44 to 22 percent, the proportion of the total stand volume made up of interplants increases from 13 to 33 to 56 percent, respectively.

It bears repeating that these are idealized conditions where an exact planting spacing was maintained because we replaced "dead" seedlings with interplants in the exact same planting location. In practice, the outcome of interplanting could be quite different depending on the pattern of mortality and the ability of crews to maintain a uniform distribution of a mixture of original and interplanted seedlings. And, it is very important to note that first-year mortality at any level – even after interplanting – has resulted in sharp declines in total standing volume: at 66, 44 and 22 percent survival, total volume is reduced by 15, 25 and 60 percent, respectively, of the amount in the undisturbed original (six-year-old) plots. Ultimately, the choice between 1) interplanting; 2) site-preparing and replanting the entire stand, or 3) accepting a lower-density stand and moving ahead with no additional investment will depend on the specific investment objectives, assumptions and tolerances of the individual landowner. Although we intend to follow the development of these plots for some years to come, it is difficult to envision the lowest-survival areas recovering to anywhere near the productivity level of the original stand.

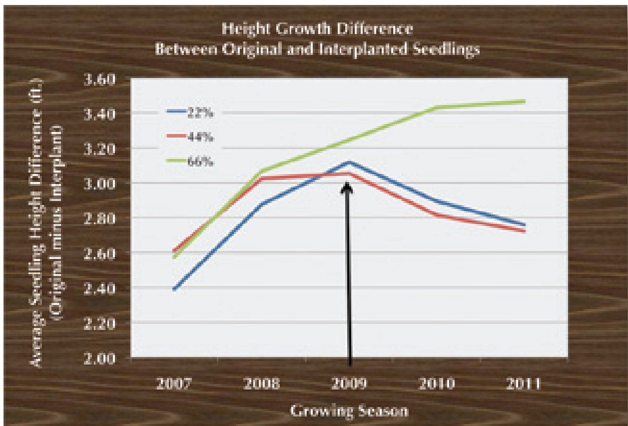

Figure 9. Difference between average heights of original and interplanted seedlings during the first five years after interplanting at three levels of simulated survival.

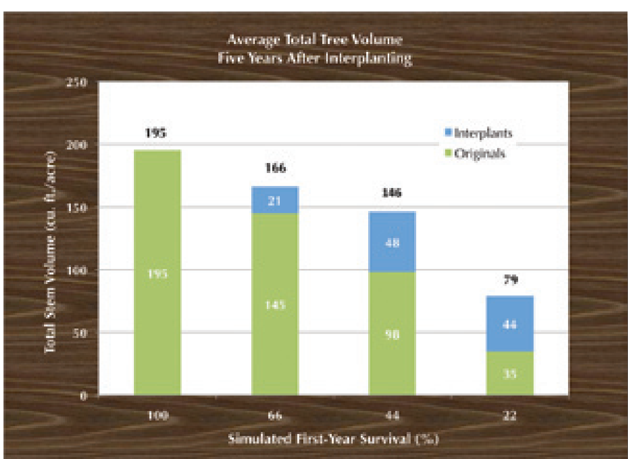

Table 7. Comparison of original (age 6) and interplanted (age 5) loblolly pine five years after interplanting at various levels of simulated initial stand survival.

Original Seedings (age 6)				
Measurement	Surviving Stems After One Season			
	100 tpa	200 tpa	300 tpa	450 tpa
Survival (%)	98%	100%	96%	98%
Height (ft.)	16.0	17.6	17.9	17.4
DBH (in.)	3.2	3.6	3.6	3.4
Basal Area (sq. ft.)	5.9	15.1	21.8	30.4
Volume (cu. ft./acre)	35	98	145	195

Interplanted Seedings (age 5)			
Measurement	Surviving Stems After One Season		
	100 tpa	200 tpa	300 tpa
Survival (%)	90%	97%	96%
Height (ft.)	13.2	14.8	14.4
DBH (in.)	2.2	2.5	2.4
Basal Area (sq. ft.)	9.5	9.1	4.1
Volume (cu. ft./acre)	44	48	21

Plot Summary				
Measurement	Surviving Stems After One Season			
	100 tpa	200 tpa	300 tpa	450 tpa
Basal Area (sq. ft./acre)	15.4	24.1	25.9	30.4
% from Interplants	61.8%	37.5%	15.8%	100.0%
Volume	79	146	166	195
% from Interplants	55.8%	22.9%	12.9%	100.0%

Figure 10. Average total tree volume (cu. ft./acre) five years after interplanting at four levels of simulated survival.

Hardwood Silviculture

Effects of Various Tree Shelters on First-Year Growth of Northern Red Oak in a Riparian Buffer Planting

In March 2011, we installed a study near Oakville in Appomattox County to compare the effects of five different types of tree shelters - 1) Tubex standard; 2) Tubex Combitube; 3) Acorn Shelterguard; 4) Acorn Bio, and 5) 4-foot woven wire cages with aluminum collars – for protection of northern red oak seedlings planted in riparian buffers. The test also includes a sixth treatment where the seedlings were left unprotected (Figure 11).

The solid Tubex standard shelter provides higher air moisture within the shelter, reducing water stress and increasing survival in dry or drought conditions. The Tubex Combitube combines the benefits of a solid base for speedy establishment, with a ventilated upper section that enhances airflow and allows more light to enter the shelter. The Acorn Shelterguard Plus is manufactured by coextruding a laminate of 12mm square plastic mesh netting and a tinted polyethylene film lining. The lining degrades leaving the plastic mesh shelter to continue to provide support and browsing protection. The Acorn Bio shelter was developed with an additive which causes the plastic mesh to break down after its useful life. In essence, the entire shelter is biodegraded into harmless CO^2, water and biomass in the presence of UV light and microbes found in the natural environment. The wire cages (supplemented with a short collar made of aluminum flashing to prevent damage from small mammals) provide maximum sunlight while still keeping large (deer) or other small (mice, voles) herbivores from damaging the seedlings.

We assessed the growth and condition of the seedlings in February 2012 – after one full growing season. The data are summarized in Table 8. The most striking result is the mortality (33 percent) in the unprotected seedlings. None of the sheltered seedlings died. In addition, it is noticeable that the seedlings either protected in wire cages or left unprotected have grown less in height than those in the solid shelters (Figure 12). We might guess that the somewhat reduced light availability (or altered spectrum) could cause the seedlings to devote more resources to a phototropic response (height growth) compared to those where light is not limiting. In addition, of course, the growth of the unprotected seedlings was affected by browsing and mortality. Our plans are to continue to monitor these seedlings for at least 10 years and include diameter measurements in future years.

Table 8. Summary of first-year height growth and survival of northern red oak seedlings in four types of protective shelters compared to unprotected seedlings.

Shelter Type	Tree Height (ft.)			Mortality (%)
	Initial	One-Year	Growth (ft.)	
Tubex Standard	2.18	3.10	0.92	0.0%
Tubex Combitube	2.93	3.76	0.83	0.0%
Acorn Shelterguard	3.46	4.32	0.86	0.0%
Acorn Bio	1.56	2.60	1.04	0.0%
Woven Wire Cage	3.31	3.88	0.57	0.0%
Unprotected	2.55	2.13	-0.42	33.3%

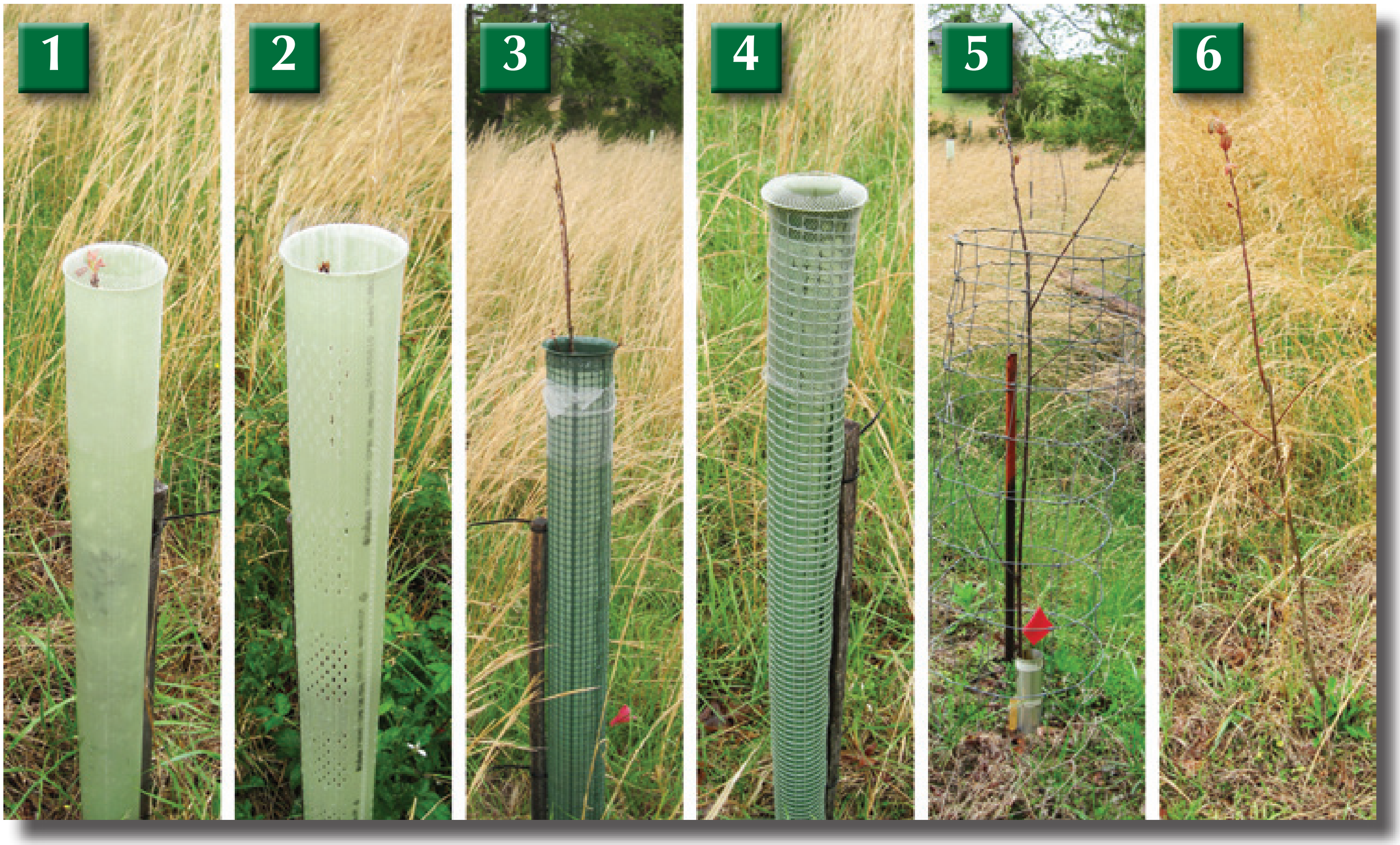

Figure 11. Protection treatments being compared in the 2011 northern red oak study in Appomattox County include: 1) tubex standard; 2) tubex combitube; 3) acorn shelterguard; 4) acorn bio; 5) woven wire cages, and 6) Unprotected.

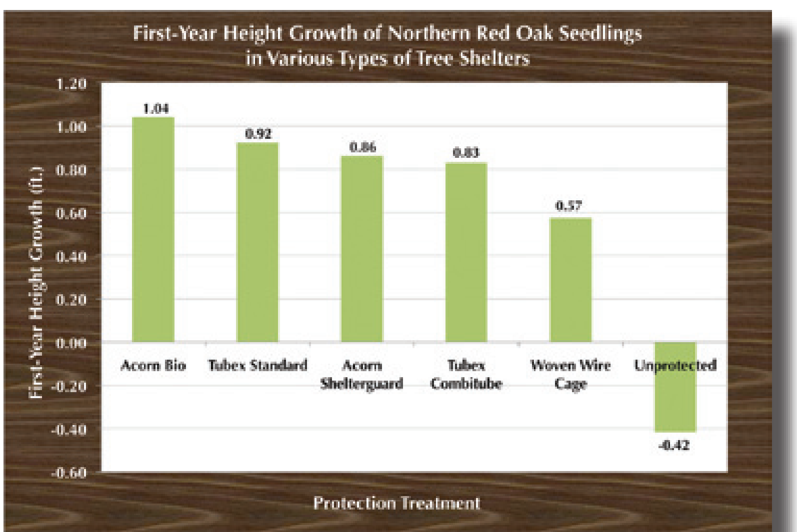

Figure 12. First-year height growth of northern red oak seedlings in various types of tree shelters.

Crop Tree Release and Fertilization Effects on the Growth of White Oak and Southern Red Oak

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 (Quercus alba L). 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 lbs. nitrogen plus 50 lbs. phosphorus per acre over a tree-centered 10-foot radius circle. The response to the added fertilizer diminished beginning in the third year after treatment, and surrounding hardwoods began to once again encroach on the crowns of the released trees. As a result, the same treatments (crop tree release with or without 200 lbs./acre plus 50 lbs. phosphorus fertilizer) were re-applied in April 2011 to the same trees that received them six years ago.

In December 2011, seven growing seasons after initial treatment, the trees were re-measured for dbh and total height (Table 9). Height growth continues to be modest and statistically not affected by treatment. On average, these white oaks have grown roughly 1.6 feet per year between ages 15 and 22. Diameter growth, meanwhile, continues to be the important response variable. Over the life of the test, released trees have now outgrown unreleased trees by 64 percent in dbh, and adding fertilizer has boosted that difference to 80 percent. Further, the second treatments applied in 2011 have enhanced diameter growth again (Figure 13). The majority of the diameter response has come from the release treatment, but a significant component has been added by the fertilizer application (Figure 14). As highlighted in the last issue, another key point from these plots is that larger trees respond more to the treatments than smaller trees, so the best strategy with crop tree release of white oak is to release largest, healthiest trees in the stand.

In November 2003, a crop tree release study was installed in Stand AB2320 on the Appomattox-Buckingham State Forest. The stand was a mixed hardwood regeneration area that followed a 1991 harvest and prescribed burn; the trees were 13 years old at the time. Predominant species in the stand [yellow-poplar (Liriodendron tulipifera L), white oak and southern red oak (Quercus falcata Michx)] were included in a crop tree release test using a herbicide (triclopyr ester) as a basal bark application to remove competing

Table 9. Summary of white oak growth response seven years after crop tree release and fertilization treatments.

Treatment	2011		7-Year Growth	
	DBH (in.)	Height (ft.)	DBH (in.)	Height (ft.)
Untreated	4.23	37.7	1.13	11.72
Released	4.97	37.1	1.85	10.81
Released & Fertilized	5.15	38.1	2.03	11.54

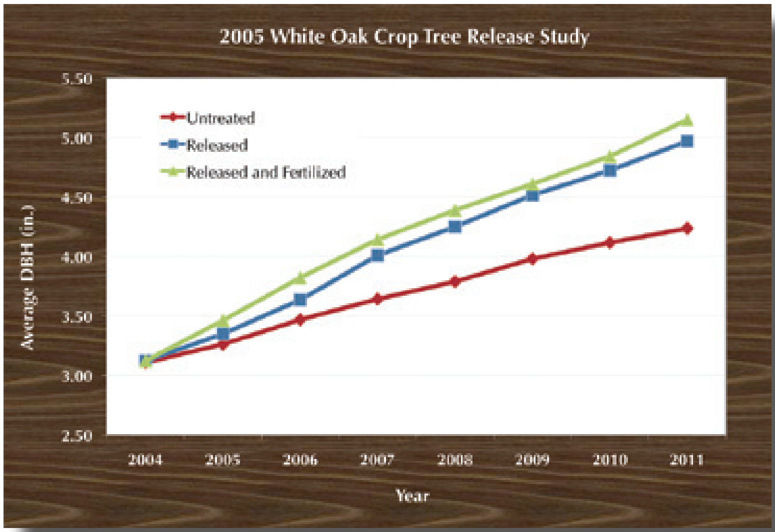

Figure 13. Average yearly diameter breast height (dbh) of white oak trees from 2004 to 2011.

hardwoods around the crop trees. After three growing seasons, the difference between the diameters of the released and unreleased southern red oaks was less than a tenth of an inch.

In April 2007, we decided to re-release and fertilize the southern red oak component of the study to look for longer term response data. Trees were randomly selected and either released (with a chain saw this time) or released and fertilized (200 lbs. nitrogen plus 50 lbs. phosphorus per acre over a tree-centered 10-foot radius circle). A total of 57 southern red oaks were available and selected to carry forward into this study with one of four treatment regimes: 1) 23 were left untreated; 2) 12 were released at age 16 only; 3) 11 were released at both age 13 and 16, and 4) 11 were released at both age 13 and 16 and fertilized at age 16. All of the trees in the study were measured annually through 2009 and then again in 2011.

The data are summarized in Table 10. Like white oak, it is clear that southern red oak responds more in diameter than height. And also like white oak, it appears that both release and enhanced nutrition are beneficial (Figure 15). At the end of 2011, the diameter growth advantage for one release (age 16), two releases (age 13 and 16), and two releases plus fertilizer are 16, 39 and 55 percent, respectively, compared to trees that were never released. And again it seems that perhaps the fertilizer response is diminishing after two to three years (Figure 16).

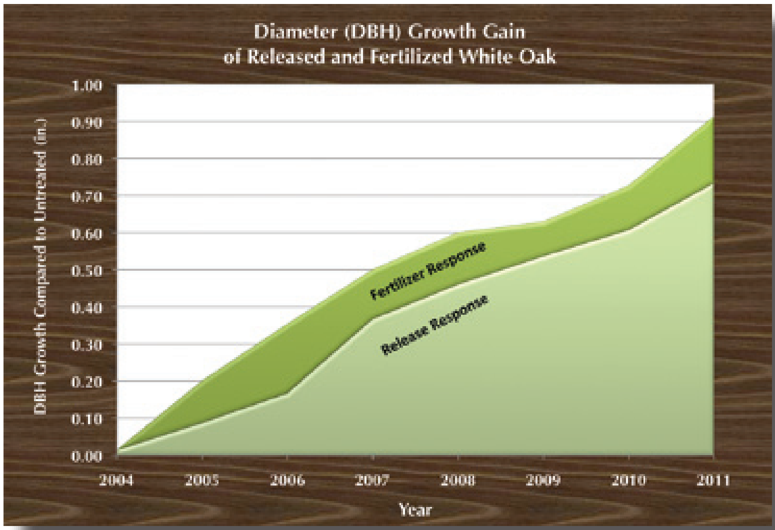

Figure 14. Diameter (dbh) growth gain (compared to untreated trees) of released and fertilized white oak for seven years following crop tree release and fertilization.

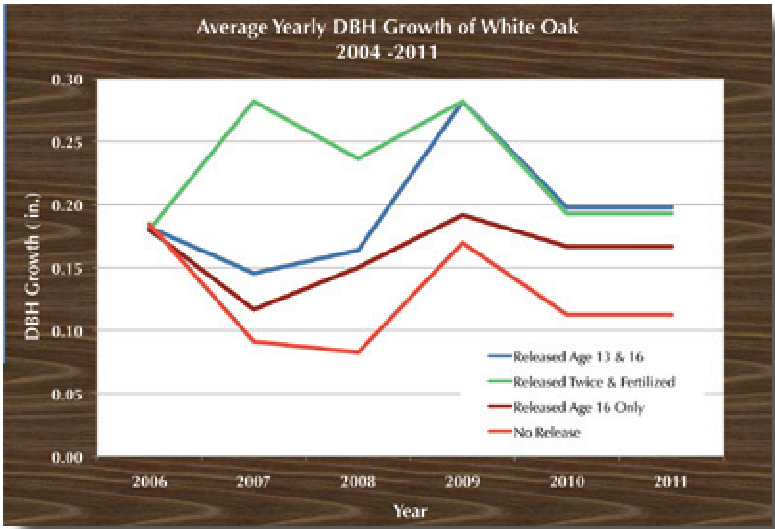

Figure 15. Average yearly diameter breast height (dbh) growth of white oak trees from 2004 to 2011.

Table 10. Average annual diameter (dbh) and total tree height for released and fertilized southern red oak crop trees.

Treatment	DBH (in.)			Height (ft.)
	2011	2007-2011 Growth	Gain vs. Untreated	2011
Untreated Controls	2.96	0.57	_	26.9
Released Age 16 Only	3.30	0.78	37%	25.6
Released Age 13 & 16	3.25	0.99	74%	26.9
Released 2x + Fertilized	3.54	1.18	107%	27.7

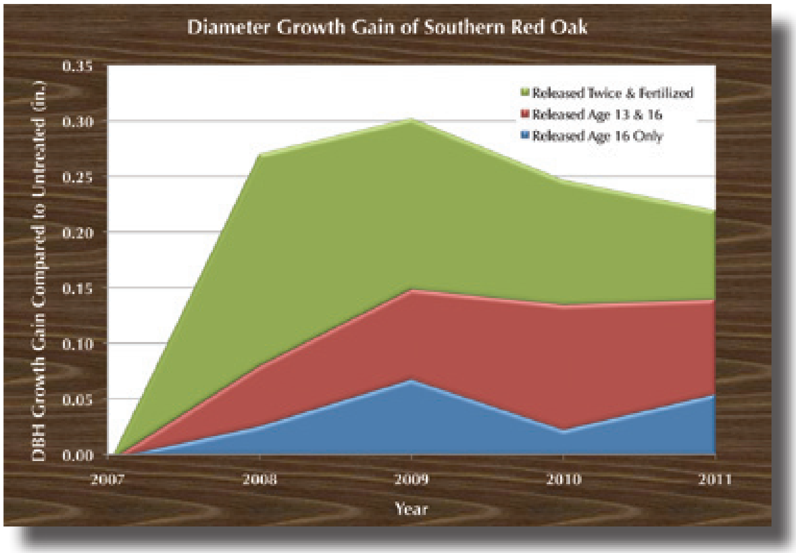

Figure 16. Diameter (dbh) growth gain (compared to untreated trees) of southern red oak released once; released twice, or released twice and fertilized for four years following treatment.

Virginia Department of Forestry
900 Natural Resources Drive, Suite 800
Charlottesville, Virginia 22903
Phone: (434) 977-6555
www.dof.virginia.gov

08/2012

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