Forest Research Review

August 2013

Wayne Bowman (VDOF) and Dr. Harold Burkhart and Dr. Amy Brunner (Virginia Tech) in the 2012 cold-hardy hybrid poplar trial located at Appomattox-Buckingham State Forest approximately 16 months after planting.

In this issue...

VDOF Research Program

Jerre Creighton, research program manager

Onesphore Bitoki, tree improvement forester

In January, we conducted a survey of Research Review readers. Thanks to the many of you who took the time to respond; we gathered some valuable insight and suggestions:

- **We have a distribution/mailing list issue.** We found 75 percent of respondents received the latest issue – which means 25 percent of those on our mailing list did not.
- **The review is well read.** Of those who received the issue, 86 percent read at least some, 65 percent most or all of it.
- **It has value to most recipients.** More than 90 percent of readers find the topics relevant, writing clear, graphics useful and number of articles good.
- **We need to send out information more often.** Most recipients (50-60 percent) would like more frequent reports. This has become a concern since we moved to once-a-year publication.
- **Delivery method is optional.** There was no clear preference for paper versus electronic delivery methods.

To address the issues raised in the survey and reduce publication and mailing costs, **this will be the last hard-copy issue of the Research Review**. To continue receiving this publication and other updates and information from the Virginia Department of Forestry Applied Research Program, you will need to subscribe at **dof.virginia.gov**. As always, our publications will continue to be archived at **dof.virginia.gov/research/publications.htm**, where you can find all VDOF research reports issued since 1955.

For now, we will continue in the format used in the Research Review's previous editions since 2006. In this issue, we present updates on replicated VDOF studies of geographic sources of longleaf pine; low-density loblolly pine plantations; interplanting loblolly pine after high first-year mortality; biosolids compared to inorganic fertilizer for loblolly pine; growth and economic returns from competition control at site prep or age two release; performance of plantation hardwoods in central Virginia, and a comparison of tree shelters for planted hardwoods. And, we'll begin with highlights from collaborative projects made possible by our memberships in the Tree Improvement, Forest Modeling and Forest Productivity Research cooperatives plus a special bonus article on the use of logging debris for skid trail stabilization written by VDOF's Water Quality Program Supervisor Bill Lakel and Virginia Tech Professor Mike Aust.

We hope you enjoy this last "paper" copy of the VDOF Forest Research Review and will choose to continue reading future releases by subscribing to our electronic delivery system.

Feel free to visit 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.

Research Cooperatives

Tree Improvement

4th Cycle Breeding

Excerpted from McKeand, S. E. Innovation and Hard Work – A Message from the Director. NC State Tree Improvement Coop. 57th Annual Report (May 2013).

Dr. McKeand's thoughts regarding the value of the breeding program are noteworthy:

By far, the most exciting development in the program this past year was the initiation of our fourth cycle of breeding. I've actually been here since the beginning of the second-generation breeding, so I've seen dramatic changes over the years in how tree improvement is managed, but nothing comes close to what is about to take off. Of course, each cycle of breeding is always different, and we feel that significant improvements are made each generation. We have new technologies available to accelerate breeding. We are much more efficient in our field-testing designs. Analytical capabilities allow for breeding values to be calculated with greater precision and accuracy than ever before. New generations of molecular markers using the loblolly pine genome sequence promise to open doors for genomic selection. New algorithms allow for the most appropriate matings to be done to increase genetic gain while maintaining genetic diversity for long-term improvements to be made. All of these technologies and more are being brought to bear on our 4th-cycle breeding program.

Details of the new breeding strategy are described in the annual report. What I want to focus on here is my favorite question – so what? What impact will the increased genetic gain have on our members, landowners in the southern U.S. and citizens of the region? The story I emphasize is the economic impact that tree improvement has by delivering gain to the forest and to the people who benefit from it. As scientists, it's gratifying to do research and get information published to impact research and development. As breeders, we get the chance to extend far beyond the academic exercises and put our research and innovations into practice. My best projection is that **we will be able to increase the rate of gain getting to landowners by up to 25 percent or more in the 4th cycle of breeding**. Based on our estimates of operational gain delivered to the forest, **the Cooperative has delivered a rate of gain of about 0.5 percent per year over the last 40 years**. Over the last decade, we estimate that this has increased to one percent gain per year. With more emphasis on breeding the best genotypes to increase both volume and value to landowners and with better delivery systems (e.g. increased operational production of full-sib seedlings and clones), I believe we can increase this annual rate of improvement to 1.25 percent or higher. The present value of increasing the rate of gain from one percent per year to 1.25 percent per year is conservatively estimated to be about $600 per acre planted. Historically, about 900,000 acres have been planted each year with loblolly pine seedlings derived from the Cooperative's breeding effort. If this continues, **the present value of getting more genetic gain to landowners is more than $500 million each year**. Even if the assumptions are drastically reduced, the economic consequence of our work is staggering.

It is both gratifying and a bit frightening to think about the impact that southern pine tree improvement has had and will continue to have on the region. The Cooperative's staff and each member of the program should be very proud of the work we are doing, putting innovations to work for the benefit of landowners for decades and centuries to come.

Forest Modeling

Spacing Impacts on Lumber Quality of Loblolly Pine

Relating Mechanical Properties of Lumber to Planting Density for Loblolly Pine Plantations. From: Ralph Amateis, Harold Burkhart, and Gi Yong Jeong. Forest Modeling Cooperative Report No. 171 (May 2013).

Loblolly pine is often grown in intensively-managed plantations for wood production. To fully evaluate the effects of management practices on wood quality and ultimately value, it is necessary to relate mechanical properties to management practices. The aim of this study was to evaluate the effect of planting density on mechanical properties of lumber recovered from loblolly pine trees from a 27-year-old spacing trial and develop prediction equations for MOE (modulus of elasticity) and MOR (modulus of rupture) from stand, tree and board characteristics.

Regression methods were applied to sample trees from three planting densities (1210, 682 and 302 trees per acre) and used to relate mechanical properties of lumber extracted from the trees to stand, tree and

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board characteristics. Initial planting density was found to be correlated with MOE and, to a lesser extent, with MOR. Including board characteristics and utilizing the visual grade as a regressor produced improved prediction equations.

The mean MOE declines with decreasing planting density while the variability increases, suggesting that planting density is a surrogate for frequency and size of knots. **Thus, lower planting densities, while producing more lumber, may produce proportionally fewer boards of greater MOE than higher planting densities**.

[Note: A paper reporting on this research has been accepted for publication in the Annals of Forest Science under the title "Modulus of elasticity declines with decreasing planting density for loblolly pine (*Pinus taeda*) plantations."]

Forest Productivity

PineMap: Fertilizer Nitrogen Fate and Carbon Sequestration

The PineMap project location at Appomattox-Buckingham State Forest (described in the August 2012 Forest Research Review) is a direct result of our participation in both the Forest Modeling and Forest Productivity Cooperatives, and, after just two years, it is beginning to produce important results. Updates from two of its 24 component efforts follow, but for full details on all 24, refer to the **PineMap Year 2 Annual Report at http://www.pinemap.org/reports/annual-reports/PINEMAP_Year_2_Annual_Report_FINAL.pdf**.

The first update reveals nitrogen applied in fertilizer is being taken up by trees throughout the growing season (primarily into the leaves) and that more is available when fertilizer is applied in the winter instead of the summer. The results from the second - if verified – tell us we have been significantly overestimating the impacts of forests on carbon sequestration.

The fate of fertilizer nitrogen in southern plantation forests to address economic and environmental issues. Jay Raymond, Thomas Fox, Brian Strahm. Pages 14-15 In: PineMap Year 2 Annual Report.

For the last several decades, nitrogen (N) containing fertilizers, generally in the form of urea, have been an integral management tool for plantation forestry in the southern United States. This has increased growth rates of forest plantations, translating into economic benefits for landowners. But not all applied fertilizer nitrogen is incorporated into desired target crop trees. Dependent on timing of application and climatic conditions, a large portion of the nitrogen derived from the fertilizer may be incorporated into other parts of the forest (understory competition, soils), or lost from the system due to gaseous transformations and movement into ground or surface water. These economic and environmental concerns are directing our research to achieve a better fundamental understanding of the fate of applied fertilizer nitrogen in southern forested plantations to improve our management decisions.

We are using fertilizers enriched with the stable isotope nitrogen-15 to track the fate of applied-fertilizer nitrogen in plantation forests. Because only a small percentage of nitrogen-15 exists in the environment, enriching fertilizers with this isotope allows an accurate accounting of the movement of nitrogen derived from the fertilizers. The use of nitrogen-15 allows us to calculate how much and how quickly a crop tree incorporates nitrogen applied from fertilizers. Additionally, because large nitrogen losses to the atmosphere can occur when using conventional fertilizers (urea), we are investigating whether enhanced efficiency fertilizers are able to reduce these gaseous losses. NBPT (n-butyl thiophosphoric triamide) inhibits conversion of urea to ammonia and carbon dioxide, which slows nitrogen loss. CUF (coated urea fertilizer) consists of urea granules coated in less-soluble chemicals, such as sulfur, polymers or other products that release the urea slowly - either when penetrated by water or when broken down. This test compares urea, CUF, NBPT and CUF+ NBPT. We are also investigating the seasonal timing of fertilization, which is traditionally conducted in late winter or early spring when plant-available nitrogen may not be as limiting as during summer months. Finally, we are examining how much fertilizer-derived nitrogen is retained by understory competition. These research initiatives are collectively trying to allow more nitrogen derived from fertilizer to enter crop trees while reducing overall losses from the system.

Eighteen sites were established in 2011 and 2012 across the entire region of loblolly pine plantations in the southern United States. Five fertilizer treatments (including a control with no fertilizer application) were administered at two different times (late winter and summer) in 2011, and once in 2012 (late winter) in 100 sq. meter circular plots having similar characteristics. The

location adjacent to the PINEMAP Tier III site in Virginia on the Appomattox-Buckingham State Forest also included five additional plots investigating the impact of retaining the understory. After fertilizer application, measurements were taken to estimate gaseous and leaching losses of nitrogen; foliar sampling was conducted every six weeks to estimate nitrogen uptake over the growing season, and all components of the ecosystem were sampled at the end of the growing season to calculate the location of the nitrogen-15.

The preliminary results indicate nitrogen-15-enriched fertilizers are being incorporated in the aboveground biomass of crop trees through the entire growing season, as evident by percent nitrogen uptake and foliar nitrogen concentrations. Pre-treatment foliar nitrogen concentration (nitrogen percent) ranged from 1.08 percent to 1.10 percent for winter and summer plots. At biomass harvest, foliar nitrogen percent levels increased, ranging from 1.40 percent to 1.55 percent for winter plots and 1.44 percent to 1.67 percent for summer plots. Winter fertilized plots had a larger percentage of nitrogen attributable to fertilizer when compared to summer, with the exception of CUF+NBPT, which displayed an opposing trend. Preliminary recovery rates are highly variable between treatments, although recovery of nitrogen-15 for aboveground biomass was greatest in foliage for all treatments, followed by the stem (Figure 1).

Forest Carbon Sequestration: Big Changes Underfoot. Brett Heim, Brian Strahm, and John Seiler. Pages 12-13 In: PineMap Year 2 Annual Report.

Carbon (C) in terrestrial ecosystems is one of the main reservoirs in the global carbon cycle, and soil carbon in the form of organic matter and plant biomass are the two largest pools of carbon. Further, the processes of photosynthesis and respiration that occur in these systems are the two largest fluxes of carbon globally. Given their size, even small changes in these pools and fluxes can significantly impact atmospheric CO^2 concentrations. Forest ecosystem management can influence global carbon dynamics by manipulating these pools and fluxes. Afforestation, in general, and forest management (silviculture), specifically, can increase terrestrial ecosystem carbon in soils and biomass. Understanding the interacting effects of management (e.g. fertilization) and climate variability (e.g., drought) will be critical in guiding the adaptation of these forest ecosystems for the mitigation of negative climate impacts.

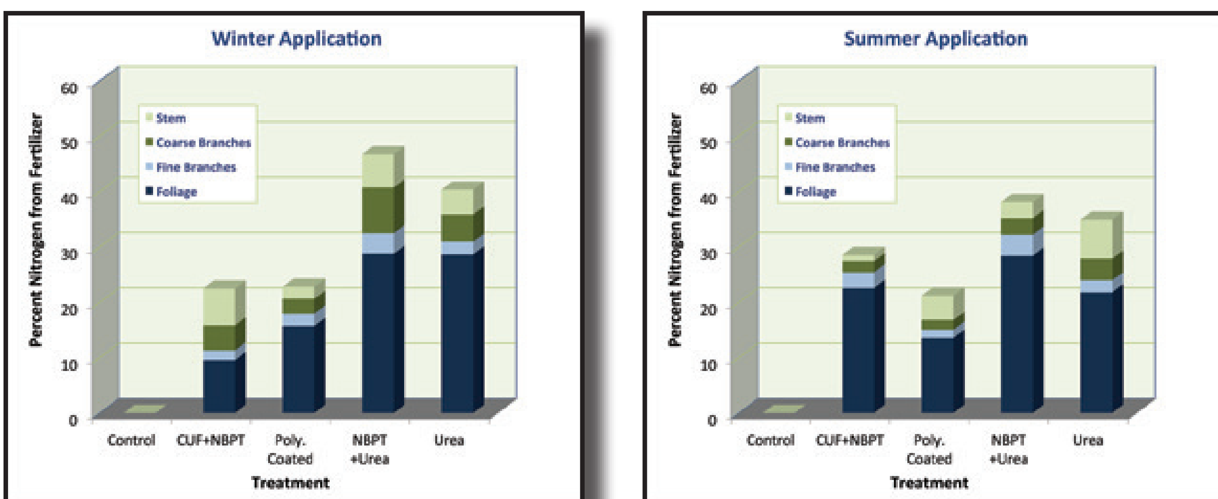

Figure 1. Graphs comparing winter and summer nitrogen-15 fertilizer application. Foliage contains the largest levels of nitrogen attributed to the fertilizer for the aboveground portion of the tree.

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To quantify the effects of management and climate change, a measure of carbon storage is necessary. One such measure is net ecosystem productivity (NEP), a measure of the net carbon accumulated by an ecosystem. For a loblolly pine ecosystem, it represents the carbon captured by photosynthesis minus the losses due to plant and soil respiration. Unfortunately, a direct measurement of NEP is difficult over large geographic areas. Ecosystem carbon models have the capacity to predict NEP with one modification of their present configuration – there is a need to understand the relative contributions of soil heterotrophic, microbial respiration (RH) and autotrophic, root respiration (RA) to the overall belowground soil respiration (RS). **Present estimates suggest RA and RH are roughly evenly split, but deviations from this even split could have significant impacts on the estimates of carbon storage in managed forest ecosystems.** In short, a higher proportion of RH would result in lower measures of NEP; whereas, a lower proportion of RH would indicate greater estimates of ecosystem carbon storage.

Figure 2. A root exclusion core being excavated after a 90-day installation so that roots can be collected for analysis. Photo by Brett Heim.

To partition RS into its RH and RA components, RS needs to be measured in a root-free environment, and such conditions hardly exist in nature. On small scales, however, these conditions can be artificially created by severing the roots from their supply of plant carbohydrates (i.e., photosynthesis). Over time, the roots run out of carbohydrates for respiration and RA falls to zero. At this point, a measure of RS is equal to RH. Practically, this is achieved by driving a 10 cm wide core 35 cm into the ground to sever tree roots and waiting for the exhaustion of RA (Figure 2). Then, comparing measures of RS inside (now simply RH) and outside (RS = RH + RA) the core provides the information necessary to allow current ecosystem carbon models to more accurately predict NEP to determine if managed southern pine ecosystems can meet the objective of increased carbon storage.

During the 2012 field season, we tested this coring method at the PINEMAP Tier III site in Virginia at Appomattox-Buckingham State Forest. This location represents the northernmost range of climatic conditions where loblolly pine is intensively managed in the southeastern U.S. Respiration measurements were taken approximately every two weeks both adjacent to and on top of each root-severing core to measure the decline in RA over the course of a three-month period.

Respiration initially increased inside the cores due to the disturbance of installation. After a period of equilibration, however, the respiration inside the core began to decrease relative to outside the core before stabilizing after approximately 65 days (Figure 3). At the point of stabilization, the respiration measured inside the root-severing cores was about 25 percent lower than respiration measured adjacent to the cores. **This suggests that the assumed partitioning of RS into equal proportions of RH and RA may overestimate the amount of carbon stored in these systems.** It will be important to monitor changes in this partitioning, however, to better understand how forest management can optimize ecosystem carbon storage under predicted increases in climate variability.

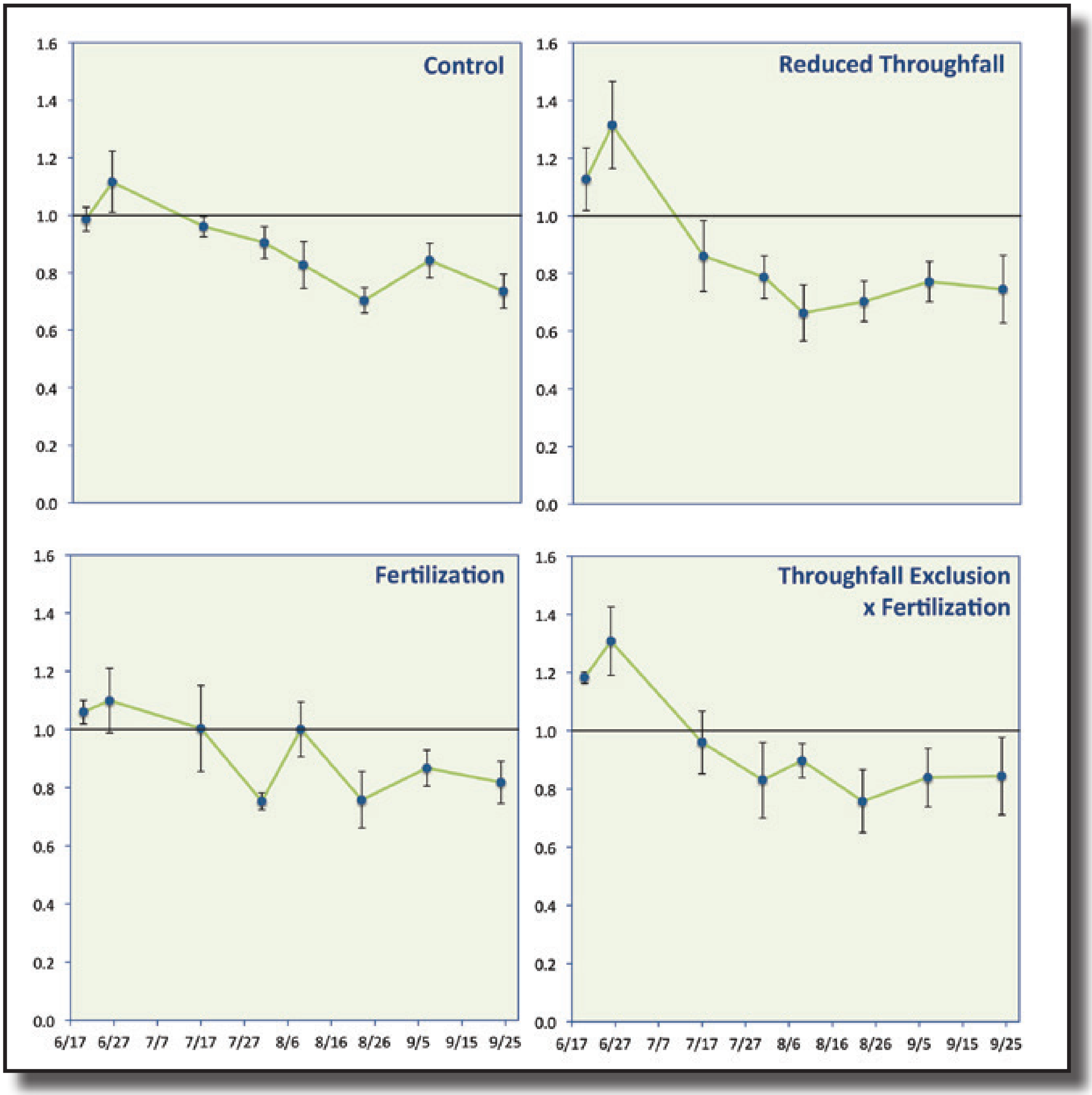

Figure 3. A time series showing the ratio of soil respiration measurements inside to soil respiration measurements outside root-severing cores relative to time of core installation.

Utilizing Logging Slash for Skid Trail Stabilization

Bill Lakel, VDOF, and Mike Aust, Virginia Tech

It is generally accepted that roads, decks and skid trails are the primary sources of silvicultural sediment associated with timber harvesting. These structures tend to expose large areas of bare soil that are easily eroded by rainfall and subsequent surface water runoff. The interconnected nature of road and trail networks on harvested tracts increases the potential for eroded sediments from these structures to enter a watercourse and become sediment pollution. The Virginia Department of Forestry (VDOF) developed and maintains a Best Management Practices (BMP) manual and field guide with numerous recommendations and specifications for harvesting operators to utilize to prevent water pollution associated with timber harvesting (**dof.virginia.gov/water/index-BMP-Guide.htm**). The Virginia Silvicultural Water Quality Law (§ 10.1-1181.2.) also requires all owners and operators to prevent sediment pollution in the waters of Virginia as a result of their silvicultural activities. The VDOF subsequently has the responsibility to enforce that law and assist landowners, timber buyers and loggers with the practical application of BMPs to prevent silvicultural pollution.

In 2010, two study sites were selected in Patrick County, VA, on the Reynolds Homestead Research and Extension Forest to evaluate the potential for using logging slash as a low-cost BMP to reduce soil erosion on overland and bladed skid trails and subsequently reduce the risk of water pollution associated with timber harvesting in the Virginia Piedmont. This research project was a collaborative effort among researchers at Virginia Tech, VDOF, Greif Brothers Packaging, Plum Creek Timber and The National Council for Air and Stream Improvement (NCASI). The two selected sites were treated as separate experiments (bladed and overland) and both were organized as a Randomized Complete Block Design (RCBD) with six skid trails as blocks and five trail segments per block as experimental units for analysis. Each skid trail segment utilized a "Dirt Bag" (ACF Environmental) sediment collection system to capture eroded sediments from each transect for weight measurements. Five treatments were evaluated on each site: 1) bare soil only (Figure 4); 2) grass seed only; 3) grass seed and straw mulch; 4) hardwood slash, and 5) pine slash (Figures 5 and 6). Both slash treatments were packed in with a dozer to mimic conditions on most logging jobs where slash is commonly packed by skidder traffic. Sediments from all treatments were collected and weighed for a one-year period to determine which treatments were most effective.

The results (Table 1) reveal that skid trails that are not reclaimed with some type of ground cover will erode heavily in the first year and it is clear that the bladed trails are much more of an erosion hazard than the overland trails in all cases. This is true in spite of the fact that the skid trail slopes on the overland site were much steeper for all blocks than the slopes on the bladed site. This is due to the fact that overland skid trails have much more organic matter covering the soil in the form of leaf litter and residual slash since these trails were not bladed. The differences between treatment averages on both sites indicate that simply applying seed to bare soil does reduce erosion significantly but not to the degree that the other three cover treatments do. Simply adding straw mulch over the seed to protect the soil, seed and young grass seedlings will greatly increase grass establishment and ground cover and as a result reduce measured erosion on bladed and overland trails.

Figure 4: Sediment-laden runoff traveling down an untreated bladed skid trail during a brief but heavy rainfall on the "Dirt Bag" study site in Patrick County, VA.


Figure 5: Seed-only treatment (left) and the seed-and-mulch treatment (right).


Figure 6: Hardwood-slash treatment (left) and pine-slash treatment (right).

Table 1: Tons of sediment collected per acre of treatment skid trail in the first year of the "Dirt Bag" study in Patrick County, VA. Statistical significance at α=0.05 is indicated by lower case letters to the right of each mean value.

Treatment	Bladed	Trails	Overland	Trails
Bare Soil	61.2	a	12.3	a
Seed Only	14.0	b	9.7	b
Seed and Mulch	1.3	c	0.8	c
Hardwood Slash	3.9	bc	1.0	c
Pine Slash	2.6	c	0.5	c

Perhaps the most important story in these data is that **utilizing slash that is already on site is just as effective as the relatively more expensive seed and straw mulch treatment**. It is important to note that on the bladed trails, the hardwood slash was slightly less effective than pine slash and seed and mulch due to the tendency of hardwood slash to resist tight packing on the soil surface even when tracked with a dozer. It is likely that exposed soil underneath of the slightly elevated hardwood slash lead to a slightly higher erosion value on the bladed sites. Given the protective effect of the residual organic matter on most overland

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skid trails, this effect was not measured on those trails. A more in depth analysis of these two studies can be found in the articles cited below.

- Wade, C.R., **M.C. Bolding**, W.M. Aust and W.A. Lakel III. Comparison of five erosion control techniques for bladed skid trails in Virginia. *Southern Journal of Applied Forestry*. November 2012. Vol. 36, No. 4.
- Sawyers, B.C., **M.C. Bolding**, W.M. Aust and W.A. Lakel III. Effectiveness and implementation costs of overland skid trail closure techniques in the Virginia piedmont. *Journal of Soil and Water Conservation*. July/August 2012. Vol. 67 No. 4. pp. 300-310.

Tree Improvement

Longleaf Pine Provenances in Virginia: Age Seven Update

Establishment details and prior data summaries for this comparison of longleaf pines from different regions of the native range can be found in the April 2008, April 2009, and May 2011issues of the Forest Research Review. 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. We now have measurements and data analysis of this test completed through age 7.

After seven years of growth, the results continue to support preservation of the northern Virginia native source. There are certainly differences among sites and replications in the performance of the various sources, and between ages 5 and 7, some other provenances grew as well as or better than Virginia trees in height and/or diameter. Statistically, height and survival do not differ among sources, but diameter does (Pr>F = 0.02). The Southampton County seedlings are still outperforming the other sources when viewed in terms of estimated total volume or fitness ranking (Table 2, Figures 7 and 8).

Table 2. Age 7 average height, dbh, survival, volume and fitness of eight longleaf pine provenances planted in Virginia.

Provenance	Height (ft.)	DBH (in.)	Survival (%)	Volume (cu. ft./tree)	Volume (cu. ft./acre)	Fitness Score
VA	12.56	2.63	86.0%	0.70	302	0.94
NC Orchard	12.80	2.75	72.7%	0.79	287	0.84
SC	11.72	2.49	68.0%	0.63	214	0.66
MS	11.18	2.42	67.3%	0.58	195	0.60
FL	11.95	2.46	65.3%	0.60	195	0.64
NC	11.86	2.55	68.1%	0.65	222	0.68
AL	11.36	2.43	76.0%	0.58	220	0.69
GA	11.65	2.42	77.3%	0.60	231	0.72

Figure 7. Volume-per-acre index of eight longleaf pine provenances planted in Virginia after seven years. [Index calculated as average height x dbh squared x survival x 500 planted trees per acre].

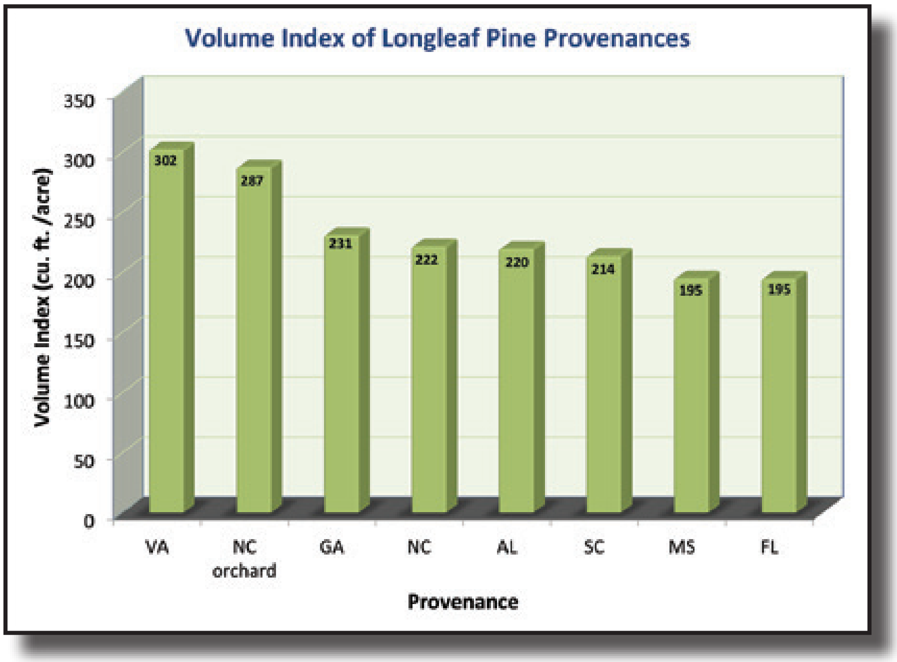
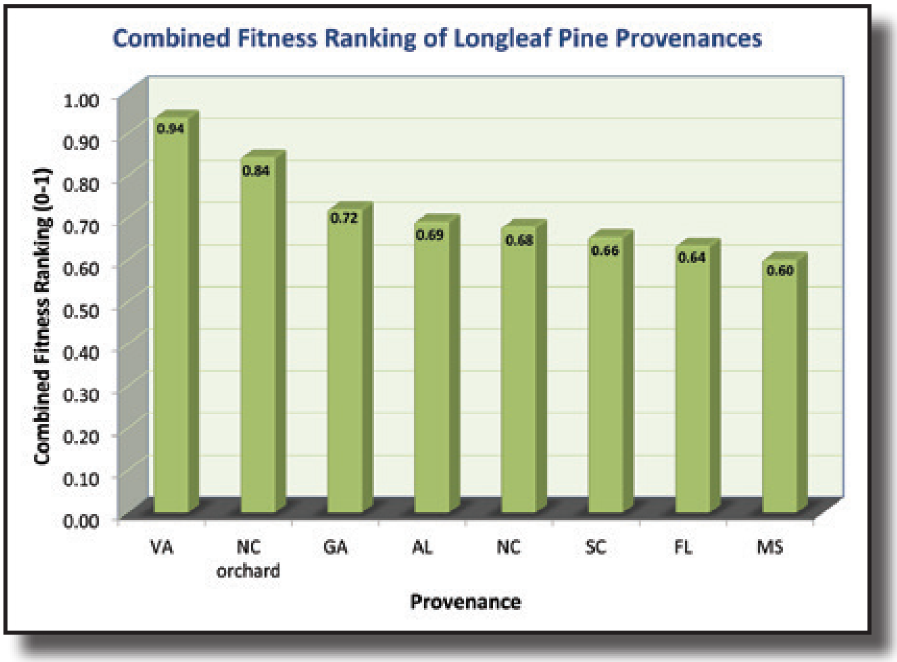


Figure 8. Combined fitness scores of eight longleaf pine provenances planted in Virginia after seven years. [Fitness rankings for height, dbh and survival were first calculated by dividing the average for each source by the average for the top ranked source. The combined ranking in this figure was then calculated as the product of those individual attribute rankings].



Growth and Value of Low-Density Loblolly Pine Plantations at Age 20

In the springs of 1990, 1992 and 1993, plantings of 100 percent-genetically-improved, first-generation loblolly seedlings from the Virginia Department of Forestry tree nurseries were planted on tracts located in the Appomattox-Buckingham State Forest in the Virginia piedmont. Each year, three replications were planted on a single tract. The spacing and number of seedlings were varied in three plots per replication to obtain densities of 200, 300 and 400 trees per acre (tpa). Earlier data from this study were summarized in the September 2007 issue of the Research Review.

With the measurements made after the 2012 growing season (Table 3), we now have 20-year information about all three sites. Survival has been good to excellent, and, along with height, has been relatively unaffected by planting density. Individual tree dbh is greater at lower densities while stand basal area is greatest at higher densities. Individual trees average 11.4 inches in dbh on the 200-tpa plots, which carry a total of 130 sq. ft./acre of basal area. The 400-tpa plots have a 9.3-inch individual tree diameter but contain more than 173 sq. ft./acre in basal area. Similarly, total stand volume is directly related to tpa even at these low densities.

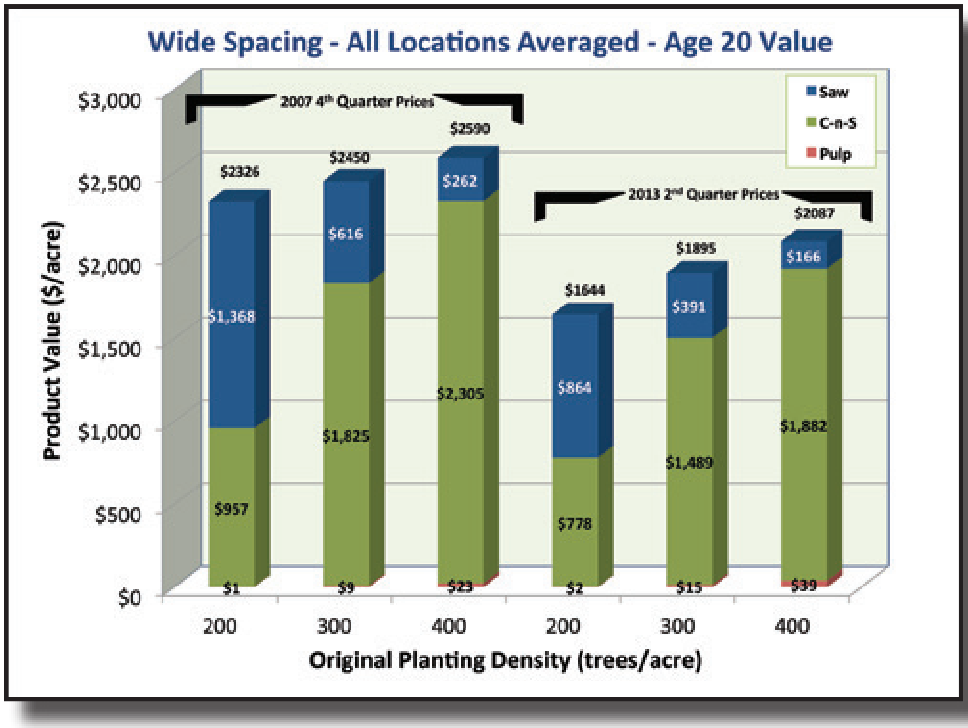
Table 3. Age 20 survival (percent), height (feet), dbh (inches), basal area (sq. ft./acre) and total stem volume (cu. ft./acre, inside bark) on the VDOF loblolly pine planting spacing study at three locations: a) Talbert; b) Abbitt, and c) Rinehart.

Location	Measurement	200	300	400
Abbitt	Survival (%)	97%	91%	92%
	Height (ft.)	60.1	60.1	59.4
	DBH (in.)	11.43	10.43	9.88
	Basal Area (sq. ft./acre)	145.6	169.9	201.8
	Total Volume (cu. ft./acre ib)	3,172	3,700	4,345
Rinehart	Survival (%)	93%	93%	93%
	Height (ft.)	59.0	58.2	56.5
	DBH (in.)	10.52	9.74	8.85
	Basal Area (sq. ft./acre)	120.3	151.0	168.9
	Total Volume (cu. ft./acre ib)	2,571	3,188	3,454
Talbert	Survival (%)	88%	83%	77%
	Height (ft.)	56.3	54.1	54.1
	DBH (in.)	11.09	9.91	9.21
	Basal Area (sq. ft./acre)	124.3	140.1	148.7
	Total Volume (cu. ft./acre ib)	2,542	2,742	2,936
Combined Average	Survival (%)	93%	89%	88%
	Height (ft.)	58.5	57.5	56.7
	DBH (in.)	11.01	10.03	9.31
	Basal Area (sq. ft./acre)	130.1	153.7	173.1
	Total Volume (cu. ft./acre ib)	2,761	3,210	3,579

Since the stand is now at a commercial age, it seems fitting to put some value estimates on the plots. Using current pulpwood, chip-n-saw and sawtimber prices, the total stand value increases with increasing density (Figure 9). Once the trees begin to transition into a heavier sawtimber component, this trend may change (depending on product pricing).

This study continues to show that relatively low-density plantings of genetically improved loblolly pine seedlings can result in well-stocked stands with high-quality crop trees. Planting densities in the 300-400 tpa range may be good for single-thinning management regimes where thinning cannot be done until after 17 or 18 years of age. The 200 trees per acre stand may be a better choice for areas where intermediate harvests are not practical.

Figure 9: Estimated stumpage value ($/acre) at age 20 of plots planted at 200, 300 and 400 trees per acre. [Prices used in these analyses for pulpwood, Chip-n-Saw and sawtimber were $6.94/ton, $21.12/ton and $219/thousand board feet International in the fourth quarter of 2007 and $11.74/ton, $17.24/ton and $139/thousand board feet International in the second quarter of 2013, respectively].



Value of Interplanted Loblolly Pine: Age 7 Update

In 2007, we initiated a trial to evaluate interplanting of loblolly pine seedlings as a means of mitigating various levels of simulated poor survival in a stand on the Appomattox-Buckingham State Forest in Buckingham County, VA. The original planting density of 450 trees per acre (planted in March 2006) was reduced to 300, 200 and 100 tpa (66, 44 and 22 percent survival, respectively) in a randomized complete block design. Methods and earlier results are detailed in the April 2008, April 2009, October 2010, and August 2012 issues of the Research Review.

We measured survival, height and diameter (dbh) of all trees after the 2012 growing season when the interplants were 6 years old and the original seedlings were 7 (Table 4). 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. The original seedlings continue to be 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. As simulated initial survival increases so does average tree height. On the plots with 22 percent simulated survival, the original seedlings 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, competition for light may be driving a phototropic height response, whereas below that threshold, the trees are allocating more resources to diameter growth or crown development.

As simulated first-year survival declines from 66 to 44 to 22 percent, the proportion of the total stand volume made up of interplants increases from 21 to 42 to 66 percent, respectively.

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But first-year mortality at any level – even after interplanting – has resulted in sharp declines in total standing volume (Figure 10) at 66, 44 and 22 percent simulated survival, total volume is reduced by 7, 15 and 42 percent, respectively, of the amount in the undisturbed original (6-year-old) plots. After a few more years, we will use these data to project the ultimate value of these plots and determine whether interplanting can pay off financially.

Remember 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 would be 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.

Table 4. Comparison of original (age 7) and interplanted (age 6) loblolly pine after interplanting at various levels of simulated initial stand survival.

Measurement	Simulated Survival (%)			
	22	44	66	100
Original Seelings (OS - age 7)				
Height (ft.)	19.7	21.4	21.6	20.9
DBH (in.)	4.2	4.6	4.7	4.4
Basal Area (sq. ft./acre)	10.0	24.1	35.4	49.3
Total Volume (cu. ft./acre ib)	112	278	411	564
Interplanted Seedlings (IP - age 6)				
Height (ft.)	16.8	18.6	18.0	–
DBH (in.)	3.3	3.6	3.4	–
Basal Area (sq. ft./acre)	19.3	17.8	9.7	–
Total Volume (cu. ft./acre ib)	215	204	112	–
Total Plot Summary				
Basal Area (sq. ft./acre)	29.3	41.9	45.0	49.3
Total Volume (cu. ft./acre ib)	326	482	523	564
Percent from IP	66%	42%	21%	100%

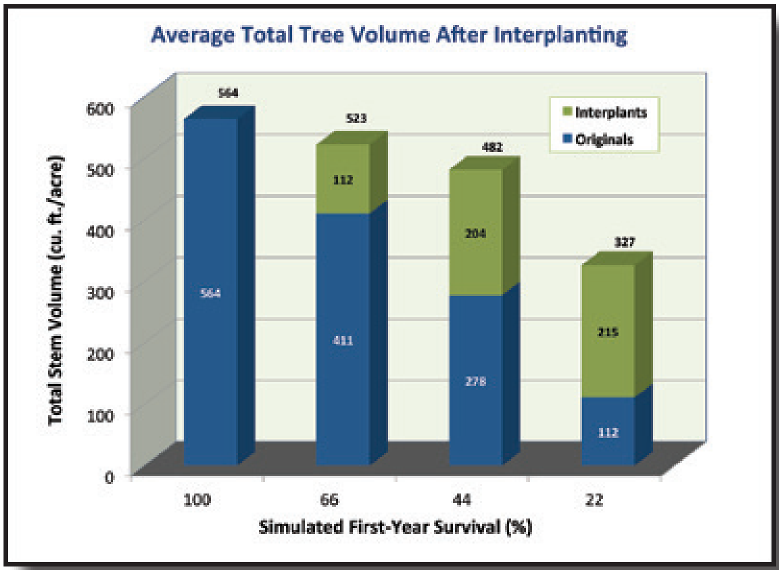

Figure 10. Average total tree volume (cu. ft./acre) six years after interplanting on plots at four different levels of simulated first-year mortality.

COMPARING BIOSOLIDS TO TRADITIONAL FERTILIZERS FOR LOBLOLLY PINE – AGE 7 UPDATE

In 2006, we installed a test of the use of biosolids as a substitute for traditional fertilizer (urea and diammonium phosphate (DAP)) as a nutrient source in thinned mid-rotation loblolly pine plantations. The four treatments (all applied in June 2007) are: 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 (PAN), and 4) biosolids at 400 lbs./acre PAN.

The experimental design and prior results have been described in Research Reviews from April 2008, April 2009, October 2010, May 2011 and August 2012. After the 2012 growing season, the plots were re-measured and the six-year responses have been summarized (Table 5).

Height growth has not been significantly influenced by the treatments, but diameter, basal area and volume growth have. Statistically, all three nutrient sources are producing similar growth responses, and all three are significantly outgrowing the untreated plots. Diameter growth slowed in 2010, perhaps due to dry conditions, but has accelerated again in the last two growing seasons (Figure 11). Fertilized plots have produced up to 41 percent more total tree volume over the six years since application, and we may be seeing a divergence between rates, as the 400 PAN plots have exhibited the greatest growth over the last year.

The study continues to show that 1) nutrient additions as either biosolids or traditional inorganic fertilizer have been beneficial to tree growth for at least six years following application, and 2) there is no evidence of any negative effects of the biosolids on loblolly pine growth or vigor.

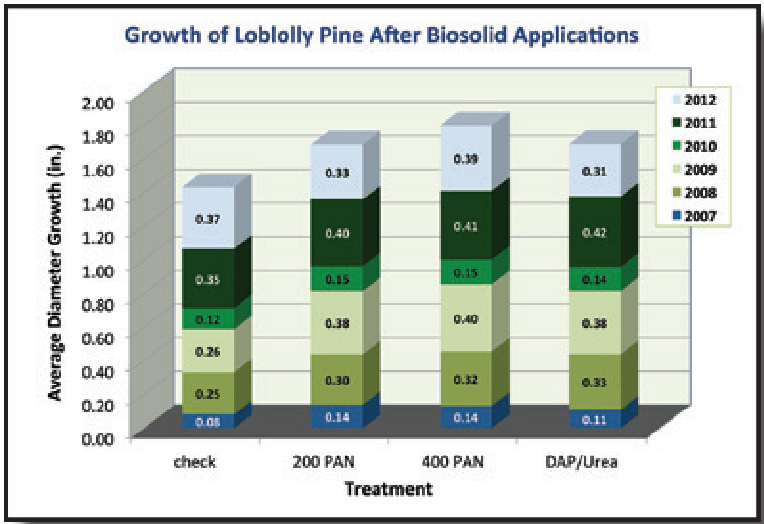

Figure 11. Annual diameter breast height (dbh) growth (in.) of loblolly pine in the study of biosolids applications.

Table 5. Summary of loblolly pine growth responses through six 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	9.6	1.4	62	9.5	2992	1100	–
Biosolids-200 lbs. N	9.6	1.7	66	12.7	3460	1430	30%
Biosolids-400 lbs. N	10.0	1.8	65	14.2	3452	1548	41%
DAP + Urea	10.0	1.7	65	14.6	3188	1381	26%

Site Prep vs Release for Woody Competition Control in Loblolly Pine: Growth and Projected Economic Returns

In the summer of 2005, we collaborated with BASF on the installation of a test to compare the effects of various chemical weed control strategies on loblolly pine growth. The description of methods and earlier results were reported in the October 2010 and May 2011 issues of the Research Review.

Briefly, the study compares eight treatments:

- 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, 2005) – a total of six treatments;
- and one chemical release treatment [imazapyr (Arsenal at 12 oz./acre applied on September 12, 2007].

Half of each whole plot was treated for first-season herbaceous weed control on 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. There was no pine growth response to either the site prep treatments that included Sulfometuron Max or the first-year Arsenal/Oust site prep treatments, so the data presented here are averages of the combined data from those plots. The study was re-measured in the spring of 2013 when the pines were 7 years old.

The results (Table 6, Figure 12) continue to show the importance of hardwood competition control. The best plots in the test have trees that average 5 inches in diameter and 25 feet in height at age 7. The herbicide release at age 2 increased volume growth by 53 percent over no treatment, but the site prep was applied two years earlier and further increased volume growth by 72 (August) to 110 (October) percent.

Table 6. Age 7 growth summary for loblolly pines following chemical site preparation before planting, hardwood competition control at age 2, or no competition control treatment.
(*Tree volume calculated as the volume of a cylinder: DBH^2 x Height x Survival x 454 trees per acre)

Treatment	DBH (in.)	DBH Growth (in.)*	Height (ft.)	Height Growth (ft.)*	Survival (%)	Basal Area (sq. ft./acre)	Volume (cu. ft./ acre)	Volume Response (cu. ft./ acre)	Volume Response (%)
Untreated	3.2	1.3	19.3	7.1	93%	26	349	–	–
October Site Prep	5.0	1.7	25.0	8.6	96%	57	734	384	110%
September Site Prep	4.9	1.6	25.0	9.0	93%	53	686	336	96%
August Site Prep	1.5	1.5	24.3	8.7	94%	46	601	251	72%
Age 2 Release	1.3	1.6	22.4	8.4	94%	44	534	185	53%

***Two-year growth (during the 2011 and 2012 growing seasons).**

As Figure 13 demonstrates, more complete hardwood competition control has resulted in a shift upward in the diameter distribution. The observed diameter distributions in these study plots at age 7 were used as input to project the present net value of similar stands using the LobDSS model developed by the Forest Productivity and Forest Modeling Cooperative. Using recent average product pricing for pulpwood, chip-n-saw and sawtimber stumpage and a five percent alternate rate of return (i.e. discount rate), the model estimated the value of the site prepared, released and untreated stands after a 30-year rotation as $1,630, $1,283 and $825 per acre, respectively. This indicates that the responses seen in this test would warrant an additional expenditure of up to $347 per acre to transition from a second-year release to a pre-plant site prep hardwood control strategy. The difference between release and site prep treatments is nowhere near that amount. For example, if site prep cost $50 per acre more than release, a landowner would be sacrificing nearly $300 per acre to save that amount by waiting to do the release treatment. Site prep is the way to go for hardwood control.

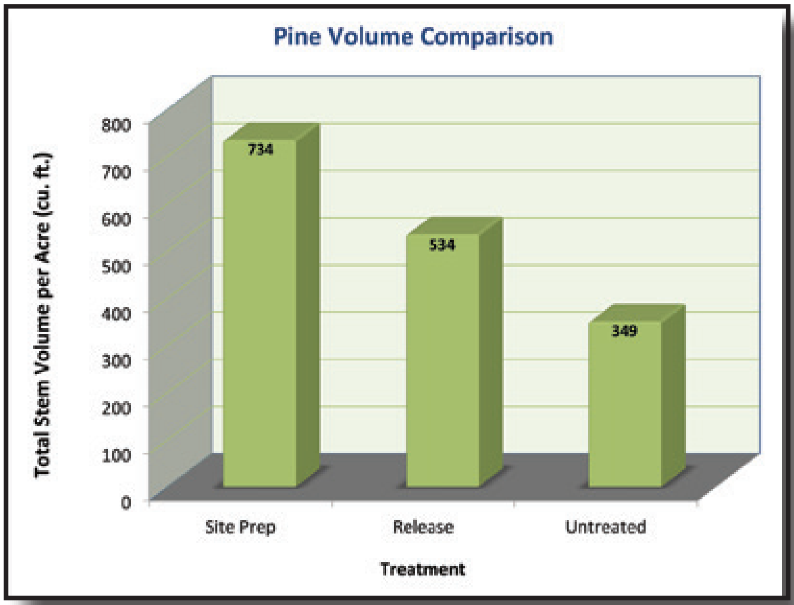

Figure 12: Age seven loblolly pine volume comparison in the 2005 woody competition control study. (*Tree volume index calculated as the volume of a cylinder: DBH^2 x Height x Survival x 454 trees per acre).

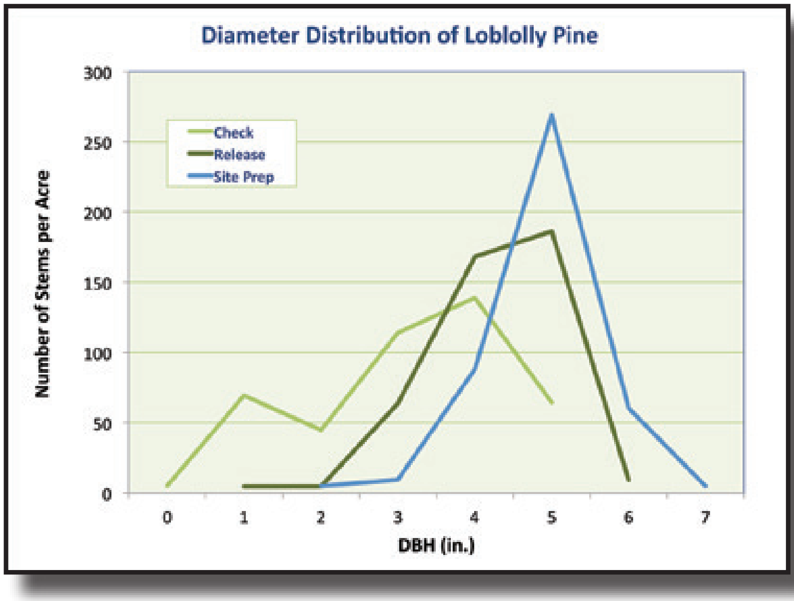

Figure 13: Age 7 diameter distribution of loblolly pine without hardwood control (check) and after age 2 release and pre-planting chemical site preparation.

Performance of Four Hybrid Poplars and Three Native Hardwoods in Plantations in Central Virginia at Age 14

Interest in bioenergy production capacity in Virginia is increasing, and the planting of hardwoods or hybrids is one opportunity that has been discussed as a fiber source. As an alternative to traditional non-renewable fuel sources, bionergy crops may offer reduced greenhouse gas emissions, increased carbon sequestration, decreased dependence on foreign energy supplies, and potential improvements in economic alternatives for rural economies. In particular, *Populus* species and hybrids have been studied and identified as excellent options for several areas of the United States. Research has proven that selection of the appropriate species or genotype for specific site conditions can have large impacts on potential productivity.

In the spring of 1999, MeadWestvaco researchers planted a test of eight tree species - loblolly pine, sweetgum, yellow poplar, hybrid aspen (Crandon), and four hybrid poplars: NxM [*Populus nigra* x *P. maximowiczii*], TD x M = [(*P. trichocarpa* x *P. deltoides*) x *P. maximowiczii*], T x D [*P. trichocarpa* x *P. deltoides*], and T x M [*P. trichocarpa* x P. *maximowiczii*]. Seedlings were planted in 49-tree plots in a randomized complete block experimental design with four replications on a cutover site located on the Walton Tract in Appomattox County, VA, approximately 3.5 miles south of the James River (37o 29′ 48.28″ N x 78o 52′ 08.07″ W). The site was prepared with subsoiling and a broadcast herbicide spray to control competing vegetation in the fall of 1998. In the winter of 2012-2013, VDOF was invited to remeasure the study plots. The age 14 data are summarized in Table 7.

Survival and growth differed widely among species. Sweetgum and yellow poplar – two species common in central and southern Virginia – survived quite well (99 and 86 percent, respectively). But they didn't grow particularly well. The Crandon hybrid aspen grew better than any other genotype in the trial, but only 37 percent of them survived at age 14. Loblolly pine – which is widely planted and generally very productive in Virginia – was expected to represent maximum productivity on the site but was instead a failure. Probably the best balance of growth and survival under the conditions in this test was exhibited by the *P. trichocarpa* x deltoides hybrid, which ranked third in survival and was exceeded only by aspen in individual tree size. It produced the greatest amount of biomass (Figure 14). In this study, species had a large impact on productivity.

Three of the genotypes (TDxM, TxM, and aspen) showed evidence (i.e. large standing dead or broken trees) of delayed mortality indicating poor longer-term adaptability. *Septoria musiva* is a disease threat shown to affect *P. trichocarpa* hybrids in the northeastern and central United States. Although we were unable to test for its presence at this site, the observed condition of the TDxM and TxM make it appear a possible cause. In addition, numerous trees were observed with broken stems and appear to have suffered mechanical damage around the time of the derecho that occurred in late June of 1012. In any case, the delayed mortality following successful establishment casts doubt on the viability of these species as bioenergy crops in this part of Virginia.

To develop a commercially viable bioenergy crop for Virginia, more research will be needed to identify site requirements, adaptability, and appropriate management regimes for individual species.

Table 7. Average survival, size, and volume of eight tree species evaluated for bioenergy planting in central Virginia fourteen years after planting.

Species	Survival (%)	DBH (in.)	Height (ft.)	Volume Index (cu. ft./acre)
Aspen	37%	8.2	92	450
Loblolly	49%	6.4	46	150
NxM	72%	5.9	60	299
Sweetgum	99%	6.3	54	415
TDxM	6%	6.6	52	26
TxD	76%	8.2	78	762
TxM	55%	6.3	40	165
Yellow Poplar	86%	6.4	60	407

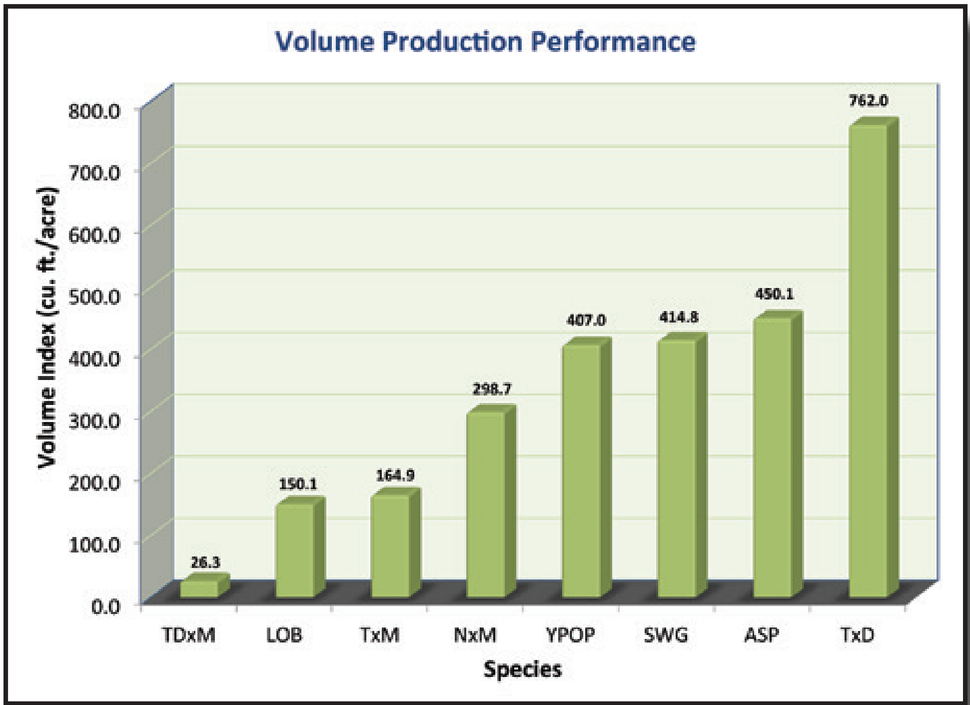

Figure 14. Average fourteen-year volume production by eight tree species planted in a test of biomass production potential in central Virginia.

TREE SHELTERS FOR NORTHERN RED OAK IN RIPARIAN BUFFERS – TWO-YEAR UPDATE

In March 2011, we installed a study comparing five different types of tree shelters - 1) Tubex standard; 2) Tubex Combitube; 3) Acorn Shelterguard; 4) Acorn Bio; and 5) four-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. A more detailed description of the site, shelters and first-year results can be found in the August 2012 issue of the Research Review.

The seedlings were re-measured in February of 2013 – after the second growing season. The data are summarized in Table 8. Trends observed the first year are continuing, with unprotected seedlings experiencing heavy mortality and – along with caged seedlings - displaying relatively slower height growth (Figure 15). There is little doubt that the four solid shelters are successfully protecting the seedlings from browse damage. Trends are beginning to emerge between the four styles of shelters, so we will continue to assess the test annually to see if they become significant at some point.

Table 8. Summary of age 2 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	Age Two	Growth (ft.)	
tubex	2.2	4.0	1.8	0.0%
tubex combi	2.9	4.3	1.4	0.0%
acorn	3.5	4.5	1.0	0.0%
acorn bio	1.6	3.0	1.4	0.0%
wire cage	3.3	4.1	0.8	9%
unprotected	1.8	2.6	0.8	67%

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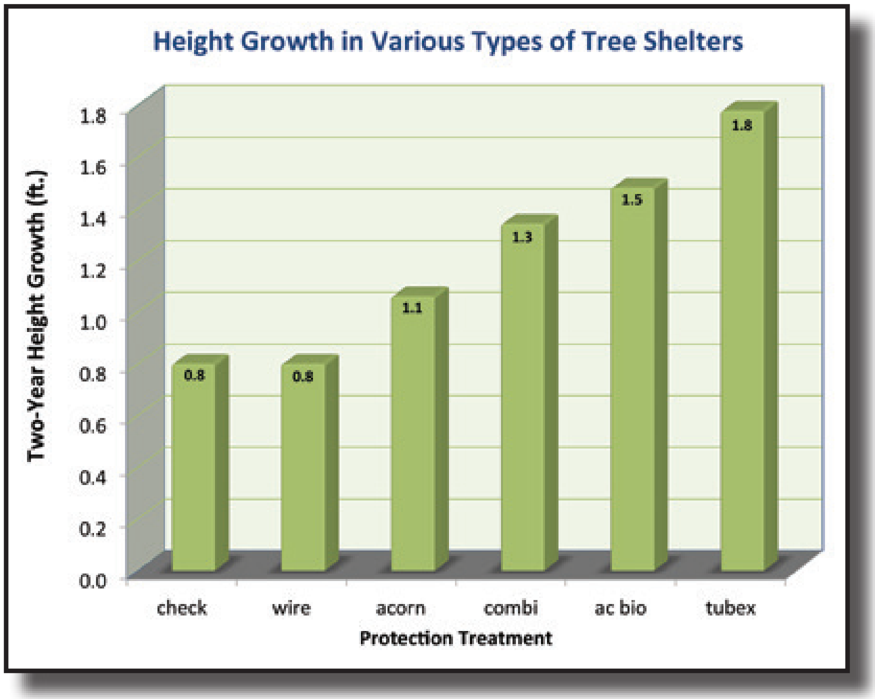

Figure 15. Two-year height growth of northern red oak seedlings in various types of tree shelters.

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