FOREST RESEARCH REVIEW

October 2010

Competing hardwoods surround a 4-year-old loblolly pine on an untreated plot (left), while the pines (also age 4) thrive on a plot sprayed the October prior to planting with Chopper at 40 ounces/acre (right).

IN THIS ISSUE...

VDOF Research Program

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It's time again for another update from the Virginia Department of Forestry's Research Program – now in its 56th year. Every now and then, I pause to think about all the changes in forestry over the last 50+ years, and in the years to come. How does research fit into the long-term conservation and sustainability of our forests and all the products and services we demand from them?

If anything, it seems that the emerging markets for bioenergy and carbon sequestration combined with more stringent expectations for sustainable and certifiable production systems for traditional forest products will tend to make forest research all the more important. We will need to learn to further increase yields from land devoted to production as forest biomass is removed more frequently and more completely, yet we will also need to better understand how to protect those sites from nutrient depletion and soil disturbance. We'll need to be able to predict tree growth and site responses to conditions and practices different from any we've studied in the past, and to translate those predictions into financial options a landowner can use to make decisions. If we are successful, conserving forestland will continue to be an attractive option financially, as well as philosophically. All this comes at a time when changing land ownership and economic challenges have diminished the support for ongoing research while complicating the all-important task of communicating new information to landowners and applying it on the land. There is much work yet ahead of us.

In this issue, you'll find information from several ongoing studies pertaining to loblolly pine: effects of biosolid applications on growth; response of seedlings interplanted in stand gaps after the first growing season of the original stand; effects of herbicide release treatments on growth through age seven, and comparative effects of hardwood control before planting (site prep) and two years after planting (release). We also have four-year data from our northern red oak establishment study.

As usual, we'll start with some recent reports from our research cooperatives. These groups, with their extensive field trial networks, have probably done more to advance our knowledge of forest responses and underlying mechanisms than anyone else, and their continued and expanded study of new treatment combinations, tree genetics and predictive tools are essential to our continued progress. The VDOF research program is proud and fortunate to be a member of the Forest Modeling Cooperative; Forest Nutrition Cooperative, and Cooperative Tree Improvement Program.

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.

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Research Cooperatives

Forest Modeling Research Cooperative

(www.forestry.vt.edu/ ForestModelingResearchCooperative/)

From its inception in 1979, the Loblolly Pine Growth and Yield Cooperative focused mainly on developing models for loblolly pine plantations in the southern U.S. Along the way, however, models were developed for other types of stand conditions, including Appalachian hardwoods and yellow-poplar. A growing need for modeling other species both in the U.S. and South America offers new opportunities for the Co-op and prompted a name change appropriate for the expanded mission. Effective in January 2010, the new name of the Co-op became the Forest Modeling Research Cooperative (FMRC). The name better reflects the Co-op's expanded scope of modeling work that includes diverse species, production objectives and regions. Although loblolly pine remains a primary research thrust, the FMRC is addressing an expanded array of growth and yield modeling projects both in the U.S. and South America.

In conjunction with this expanded scope and mandate, a number of forest enterprises owning or managing forestland in the U.S. and South America have been approached about joining the FMRC. It is anticipated that, over the next two to three years, several new members will join the Co-op.

Forest Nutrition Cooperative

(www.forestnutrition.org)

A recent article[1] in *Biomass and Bioenergy* summarized the potential for pine plantations in the South to provide woody biomass. In the near future, wood from the 32 million acres of pine plantations in the southern U.S. could be called on as a source of feedstock for emerging bioenergy industries. Intensive management of southern U.S. pine plantations could significantly increase the amount of biomass available to supply bioenergy firms. Studies and operational experience have shown that total plantation biomass productivity exceeding 10 tons per acre per year on a green weight basis with rotations less than 25 years is biologically and financially feasible and sustainable. But gains like that depend on intensively managed forest plantations treated as agro-ecosystems where both the crop trees and the soil are managed to optimize productivity and value. Results from growth and yield simulations show that if the existing cutover pine plantations and an additional five million acres of planted idle farmland are intensively managed in the most profitable regimes, up to 8.5 million tons (green weight basis) of woody biomass could be produced annually. But how much can these regimes for biomass production improve financial returns – enough to motivate owners to adopt these systems? The financial analyses tell us that biomass production will be most profitable when intensive management is used to produce a mixture of both traditional forest products and biomass for energy. Returns from dedicated biomass plantations on cutover sites and idle farmland will be lower unless prices for biomass increase or subsidies are available.

[1] John F. Munsell, Thomas R. Fox, An analysis of the feasibility for increasing woody biomass production from pine plantations in the southern United States, Biomass and Bioenergy (2010), doi:10.1016/j.biombioe.2010.05.009

Cooperative Tree Improvement Program

(www.treeimprovement.org)

The genetic basis of forking in loblolly pine was tested by assessing trees in a large number of diallel tests (268 test series, ~1,000 tests in the 2nd-generation testing program) and in a clonal test of MeadWestvaco in South Carolina. By using family selection with a selection differential of 20 percent, forking could be reduced 12 percent to 23 percent across the different regions of the Cooperative. A single-marker analysis of 1,257 loci identified 11 and nine markers that were significantly associated with stem forking and ramicorn branching, respectively.

In a study looking at physiological variation in different loblolly pine genotypes, results provided little support of the hypothesis that more genetically homogeneous individuals would show greater uniformity in a plantation setting, at least not in the first three years. Also, differences in biomass partitioning may be partially related to genetic differences in productivity, but actual height and ground-line diameter growth rate over time was the best indicator of productivity.

Comparing Biosolids to Traditional Fertilizers for Loblolly Pine

Interest in using biosolids (solid or liquid materials produced from the treatment of municipal sewage sludge) as fertilizers in forest stands has increased in recent years. Beginning in October 2006, the VDOF research team installed a study to compare the effects of biosolid applications and traditional inorganic fertilizer (urea + diammonium phosphate [DAP]) on the growth of thinned mid-rotation loblolly pine.

In summary:

- Plots were installed in western Essex County in a mid-rotation loblolly pine stand thinned in the summer of 2006.
- The experimental design is a randomized complete block with four replications using 0.25-acre treatment plots; trees were measured on the interior 0.1 acres of each plot.
- Four treatments (all applied in June 2007) are being compared: 1) no application; 2) urea + DAP at a rate of 200 lbs./acre of nitrogen; 3) lime-stabilized biosolids at 200 lbs./acre of plant available nitrogen (PAN), and 4) biosolids at 400 lbs./acre PAN.
- All biosolids were lime-stabilized and were delivered from Arlington, VA.

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. Earlier reports from this study are in the April 2009 and April 2008 editions of the review.

Three growing seasons after treatment, the fertilized trees are continuing to outgrow the unfertilized trees in diameter (by 40 percent in 2009 – Table 1). Statistically, all three nutrient sources are producing similar growth responses, and all three are significantly outgrowing the untreated plots in terms of diameter. The difference has been greater with each succeeding year (Figure 1). Although there is a trend of increasing height growth on the fertilized plots, the data are not statistically significant so we can say only that height has been neither harmed nor enhanced by the treatments. Taken together, the diameter and height translate into a 12 percent increase in average total volume (outside bark) of the treated trees.

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 to date of any negative effects of the biosolids on loblolly pine growth or vigor.

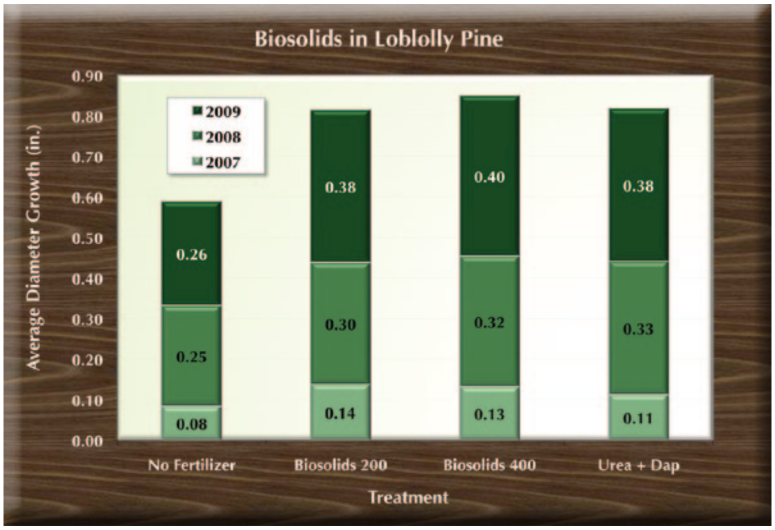

Figure 1. Annual diameter breast height (dbh) growth (in.) of loblolly pine in the study of biosolids applications.

Table 1. Summary of loblolly pine growth responses through three growing seasons following application of biosolids and inorganic fertilizer.

Treatment	DBH (in.) 3 Years Post-Treatment	2009 DBH Growth	DBH Growth Since Treatment	Height (ft.) 3 Years Post-Treatment	2009 Height Growth	Height Growth Since Treatment	Average Total Tree Volume (cu. ft.)
No Fertilizer	8.71	0.26	0.59	56.93	1.26	2.19	8.82
Biosolids 200	8.98	0.38	0.99	60.09	0.49	4.51	9.86
Biosolids 400	9.02	0.40	0.99	59.05	1.71	4.76	9.76
Urea + DAP	9.17	0.38	0.92	59.18	0.47	4.88	10.05

Pine Silviculture, continued

Thanks to the lab assistance of our colleagues with the Forest Nutrition Co-op, we also repeated foliar nutrient analyses of needle samples collected from each plot after the 2009 growing season. The results continue to show significantly higher concentrations of nitrogen in the foliage on the fertilized plots (Table 2) compared to the untreated check plots. And there appears to be no difference yet between biosolids and urea + DAP in either the availability or persistence of the added nitrogen.

Table 2. Foliar nitrogen concentration in loblolly pine needles before (2006); one year after (2007), and three years after (2009) application of biosolids and inorganic fertilizer.

Treatment	2006	2007	2009
Check	1.0832	1.1797	1.39
200	1.0389	1.4213	1.57
400	1.0786	1.5565	1.53
Inorganic Fertilizer	1.0203	1.6106	1.58

Interplanting Loblolly Pine in Low-Density Plantations

Our 2007 study of interplanting loblolly pine in a stand established one year earlier at today's reduced planting density (around 450 trees per acre [tpa]) has now completed its third growing season. Results one and two years after interplanting have been reported previously (in the April 2008 and April 2009 issues, respectively).

The initial planting took place in March 2006 and one year later, the research team installed tenth-acre square plots in a randomized complete block design with four replications testing four treatments: 1) no interplanting; 2) simulated mortality with a residual stand density of 300 tpa; 3) residual stand density of 200 tpa, and 4) residual stand density of 100 tpa, followed by interplanting of empty planting spots. To accomplish the density reductions, we pin flagged all surviving trees and randomly pulled up enough to reach the target density (simulated mortality). We then replaced the trees that had been pulled up with an interplant.

This is likely a best-case scenario because the research crew was careful to interplant seedlings at exactly the same spacing as the original seedlings (i.e. in the exact spot where an original seedling was removed). In practice, operational planting crews would plant a specified number of seedlings per acre to bring the density back to some target (in this study, 450 trees per acre) and, as a result, would likely have a much more patchy stand distribution and different results.

After three years – when the "original" seedlings were four years old and the "interplants" were three – there were continuing differences in total height and height growth at all residual densities, and the interplanted trees were not catching up so far (Table 3) (Figure 2 and Figure 3 on page 6). However, there are positive signs for the

Table 3. Comparison of heights and survival of loblolly pine three years after interplanting. (* = Original stand – no interplanting).

Density (TPA)	Average Height (ft.)		Height of Tallest Tree (ft.)		Survival (%)	
	Original Trees	Interplanted Trees	Original Trees	Interplanted Trees	Original Trees	Interplanted Trees
450*	9.17	–	13.4	–	98	–
300	9.62	6.37	16.1	11.8	97	96
200	9.39	6.33	14.4	10.8	100	97
100	8.43	5.31	12.1	8.6	100	90

interplants: 90 percent or more of them continue to survive; they are taller at age two in the field (after the 2009 growing season) than the original seedlings were at the same age (after the 2008 growing season); and in the past year, they have grown roughly the same amount as the originals – not enough to catch up, but the difference between the two ages is leveling off (Figure 4).

Figure 2. An original seedling (left) and an interplanted seedling (right) in July 2010 at age 4 from planting.

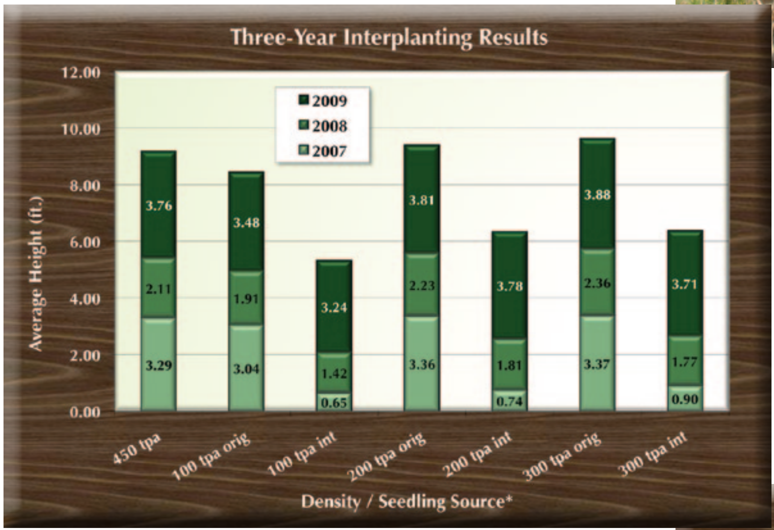

Figure 3. Height development of original ("orig", current age 4) and interplanted ("int", current age 3) loblolly pine. Note: 450 tpa is the original, undisturbed stand condition.

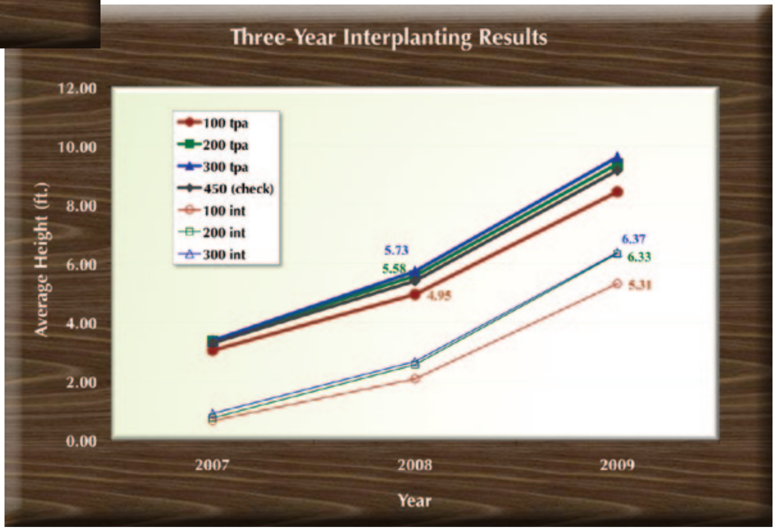

Figure 4. Height growth curves for original and interplanted loblolly pines on plots with simulated mortality at age 1 (prior to the 2007 growing season).

Loblolly Pine Growth for Five Years Following Herbicide Release

In September 2005, test plots were installed in Stand AB-0505 of the Talbert Management Unit at the Appomattox-Buckingham State Forest. The site had been harvested in 2003 and planted with second generation loblolly pine seedlings in March 2004. The study compares 13 treatments, including common herbicide release tank mixes: Arsenal alone at 12 oz./acre; Arsenal at 12 oz./acre plus Accord at 32 oz./acre; and Arsenal at 12 oz./acre plus Escort XP at 1 oz./acre) with either no surfactant, TimberSurf 90, Red River Forestry Oil, Entry II, Entrée 5735 or Brewer TA 35 at 0.25 percent by volume. Treatments were replicated three times in a randomized complete block experimental design.

Early results from this work were aimed at documenting any potential damage caused by the various surfactants. As reported in the August 2006 issue of the Forest Research Review, most of the plots showed minimal damage to the terminal shoot (3 to 6 inches of dead needles and stem), but there was no evidence of more widespread effects on the lower parts of the crown. The damage was most often associated with the Arsenal x Accord tank mix, either with or without surfactants. By July of the year following treatment, damage was no longer apparent and the trees all appeared to be growing normally.

We remeasured pine growth attributes and free-to-grow status (0-4 scale with 0 being completely free to grow and 4 being completely suppressed) after the 2009 growing season (pine age 7, five years after the release treatments were applied). All of the release treatments have significantly improved pine height, diameter and volume growth, and all have significantly reduced the amount of competing hardwood vegetation (Table 4) (Figure 5 on page 8). There is no detectable difference among the three herbicide mixes, although there is a trend indicating that the Arsenal x Escort mixes are giving slightly less hardwood control and, probably as a result, slightly less diameter growth (Figures 6 and 7 on page 8). Overall, the treatments have produced average gains in height, diameter and volume of 7 percent, 18 percent and 23 percent, respectively.

Table 4. Summary of loblolly pine growth five years after treatment in the 2005 release tank mix x surfactant study.

Treatment*	Height (ft.)	DBH (in.)	FTG Rating	Height Growth (ft.)	DBH Growth (in.)	Volume per Tree (cu. ft./acre)
Untreated	16.67	2.92	1.56	12.73	1.58	6.06
Ar 12 oz.	17.53	3.40	0.77	13.69	1.93	7.65
Ar + TS	18.57	3.50	0.67	14.77	1.95	8.65
Ar + RR	17.44	3.22	0.84	13.63	1.77	7.17
Ar + Acc 32 oz.	17.38	3.43	0.63	13.53	1.93	7.64
Ar / Acc + En	16.45	2.99	0.76	12.93	1.75	6.39
Ar / Acc + TS	16.74	3.22	0.49	13.24	2.07	6.72
Ar / Acc + TA	17.99	3.43	0.69	13.82	1.96	8.05
Ar / Acc + Et	17.59	3.40	0.55	13.74	1.90	7.71
Ar / Acc + RR	17.40	3.36	0.54	13.70	1.97	7.51
Ar 8 + Es 1 oz.	17.45	3.18	1.05	13.66	1.69	7.16
Ar / Es+TS	16.45	3.21	0.85	12.64	1.81	6.66
Ar / Es+RR	17.91	3.38	1.00	13.67	1.77	7.93

*Ar = Arsenal; Acc=Accord; Es=Escort; TS=TimberSurf 90; RR=Red River Forestry Oil; En=Entry II, Et=Entree 5735; TA=Brewer TA 35

Perhaps the most important conclusion from these most recent data is summarized in Figure 8 on page 9 – there is a clear relationship between hardwood competition and pine growth. The gain in diameter growth from the heaviest competition (untreated, FTG=1.56) to the best control treatment (Arsenal x Accord + TimberSurf 90, FTG=0.49) is 30 percent. Loblolly pine grows much better without hardwood competition, and the earlier the competition is removed, the better (see the report on chemical site prep in this issue for details).

The original plot size used in this study was not intended to allow long-term growth response data to be collected, so these will be the final measurements from this study.

Figure 5. Seven-year-old loblolly pines with no competition control treatment (left) compared to hardwood competition control using Arsenal at 12 oz./acre applied as a release treatment at age 2 (right).

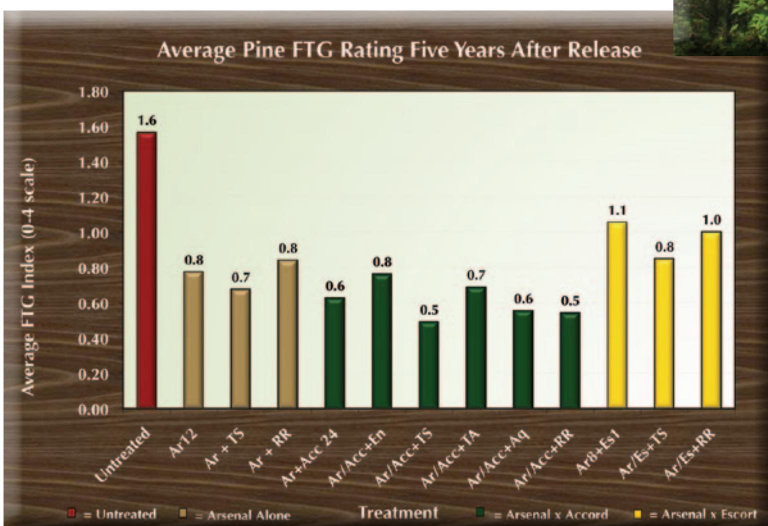

Figure 6. Average free-to-grow rating (using a modified 0-4 scale with 0 being no hardwoods anywhere and 4 being compete suppression) of loblolly pines on the 2005 release study.

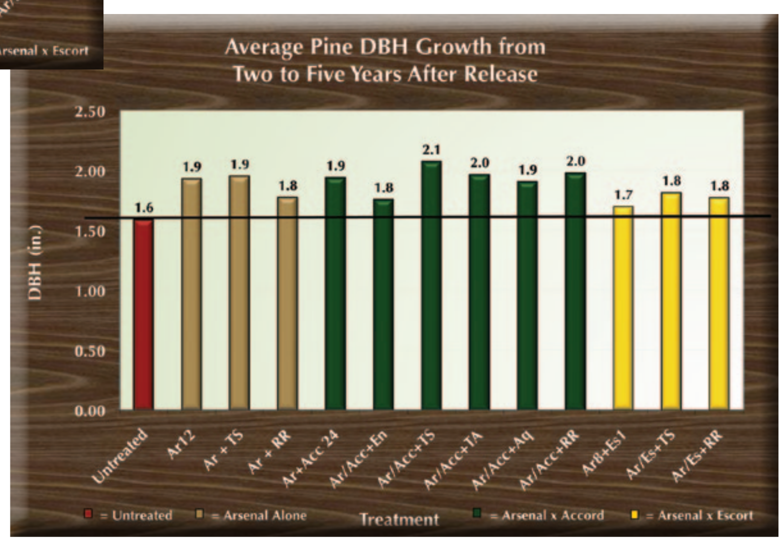

Figure 7. Average diameter (dbh) growth during the first five years after treatment on the 2005 release study.

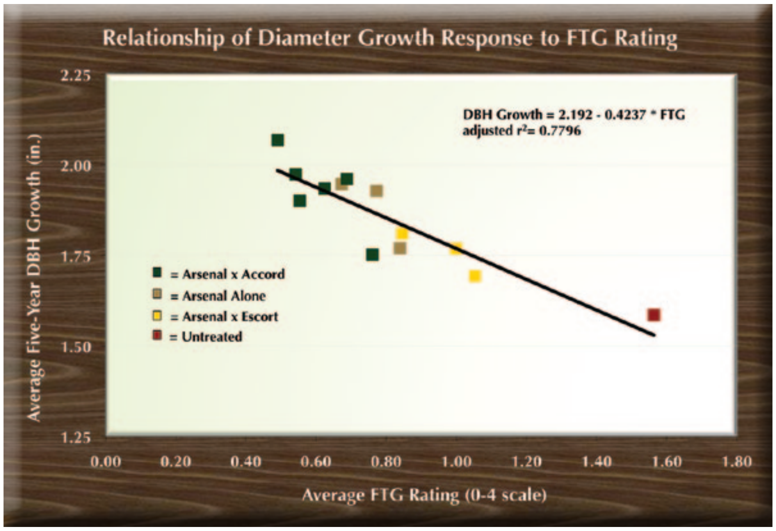

Figure 8. Relationship of diameter growth response to FTG rating (higher FTG rating means heavier hardwood competition).

Loblolly Pine Growth Following Chemical Site Preparation Compared to Age Two Release

In the summer of 2005, we collaborated with BASF Market Development Specialist Harold Quicke and Dwight Lauer of Silvics Analytic on the installation of a test to compare 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.

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 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.

We intend to complete a full measurement of the test five years after planting, but took the time to assess a subset of the treatments after four years. We measured all three replications of the untreated, released and October 1 site prep plots. Because earlier evaluations did not detect any effect of first-year herbaceous weed control, we measured both subplots and combined the data.

The results (Table 5) are of particular interest because it is our first side-by-side comparison of chemical site prep and release. These data support the notion that earlier hardwood control is best for

Table 5. Age 4 growth summary for loblolly pines following chemical site preparation before planting; hardwood release at age 2 or no competition control treatment.

Treatment	DBH (in.)	Height (ft.)	Volume Index* (cu. ft./acre)
Chemical Site Prep	2.43	12.7	182
Chemical Release	1.78	10.2	77
No Treatment	1.43	9.1	38

increasing pine growth. The herbicide release doubled the volume yield compared to no treatment, which is a pretty encouraging result. But chemical site prep more than doubled the response compared to release (Figure 9). Moreover, this was on a tract that was site prep burned just weeks prior to the first of the site prep application. There was virtually no leaf area present at the first (July) application, and not much more by the time of the October treatments we measured (Figure 10). But the hardwood competition was heavy at this site (typical of Piedmont Virginia sites) and proved the value of competition control for those landowners wanting to maximize pine growth (cover photo). We look forward to bringing you a more comprehensive analysis of this test following the fifth growing season.

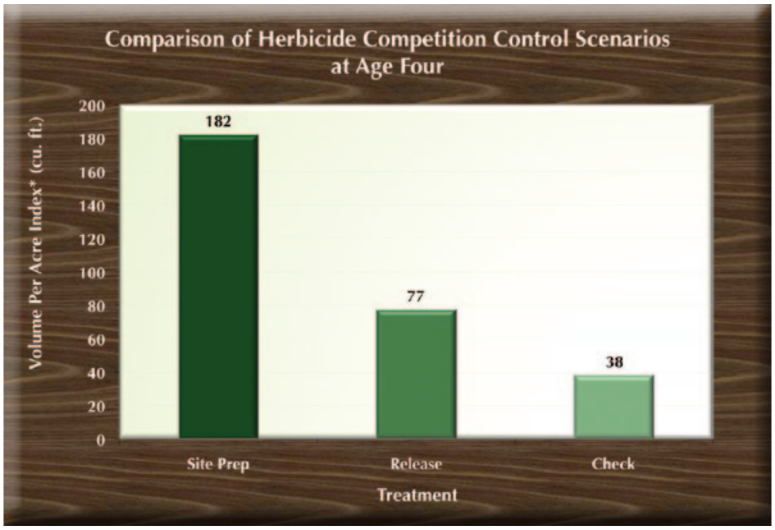

Figure 9. Age four loblolly pine volume comparison in the 2005 woody competition control study. (*Tree volume index calculated as the volume of a cylinder: DBH^2 * Height * Survival * 454 trees per acre.)

Figure 10. View of the study area on July 21, 2005 - four weeks after burning, at the approximate time when chemical site prep treatments were applied.

Effects of Establishment Methods and Initial Seedling Size on Early Northern Red Oak Performance

In early 2006, the VDOF installed a test of the effects of different establishment methods and initial seedling size on northern red oak survival and growth. The study design is described in detail in the August 2006 issue of the Research Review; first-year results are in the March 2007 issue, and two-year data are in the October 2008 issue. Two locations were originally installed; one has suffered extensive mortality due to unknown causes (probably a combination of dense competing grasses and rodent damage), and has been abandoned. The other, in Louisa County on Henry Taylor's West End Farm, was remeasured after its fourth growing season and is the subject of this report.

To review: northern red oak seedlings were graded into three root collar diameter classes – small (<0.2 inches), medium (0.2 - 0.3 inches), and large (>0.4 inches), and planted in March 2006 using one of five establishment treatments: 1) no treatment; 2) VisPore mulch mat plus four-foot Tubex tree shelter; 3) spot spraying of a two-foot radius spot using a two percent glyphosate solution; 4) four-foot Tubex tree shelter plus two-foot radius glyphosate spot spraying, and 5) VisPore mulch mat only.

After four years, trees sheltered by Tubex shelters average 84-93 percent in survival, four feet to five feet in height, and ½ to ¾ inches in diameter at groundline. Most have emerged from the shelters (Table 6) (Figure 11 on back cover). It is noteworthy that the spot application of glyphosate herbicide produced survival and growth equal to or greater than that achieved with the mulch mats; diameter growth was more than doubled. Perhaps the herbicide is providing more complete weed control and/or a more favorable soil surface microenvironment for the seedlings.

But without protection from shelters, survival and growth have been unacceptable. We believe, at this site, the primary damaging agent has been rabbits, with some assistance from deer and mice. And it appears that herbicide spraying alone has only made the seedlings more apparent to the predators; they have actually decreased in both diameter and height over the duration of the test.

In terms of seedling size (Table 7), we looked just at seedlings that were protected inside tubes so that the browse damage would not affect the data. The seedlings that were larger initially are still larger, and have grown far more than those in the medium- or small-diameter classes (Figure 12 on back cover). Medium-diameter seedlings have grown reasonably well in height, but not in groundline diameter. Survival has not varied due to initial size.

Based on these data, it appears that for northern red oak a seedling diameter of 0.4 inches or more combined with protection in Tubex shelters and either a mulch mat or herbicide spot spray is the recommended combination for successful planting.

Table 6. Four-year growth and survival of northern red oak seedlings in response to different establishment treatments (averaged across all three initial seedling sizes).

	Check	Tube + Mat	Herbicide Only	Tube + Herbicide	Mat Only
GLD (in)	0.31	0.48	0.25	0.72	0.38
Height (ft)	1.86	4.45	0.96	5.11	1.83
GLD Growth	0.06	0.22	-0.02	0.45	0.12
Height Growth	0.22	3.12	-0.47	3.51	0.58
Survival	37%	84%	42%	93%	31%

Table 7. Four-year growth and survival of northern red oak seedlings of different initial diameter classes (averaged across the two establishment treatments that included tubes).

	Large	Medium	Small
GLD (in.)	1.04	0.45	0.32
Height (ft.)	6.26	4.84	3.24
GLD Growth	0.69	0.20	0.12
Height Growth	3.84	3.71	2.41
Survival	92%	85%	90%

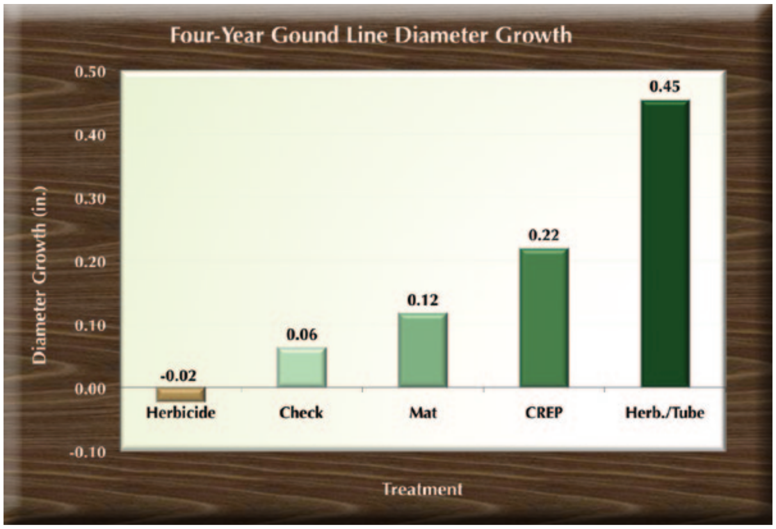

Figure 11. Four-year growth and survival of northern red oak seedlings in response to different establishment treatments (averaged across all three initial seedling sizes).

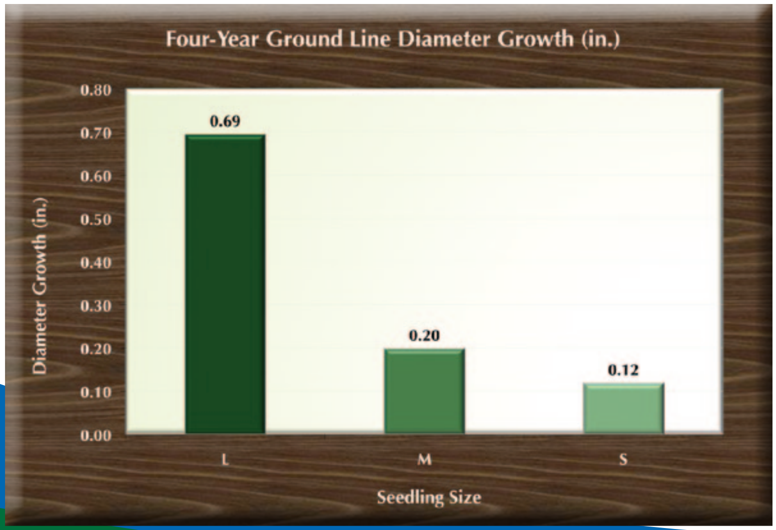

Figure 12. Four-year growth and survival of northern red oak seedlings of different initial diameter classes (averaged across the two establishment treatments that included tubes).

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