Seedling Quality Standards for Bottomland Hardwood Afforestation in the Lower Mississippi River Alluvial Valley: Preliminary Results

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Abstract: Afforestation of bottomland hardwood species has increased in the Lower Mississippi River Alluvial Valley (LMRAV) in recent years. Rising demand for hardwood nursery stock and poor performance of some planted seedlings has created concern regarding the quality of seedlings currently available for afforestation in the LMRAV. Furthermore, no definitive guidelines for optimal seedling morphological quality of bottomland hardwoods in the LMRAV have been developed. We measured initial morphology of green ash (*Fraxinus pennsylvanica* Marsh.) and water oak (*Quercus nigra* L.) seedlings from 3 nurseries and examined field response after planting with or without chemical weed control on a LMRAV site in Mississippi. Seedlings from different nurseries varied significantly in initial morphology and field performance during the first growing season. Weed control had a relatively minor influence on seedling survival, but growth was significantly increased when weed control was applied. Seedlings exhibited considerable transplant shock during the first growing season, and this stress was most pronounced in seedlings with larger shoot heights, implying possible shoot-to-root imbalance. Though we currently present only preliminary results from a portion of data collected, our results suggest that morphological quality of hardwood seedlings available for afforestation in the LMRAV varies considerably depending on nursery source, and this variation leads to differences in plantation performance.

Keywords: afforestation, green ash, seedling quality, transplant shock, water oak

Introduction

The Lower Mississippi River Alluvial Valley (LMRAV) comprised the largest extent of bottomland hardwood forest in the United States at the time of European settlement, consisting of about 10 million ha (25 million ac) (Hefner and Brown 1985). This area was largely deforested over the past 60 years, primarily for conversion to agriculture. It is estimated that hardwood forest cover in the LMRAV was reduced to about 2 million ha (5 million ac) by 1978 (Hefner and Brown 1985). In recent years, there has been increased interest in afforesting these sites to retain the important ecological function of these ecosystems (Gardiner and others 2002; Lockhart and others 2003). This interest has been strengthened by the apparent poor suitability of some of these sites for agriculture due to tendency for late spring and early summer flooding (Lockhart and others 2003).

Afforestation activities in the LMRAV are currently peaking (Gardiner and others 2002), largely driven by the availability of governmental cost-share programs (for example, the Conservation Reserve Program and Wetlands Reserve Program), which help to supplement planting costs. Within the past decade, about 77,000 ha (190,000 ac) of former agricultural land were afforested in the LMRAV (King and Keeland 1999). It is expected that another 89,000 to 105,000 ha (220,000 to 260,000 ac) will be afforested by 2005 (Stanturf and others 1998; King and Keeland 1999).

Though planting stock on these sites include seeds, container seedlings, and cuttings (Gardiner and others 2002), it has been estimated that over two-thirds of public land and cost-share plantings in the LMRAV have been established using 1+0 bareroot seedlings (King and Keeland 1999). The large increase in demand for hardwood bareroot seedlings for afforestation in the LMRAV has prompted the establishment of many new forest tree seedling nurseries. Additionally, some ornamental nurseries have adapted to the increased demand for seedlings by expanding their operations to include hardwood planting stock.

This has created potential for concern regarding the quality of seedlings currently available for afforestation in the LMRAV. This concern is further augmented by the poor survival and growth of many hardwood plantations in the region (Lockhart and others 2003). A meeting held in June of 2002 at the USDA Forest Service Bottomland Hardwoods Laboratory in Stoneville, MS, with members representing the National Resources Conservation Service (NRCS), the USDA Forest Service, Purdue University, and State agencies from Arkansas, Louisiana, Mississippi, and Texas suggested that a concerted research effort to better define quality specifications for bottomland hardwood nursery stock is needed.

Early researchers working with bottomland hardwood species suggested that desirable seedlings for field planting should have a shoot height of 76 to 91 cm (30 to 36 in) and a root-collar diameter of about 6 to 10 mm (McKnight and Johnson 1980; Kennedy 1981). However, specifications for morphological quality will probably vary among the vast diversity of hardwood species that are planted in the LMRAV (Gardiner and others 2002). Additionally, performance by morphological grade is likely to deviate according to the extent of site preparation conducted on the site. Many afforestation sites in the LMRAV receive little or no weed control measures, which likely limits their productivity. No definitive guidelines for optimal seedling morphological quality of bottomland hardwoods in the LMRAV have been developed or published (Gardiner and others 2002). Thus, our objectives in this current research are: (1) to examine variation in bottomland hardwood bareroot seedling morphological quality among several regional nurseries and resulting outplanting performance, (2) to document the importance of weed control in initial plantation establishment in the LMRAV, and (3) to identify relationships between initial seedling morphology and outplanting performance.

In this paper, we present first-year field trial results for green ash (*Fraxinus pennsylvanica* Marsh.) and water oak (*Quercus nigra* L.) acquired from 3 nurseries (in Arkansas, Louisiana, or Mississippi) and planted onto an afforestation site with or without weed control in the LMRAV in Mississippi. Following the completion of additional growing seasons, we expect to present more comprehensive reports summarizing all treatment combinations.

Materials and Methods

In February 2003, we obtained 1+0 bareroot seedlings of 5 different species commonly planted in LMRAV afforestation programs: pecan (*Carya illinoensis* (Wangenh.) K. Koch), water oak, cherrybark oak (*Q. pagoda* Raf.), Nuttall oak (*Q. nuttallii* Palmer), and green ash. Seedlings from each species were acquired from each of 3 nurseries: Arkansas Department of Forestry, Louisiana Department of Forestry, and the Mississippi Forestry Commission. Note that nurseries are kept anonymous in our report of the results. Seedlings were transported to the USDA Forest Service Bottomland Hardwoods Laboratory in Stoneville, MS, and placed into a cooler until processed.

Each seedling was individually tagged and measured for shoot height, root-collar diameter, fresh weight, number of first-order lateral roots (FOLR, roots >1 mm at junction with taproot), and root volume (Burdett 1979). Seedlings were then re-packaged and returned to the cooler.

Following measurements, seedlings were sorted for planting at 3 different outplanting sites located in Arkansas, Louisiana, or Mississippi. We currently present results from only the Mississippi site located near Rosedale, MS (330 53' N, 910 00' W), and only for green ash and water oak (with or without weed control). The 2 species were established in separate experiments. Green ash was planted on a Sharkey Soil while water oak was planted on a Commerce Soil. Seedlings were planted in a randomized complete block design with 3 replications of the 6 treatments (3 nurseries x 2 weed control levels). Fifty seedlings were planted within a treatment replication for a total of 900 seedlings of each species on a site. Planting was conducted using shovels in February to March 2003. The weed control treatments consisted of either no control or a pre-emergent application of Goal™ 2XL (oxyfluorfen) applied at 4,677 ml/ha (0.5 gal/ac) in early March 2003. Broadcast applications of Select® 2EC (clethodim) were then applied as needed throughout the growing season at a rate of 585 or 877 ml/ha (0.5 or 0.75 pt/ac) depending on target weed species. Additionally, direct applications of Derringer™ (glufosinate-ammonium) were applied at a rate of 118 ml/L (15 oz/gal) of water as needed throughout the growing season.

In March 2003 (following planting and prior to bud burst), each seedling was measured for field height and root-collar diameter. Seedlings were re-measured in December 2003 and assessed for survival. Analysis of variance (ANOVA) was conducted on all variables using SAS and, where appropriate, significant means were ranked according to Waller-Duncan's multiple range tests at = 0.05. To directly examine relationships between initial seedling morphology and planting performance, regression analyses were employed and a coefficient of determination (R^2 value) reported when statistically significant ($P < 0.05$).

Results

Nursery Characterization

Significant differences were detected for all initial morphological variables among nurseries (identity kept anonymous) for each species. For green ash (Figures 1 and 2), nursery A had the largest shoot height, root-collar diameter, and fresh mass. Shoot height ranked as 75 > 62 > 45 cm (30 > 24 > 18 in) in respective nurseries A, B, and C. Similarly, diameter ranked as 8 > 7 = 7 mm in the respective nurseries. Nursery C, however, had the highest mean number of FOLR and root volume. Additionally, seedlings from nursery C had approximately 50% the ratio of height to root volume (that is, an indication of shoot-to-root balance) compared to seedlings from nurseries A and B.

For water oak (Figures 3 and 4), seedlings from nursery A again had the greatest shoot height, root-collar diameter, and fresh mass. Nursery C again produced seedlings with the greatest number of FOLR, but seedlings from nursery A had the largest root volume. Seedlings from nursery B had the largest ratio of height-to-root volume.

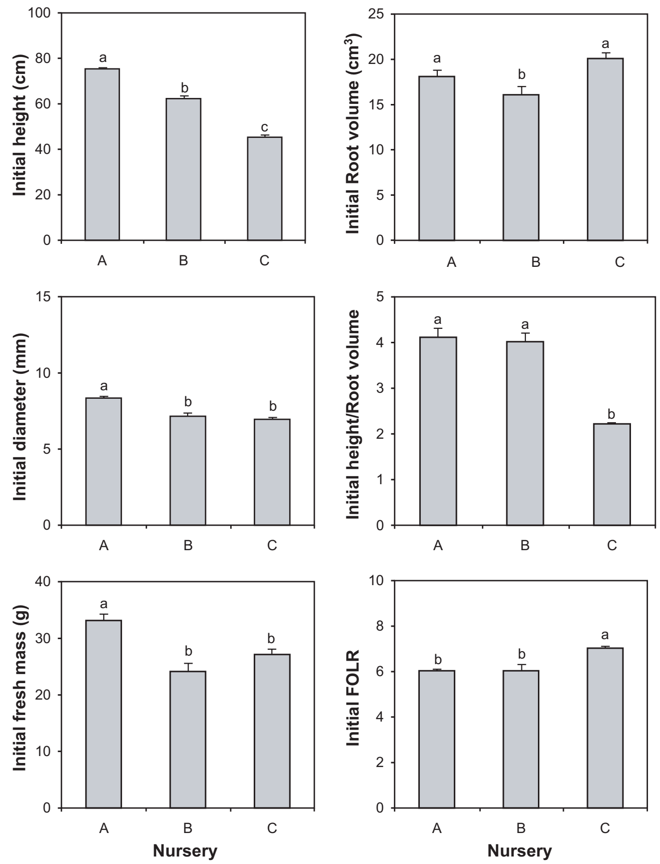

Figure 2—Green ash initial seedling morphological variables according to nursery. Treatments with different letters above the bars are significantly different at = 0.05.

Green Ash Field Response

Green ash seedlings exhibited significant nursery differences in field response. Seedlings from nurseries B and C had >95% survival, while those from nursery A had about 76% survival (Figure 5). Weed control treatments produced clear visual differences in growth during the growing season (Figure 6). No differences in survival were detected by weed

Figure 1—Typical green ash seedlings exhibiting considerable variation in morphology.

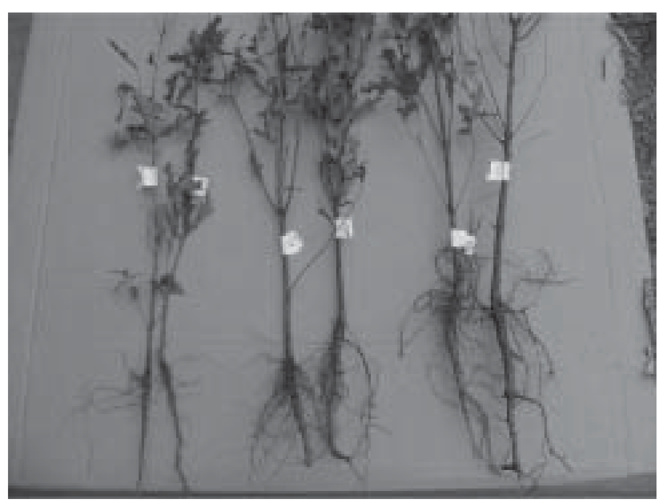

Figure 3—Typical water oak seedlings exhibiting considerable variation in morphology.

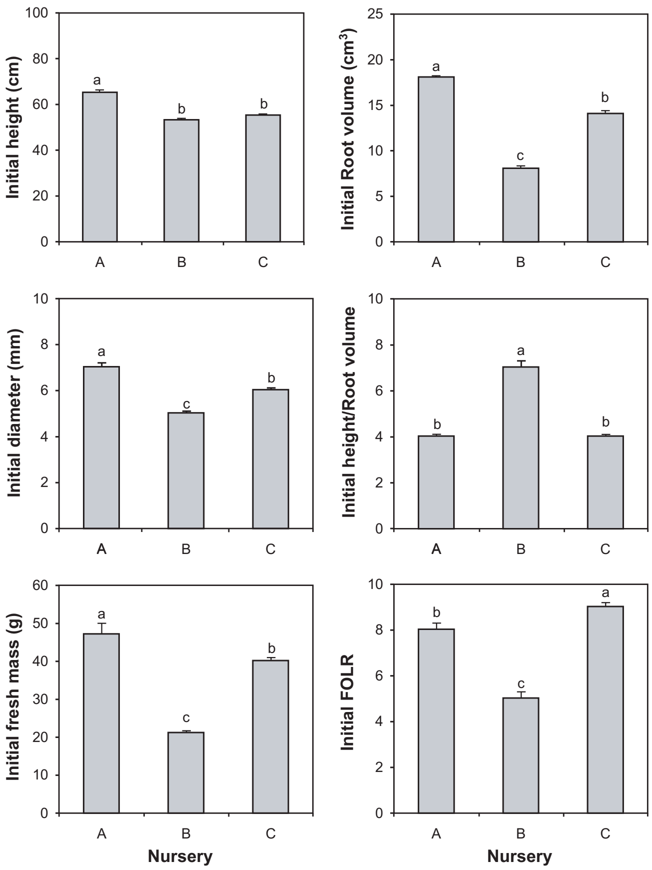

Figure 4—Water oak initial seedling morphological variables according to nursery. Treatments with different letters above the bars are significantly different at = 0.05.

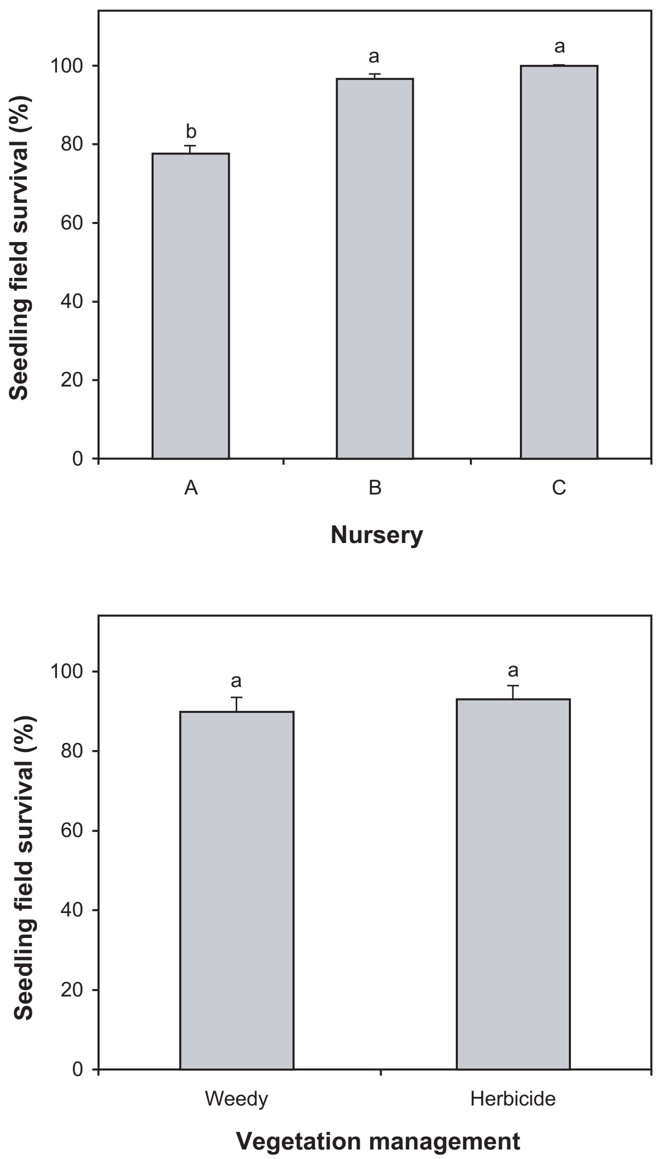

Figure 5—Green ash seedling survival by nursery and weed control treatment. For either the nursery or weed control effects, treatments with different letters above the bars are significantly different at = 0.05.

control treatment (Figure 5). Differences in seedling growth among nurseries and weed control treatments were very evident (Figure 7). Seedlings from nursery C had the greatest height and diameter growth, while those from nursery A had the lowest. The ranking of this response by nursery was similar whether seedlings received weed control or not. However, seedlings that received weed control grew significantly more than those that did not (Figure 7).

Regression analyses between initial morphological variables measured in the lab and field performance showed a generally negative relationship between initial seedling height or diameter and growth or survival, regardless of weed control treatment (Figure 8). In contrast, initial FOLR or root volume tended to show more stable or positive linear relationships with field performance (Figure 9). With an increase in the ratio of initial height-to-root volume, field performance generally decreased (Figure 10).

Water Oak Field Response

Water oak seedlings showed no differences in survival by nursery, but survival was significantly lower without weed control (Figure 11). Seedlings in all treatments exhibited severe top dieback, resulting in generally negative height growth for all size classes (Figure 12) and preventing further analysis of growth response at present. The relationship between initial lab variables and survival showed a generally positive linear relationship without weed control and a negative linear relationship when weed control was applied (Figure 13).

Discussion

Apparently, there are substantial differences in seedling morphological quality from identical species among nurseries in the LMRAV. These differences in morphology appear to translate to variation in first-year outplanting performance. Green ash seedlings from nursery A, for example, tended to have greater height, diameter, and fresh mass

Figure 6—Green ash seedlings during the first year of plantation growth either with (top photo) or without (bottom photo) chemical weed control.

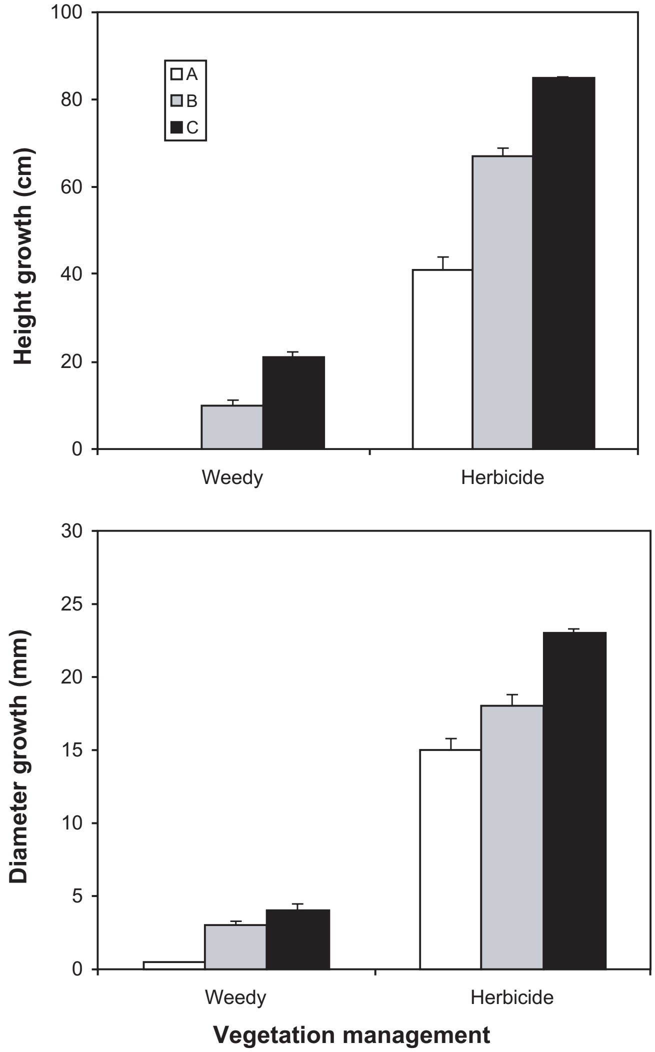

Figure 7—Height and diameter growth of green ash seedlings from 3 different nurseries either with or without chemical weed control. Weed control had a pronounced effect on seedling growth, though the ranking among nurseries was similar regardless of weed control treatment.

(Figure 2) yet the lowest survival and least field growth (Figures 5 and 7). This was in spite of the fact that seedlings from nursery A met the original morphological standards for field planting in this region (McKnight and Johnson 1980; Kennedy 1981).

The poor survival and growth observed under field conditions may be partly because of greater susceptibility of seedlings from nursery A to transplant shock incurred during the first year following planting. Transplant shock was very evident in green ash, based on the negative slope of the regression line between height and height growth as per South and Zwolinski (1996) (Figure 8). Green ash seedlings from nursery A may have had excessive shoot biomass in relation to root system size. This can act to increase initial transplant stress due to high transpirational demand from the shoot without compensatory water uptake from root systems, as has been observed previously with bareroot northern red oak (*Quercus rubra* L.) seedlings (Jacobs, unpublished data). This suggests that nursery cultural treatments (that is, sowing density, undercutting, lateral root pruning, and so on) should be designed to promote an adequate balance between shoot and root.

Our results question the validity of former seedling quality standards and call for a critical re-evaluation of morphological criteria to design new protocols for characterizing seedling quality in the LMRAV. It is likely that physiological factors and/or a combination of morphological traits may be needed to fully characterize seedling quality and outplanting response.

Chemical weed control had a relatively minor influence on seedling survival for these 2 species (though significant for water oak). However, the magnitude of the growth response differences in weeded versus unweeded plots for green ash exhibits the importance of weed control for initial plantation establishment of this species in the LMRAV. The effectiveness of chemical weed control for plantation establishment in the LMRAV has been alluded to previously (see citations in Gardiner and others 2002), and this data helps to further confirm this response. Because Federal cost-share funds are typically not provided for weed control treatments on afforestation plantings in the LMRAV, these treatments are often not employed, which may result in failed or less

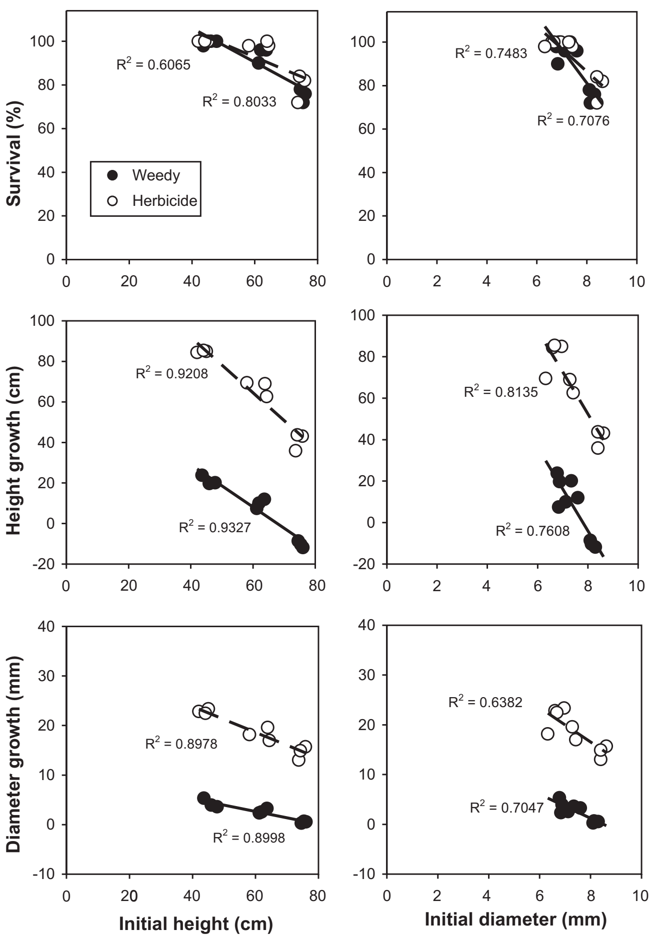

Figure 8—Regression relationships between initial height or diameter of green ash seedlings and field performance.

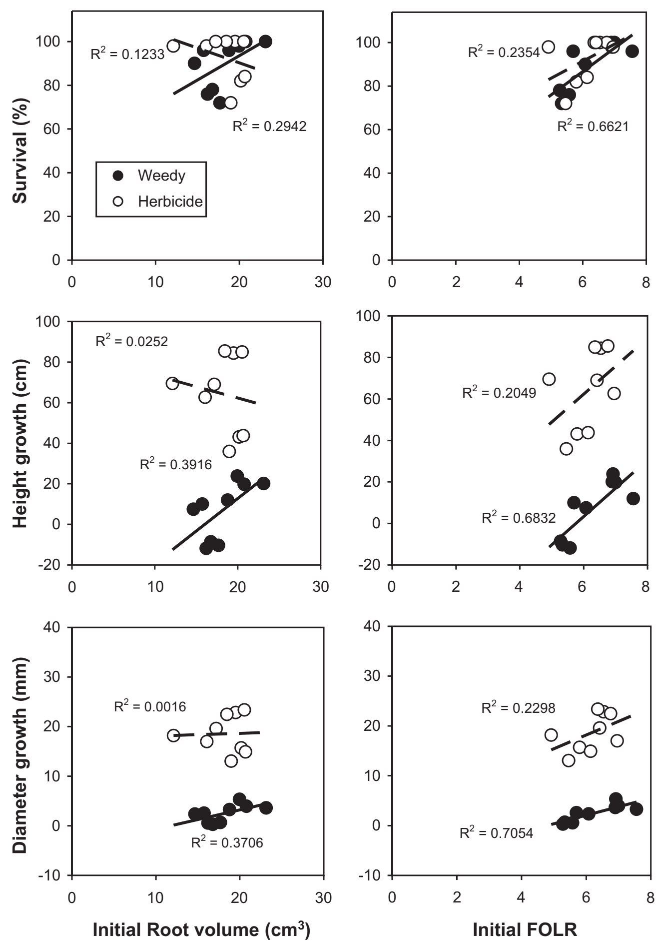

Figure 9—Regression relationships between initial root volume or FOLR of green ash seedlings and field performance.

productive hardwood plantations. Because weed control clearly promotes seedling establishment success and plantation development, we recommend provision of funds for weed control in these programs to reap benefits associated with herbicide use.

Transplant stress of 1+0 bareroot seedlings was very evident on these sites. This again suggests that further research is needed to identify nursery cultural treatments to produce seedlings that undergo minimal transplanting stress during the first growing season following planting. Generally, larger seedlings exhibited more transplant shock at least initially. We expect that growth will improve for seedlings in all treatments during the second growing season as seedling root systems become established and able to fully exploit site resources.

Future Directions

Although only a portion of the data from the study installed in 2003 was presented here, we are collecting similar data for 3 additional species across another 2 sites (totaling about 13,500 seedlings). This should provide an excellent initial data set to examine the relationship between nursery source, weed control, and seedling morphology in dictating afforestation success in the LMRAV. We installed a similar study in 2004 (about 8,000 seedlings) with several additional species to continue to broaden our scope of inference.

In the near future, we expect to solicit new cooperators and funding sources to develop a larger scale proposal to study hardwood seedling morphological quality across a larger range of sites and with a greater number of species. This proposal will promote a standardized methodology and identification of essential morphological variables for measurement. The expectation is that our data should ultimately help to establish seedling quality standards for Federal and State cost-share programs. Using this information, we expect to work with cooperators to refine nursery cultural treatments and outplanting techniques that maximize seedling performance on afforestation sites in the LMRAV.

Acknowledgments

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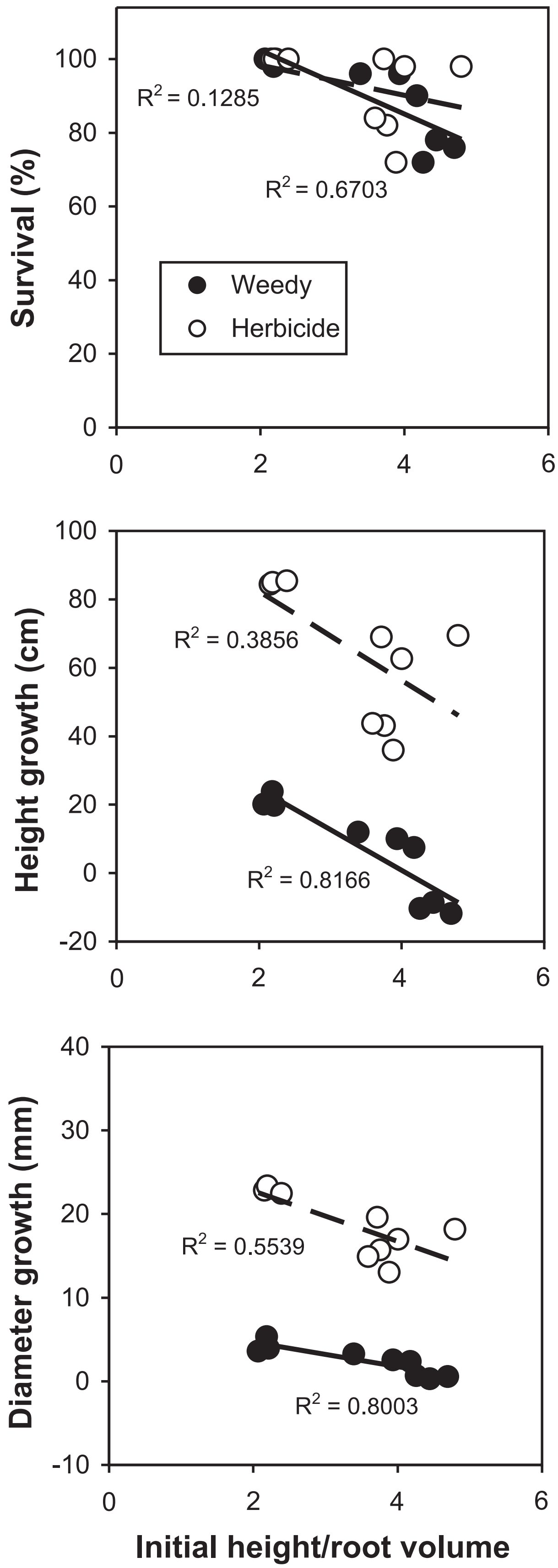

Figure 10—Regression relationship between the ratio of initial height-to-root volume of green ash seedlings and field performance.

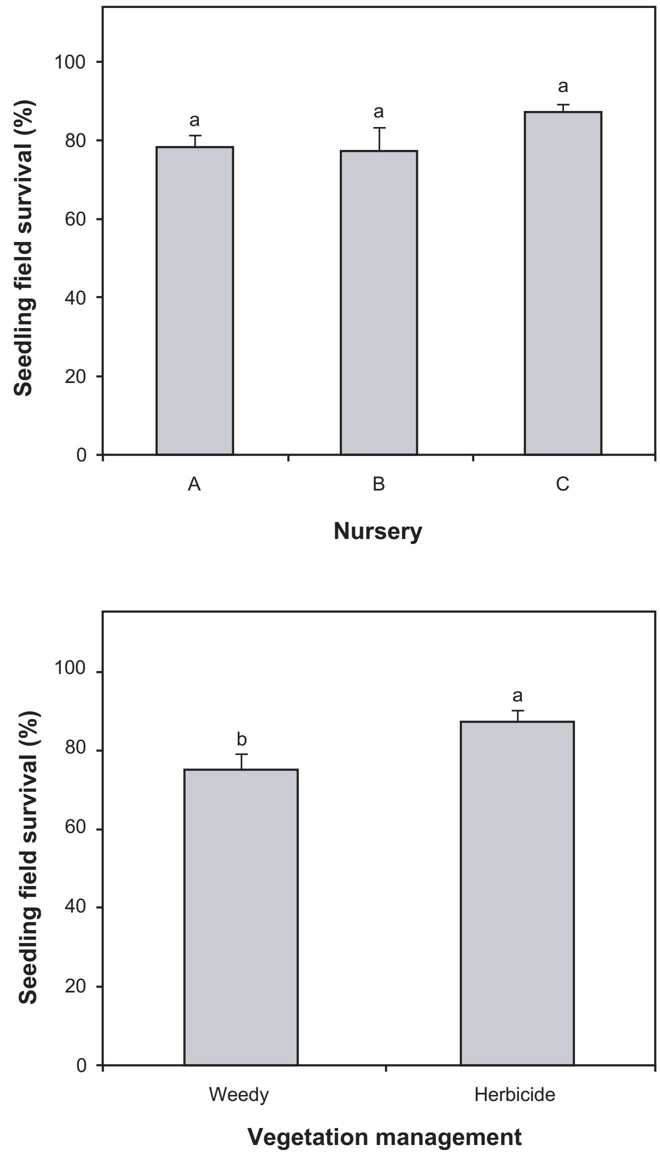

Figure 11—Water oak seedling survival by nursery and weed control treatment. For either the nursery or weed control effects, treatments with different letters above the bars are significantly different at = 0.05.

Service (NRCS). The USDA Forest Service Bottomland Hardwoods Laboratory in Stoneville, MS, provided significant funding, personnel, and site resources to help conduct this study. This research was further funded by the USDA Forest Service State and Private Forestry and the Hardwood Tree Improvement and Regeneration Center (HTIRC) at Purdue University.

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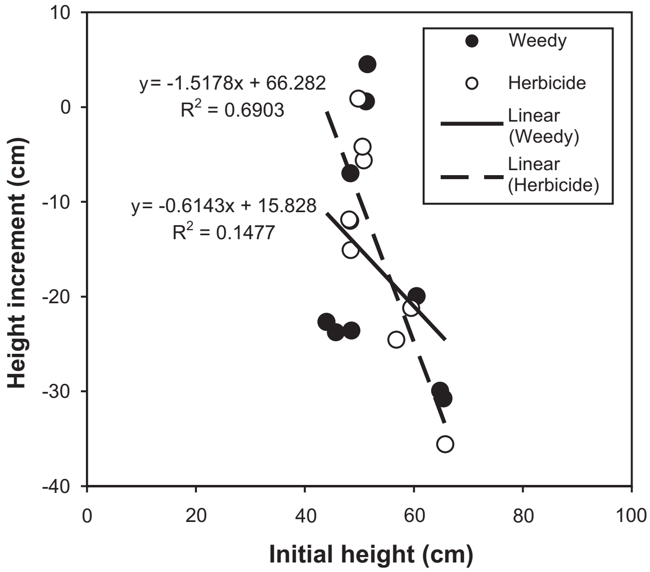

Figure 12—Regression showing initial height and field height growth for water oak. The extreme negative linear slope and tendency for negative height increment was a function of top dieback and browse pressure.

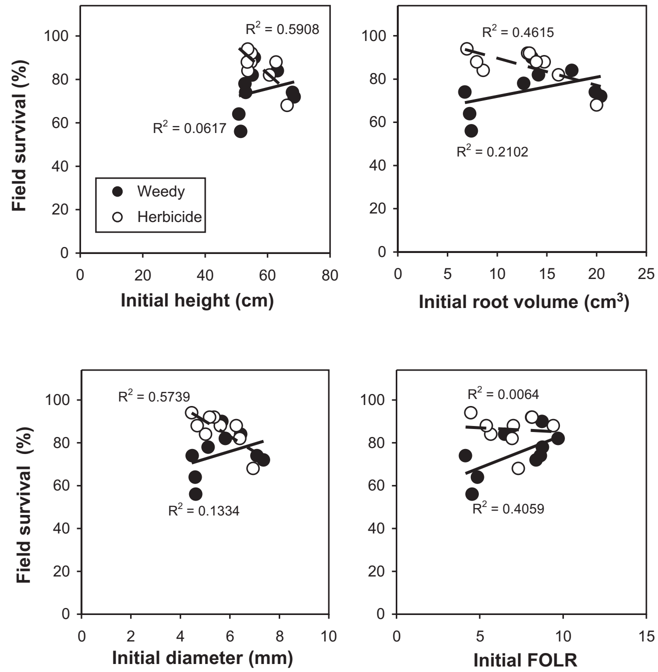

Figure 13—Regression relationships between initial morphological variables of water oak seedlings and field survival.

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Hardwood Seedling Nutrition

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Abstract: Hardwood seedling production presents several challenges that differ considerably from pine seedling production. Because of a nearly double water requirement, hardwoods need to be planted where they can be irrigated separately from pines. Nutrient requirements are generally higher for hardwoods, including especially nitrogen (N), phosphorus (P), calcium (Ca), and magnesium (Mg). Other nutrients are required in a slightly higher level. The form of N is very important. Sources of N that are "reduced," including ammonium and urea, are used efficiently. "Oxidized" forms, including mostly nitrate, are used less well. Requirements are usually described as how many pounds per acre of fertilizers are required. However, because the seedbed density for hardwoods is lower than that for pines, the cost of production per seedling is especially high.

Keywords: fertilization, irrigation, bareroot seedling production, mycorrhizae, sulfur

Introduction

Many years ago, at the University of Illinois, a professor named Cyril Hopkins taught nutrition of agronomic crops. Some of his students had difficulty remembering which elements were essential for plant growth. Professor Hopkins developed an easy way to remember the list. It was useful then, and despite the fact that the list is longer today than it was then, the idea is still useful. Cyril Hopkins said that he was going to open a fancy cafe. It will be known as C Hopkns, Cafe Mighty good (C HOPKNS CaFe Mg). The students could remember that, and they automatically learned that plants needed: carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), iron (Fe), and magnesium (Mg). His name also includes iodine (I), but plants don't need it. Animals, including humans, need iodine.

Since Professor Hopkins came up with this idea, the list of essential nutrient elements has grown considerably longer. However, the idea has stuck and today the entire reminder goes like this:

> C Hopkns, Cafe, Mighty good, managed by cousin Mo, and Clara is the waitress (C HOPKNS CaFe Mg Mn B CuZn Mo). This shows us that carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl) are needed for tree seedling growth. So, the next time you are either hungry or thinking about seedling nutrition, just hurry over to C Hopkns Cafe Mighty good.

Now that we are sure that we have the complete list, we can become serious and discuss the individual nutrient elements and say somewhat more about a few of them.

Nutrient Elements From Air and Water

The main building block element in all living things is carbon. In plants, it comes from carbon dioxide in the atmosphere by way of photosynthesis. Because there is never a shortage of carbon dioxide in the field, we never worry about a carbon deficiency.

Hydrogen is the most numerous atom in all living things. Plants get their hydrogen from breaking down water into hydrogen and oxygen. They use a little of this oxygen, but most of it goes back into the atmosphere where we breathe it. Interestingly, plants also use oxygen from the atmosphere in respiration.

For many millions of years, plants got their nitrogen from the atmosphere. After all, the atmosphere is almost 80% nitrogen. Interestingly, plants, by themselves, cannot use any of that N. There are certain microbes that can convert the atmospheric N into protein N and eventually into N that is usable by plants. Since the development of the Haber process, in 1909, to convert atmospheric N into ammoniacal N, we have become mostly dependent on fertilizer N for seedling production. Thus we could say that our seedlings get their N from the soil as fertilizer N. However, in reality, it still comes from the air.

Nitrogen Fertilization

A useful comparison between pines and hardwoods is in the amount of fertilizer N required. The minimum amount of N needed by a pine crop is 150 lb/ac (168 kg/ha) while hardwoods require a minimum of 225 lb/ac (252 kg/ha). Many people apply more than these amounts, but the ratio stays about the same. That is, hardwoods take about 1.5 times as much N per acre as pines. On a per seedling basis, the ratio is closer to 3 times as much. That is because of a lower seedbed density for most hardwoods.

The N in commercial fertilizer is available in several forms. If the N is associated with oxygen, as in nitrate (NO_3), it is called oxidized N. If the N is associated with hydrogen, as in ammonium (NH_4), it is called reduced N. The N in urea is also reduced because it is associated with H. Most plants can use either reduced or oxidized N, but their efficiency of use varies tremendously.

The relative use of different forms of N by hardwoods has been studied in considerable detail (Deines 1973; South 1975; Villarrubia 1980; Auchmoody 1982). In the study by Villarrubia (1980), 7 sources of nitrogen were tested on sweetgum (*Liquidambar styraciflua* L.) and green ash (*Fraxinus pennsylvanica* Marsh.) at 3 different rates of application. Very little effect of rate was observed, but source was very important. Growth was most favorably affected by reduced sources of nitrogen. These included 2 slow-release sources of sulfur-coated urea, ammonium sulfate, ammonium nitrate, and urea. The poorest growth was associated with sodium nitrate. A polymer of urea (IBDU) was also poorly utilized. This resulted from the fact that the urea was converted to nitrate just as fast as it was released from the polymer. Thus, in effect, it was an oxidized source of N rather than a reduced source. The only study where nitrate was found to be advantageous was in the study of Auchmoody (1982). In that one case, germination of cherry seeds was favorably affected by nitrate.

Slow-release, sulfur-coated urea was compared with regular urea and ammonium nitrate by Deines (1973). Both forms of urea were superior to ammonium nitrate in producing large seedlings. The sulfur-coated urea was applied once, preplant; the regular urea and ammonium nitrate were applied in 5 split applications over the summer. The savings in cost of application of the sulfur-coated urea were offset by its higher cost. Split applications allow the nursery manager to adjust the nitrogen regime as affected by weather. This flexibility is quite advantageous.

Foliar N Concentration

Villarrubia (1980) found that foliar N concentration, in September, varied both by species and by source. In green ash, foliar N varied from 2.4% to 2.9% with ammonium nitrate, ammonium sulfate, and urea. With both sulfur-coated ureas, it was somewhat below 2%. This difference is probably attributable to the fact that ammonium nitrate, ammonium sulfate, and urea were applied in 5 split applications, whereas the sulfur-coated urea was all applied at once, preplant. Seedlings that received split applications of sodium nitrate had foliar N concentrations from 2.2% to 2.3%. That is mostly attributable to the fact that the plants were quite small. Finally, those seedlings that received a single preplant application of IBDU were both small and had a low N concentration in their foliage (1.3% to 1.7%).

The foliar N pattern in sweetgum was quite similar to that in green ash. The ammonium nitrate, ammonium sulfate, and urea all were high and ranged from 2.7% to 3.1%. The sulfur-coated ureas were again somewhat lower at 2.1% to 2.7%. The small seedlings that received sodium nitrate had foliar N concentrations of 2.5% to 2.6%. This again shows that, because the leaves were small, a little N produces a high percentage. Finally, the IBDU again produced small seedlings and their foliage contained a low concentration of N (1.3% to 1.6%).

Soil Nitrate

There are bacteria in soil that are called nitrifiers. They will slowly convert reduced N to nitrate. Villarrubia (1980) found the soil nitrate level in September varied considerably. The highest levels were associated with the 2 sources that contained nitrate. Sodium nitrate soil contained more than 50 lb/ac (56 kg/ha) of nitrate-N. Ammonium nitrate soil contained about 45 lb/ac (50 kg/ha). Urea soil was third at about 30 lb N/ac (34 kg N/ha) as nitrate. All other sources of N were below 15 lb N/ac (17 kg N/ha) as nitrate. Thus, nitrification was only mildly active in the nursery soil.

Root Collar Diameter, Seedling Height, and Seedbed Density

An important characteristic of seedling quality is root collar diameter (RCD). At lifting time, green ash showed conclusively that the nursery soil did need sulfur, as well as N. The 3 sources of N that produced seedlings with the largest RCD were ammonium sulfate and the 2 sulfur-coated ureas (Villarrubia 1980).

Despite the fact that the sweetgum seedlings were small, IBDU had the lowest seedbed density at 12.3 seedlings/ft^2 (137 seedlings/m^2). The sweetgum had the highest seedbed density (20.4 seedlings/ft^2 [227 seedlings/m^2]) with ammonium sulfate. The lowest seedbed density with sweetgum was 15.0 seedlings/ft^2 (167 seedlings/m^2) with the very slowly soluble SCU-11. High levels of fertilization did not increase height or quality of seedlings, but they did often result in lower seedbed densities. Height did vary considerably as a response to N source (Table 1).

Nutrients From Soil

Calcium

Evidence shows that hardwoods require more calcium than pines. In general, however, most nursery soils have been supplied with ample Ca. Deines (1973) tested both calcium carbonate (lime) and calcium sulfate (gypsum). A low rate of the sulfate form produced a growth response in sweetgum. He believed it was a sulfur response rather than a calcium response because there was no positive response to the carbonate form. At high levels, there was a negative response to the carbonate form, which was attributed to the adverse effect on soil pH value.

Table 1—Height of sweetgum and green ash seedlings, at lifting, as affected by nitrogen source (from Villarrubia 1980).

N-source[a]	Seedling height at lifting[b]	
	Sweetgum	Green Ash
	- - height rounded to nearest inch[c] - -	
SCU-24	26	29
SCU-11	26	28
Urea	25	29
Ammonium sulfate	24	30
Ammonium nitrate	24	29
IBDU	18	27
Sodium nitrate	15	22
Average	**23**	**28**

[a]N source abbreviations: SCU-24 is sulfur-coated urea that releases N at a moderate rate; SCU-11 is sulfur-coated urea that releases N at a very slow rate; IBDU is isobutylidene diurea, which is a slow-release polymer of urea.
[b]Seedling height was not significantly affected by rate of N application. Thus the heights in this table are the averages of all rates.
[c]Conversion: 1 in = 2.5 cm.

Potassium

Studies in 2 nurseries with contrasting soil (Deines 1973) showed that potassium was needed, but its source was not important. Where K was needed, either the chloride or the sulfate source was satisfactory. The sulfate source gave some better growth than the chloride source, but again it was apparently a sulfur response.

Magnesium

Increasing applications of ammonium nitrate reduced Mg uptake by sweetgum at 2 nurseries (Deines 1973). Also, high levels of ammonium nitrate reduced the foliar content of K and Ca.

Mycorrhizae

In a study of endomycorrhizal inoculation of fumigated nursery soil, South (1975) reported an improvement of mycorrhiza formation from inoculation. However, there was a reduction of mycorrhiza formation when a high level of phosphorus was applied to sweetgum and sycamore. Trees that are endomycorrhizal are likely to suffer a lack of mycorrhiza formation because of over-fumigation of the soil. This is because the inoculum spores are soil-borne and thus are slow to reinfect soil. Spores of the fungi of ectomycorrhizal tree species (pines and oaks, for example) are air-borne and can reinfect the soil much more quickly. In a study by Danielson (1966), inoculum for pines was introduced from a pine straw mulch and from the air. Mycorrhiza formation was delayed by only a few weeks with loblolly pine. From personal observation, it can be reported that endomycorrhizal fungus reintroduction, without intentional inoculation, requires more than a year. Using pine straw mulch on the beds of hardwood seedlings greatly increased the amount of hand weeding needed, but it did not increase the endomycorrhizal fungus inoculation (South 1975).

Outplanting Study

In an outplanting study with green ash, tall seedlings from the nursery grew well in the field. The small seedlings that received IBDU or sodium nitrate grew the poorest in the field in the first year (Villarrubia 1980). With hardwood seedlings, it seems that bigger is better.

Conclusions

- The low (normal) rate of N tested was as effective as the highest (3X normal) rate. Thus, the nursery manager can save money by not applying excess fertilizer.
- The N sources tested fell into 2 groups. The sodium nitrate and the IBDU were each poor N sources. Despite some small differences, all other sources were useful.
- Ammonium sulfate and SCU-24 produced rapid early growth of the seedlings. They captured the bed quickly and reduced weeding costs.
- Soil acidity changes were complex. As expected, acidification with ammonium sulfate was greatest. Acidification was correlated with rate. The IBDU and S-coated ureas, which were plowed down, produced early and strong acidification. However, this decreased with time. The sodium nitrate changed the soil from being slightly acidic to alkaline.
- Foliar N concentration was highest with the sources that were used in split applications. The IBDU was lowest. It was applied preplant and was used poorly. Foliar N concentration increased with rate, regardless of source or species. Some of this was undoubtedly luxury consumption.
- Nitrogen sources that contained sulfur were superior to those that didn't. Thus, in most soil, sulfur was needed. The sulfur containing sources produced an early start in growth and a rapid bed capture.
- In sweetgum and green ash, Villarrubia (1980) reported the following in regard to the effect of the various N sources on the concentration of foliar nutrients:

1. N: Sodium nitrate and IBDU were not satisfactory N sources. All other sources tested were satisfactory.
2. P: Sodium nitrate resulted in poor P uptake. All others were satisfactory.
3. K: Sodium nitrate resulted in high foliar K concentration. Other N sources varied slightly in their effect on K uptake. In general, as the N application rate increased, foliar K concentration decreased.
4. Ca: Sodium nitrate resulted in the lowest foliar Ca concentration. IBDU resulted in the highest.
5. Mg: Sodium nitrate resulted in the lowest foliar Mg concentration. The other N sources were satisfactory.
6. Sulfate S: Ammonium sulfate, as expected, resulted in the highest foliar sulfate concentration.

References

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