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Longleaf pine seed source impacts on seedling performance in southern Georgia

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INTRODUCTION

Longleaf pine *(Pinus palustris)* restoration throughout the southeastern United States is promoted by multiple federal (e.g. United States Department of Agriculture Natural Resources Conservation Service and Farm Service Agency Conservation Reserve Program) and state (e.g. Georgia Forestry Commission Southern Pine Beetle Cost Share Program) cost-share programs in Georgia. Cost-share programs can provide funds for landowners to perform site preparation, purchase and plant seedlings, apply herbaceous weed control, and implement prescribed burns in their longleaf pine stands while enrolled in these programs. Even if landowners or managers have the capacity to conduct many of these management activities themselves, they are still left with nursery and seedling selection decisions when purchasing longleaf pine seedlings. When choosing a nursery to purchase longleaf pine seedlings from, a landowner should consider seedling cost, stock type, seedling availability in a given year and seedling quality but also seed source when planting sites within longleaf pine's native range in Georgia (Figure 1). Longleaf pine does not have the same levels of genetic improvement (e.g. faster growth and less disease occurrence than unimproved seedlings or seed sources) for landowners to select from as other pine species such as loblolly *(Pinus taeda)* and slash pine *(Pinus elliottii)*. Thus, longleaf pine seed source is one important metric that landowners can use to discern if specific longleaf pine seedlings will perform well on their property. The objective of this paper was to report on five to eight-year survival and growth performance of 12 longleaf pine seedling sources planted on five sites with a variety of site and management histories throughout southern Georgia.

Figure 1: ***Healthy, containerized longleaf pine seedlings ready for planting.*** Photo: David Clabo

LONGLEAF PINE AND GEOGRAPHIC VARIATION

Longleaf pine has an extensive native range from eastern Texas to southeastern Virginia. It is found in the Atlantic and Gulf Coastal Plains as well as the Piedmont, Ridge and Valley and Mountain physiographic regions of Alabama and northwestern Georgia (Boyer 1990). Tree species with large native ranges such as longleaf pine can have significant genetic differences among populations. This phenomenon is termed geographic variation (White et al. 2007), and primary drivers of geographic variation include: annual precipitation, minimum winter temperatures, and latitudinal (sunlight and growing season length) differences across a species' native range. Geographic variation can affect important traits that impact longleaf pine seedling performance such as adaptability to climate in a given region, survival and growth rates, disease susceptibility, duration of the grass stage, and stem form characteristics (Henry and Wells 1967). As examples, past research has shown that survival and growth differences can occur as seed is moved from areas where average minimum winter temperatures differ by 6 °F or more (Schmidtling and Sluder 1995), and brown spot needle blight *(Scirrhia acicola)*, a serious disease in grass stage longleaf pine seedlings has been reported as being more prevalent in populations located west of the Mississippi River (Henry and Wells 1967).

Planting guidelines for southern pines that consider planting and seed source locations within a species' native range as well as temperature and precipitation gradients across individual species' ranges have been developed by U.S. Forest Service researchers to assist landowners and managers with seed source planting decisions (Schmidtling 2001). Longleaf pine has its own set of geographic variation guidelines that can assist with seed source seedling planting decisions (from Schmidtling 2001; Figure 2):

1. Seed will survive and grow well if they come from a region with a minimum average temperature within 5 °F of the planting site's minimum average temperature. For climate information visit https://www.weather.gov/wrh/climate.
2. Seedlings from a region with warmer winters will grow faster than seedlings from local sources, and seedlings from an area with cooler winters will grow slower.
3. Differences in winter lows can be as much as 10 °F, but with an increased risk of damage at the cold end of the range and growth losses at the warmer end of the range.
4. East-west seed source transfers within districts are usually successful, and in some instances may be desirable if improved stock is available. West-to-east seedling transfers are usually successful because of increasing precipitation moving from west to east across longleaf pine's native range.

Previous longleaf pine seed source studies (e.g. Lantz and Kraus 1987; Wells and Wakeley 1970) have investigated these well-accepted planting guidelines across large portions of the species' native range. This study investigated longleaf pine seed source survival, growth, and stem quality across a variety of sites with various management histories using the most widely available seed sources at the time of study establishment from 2010 through 2012.

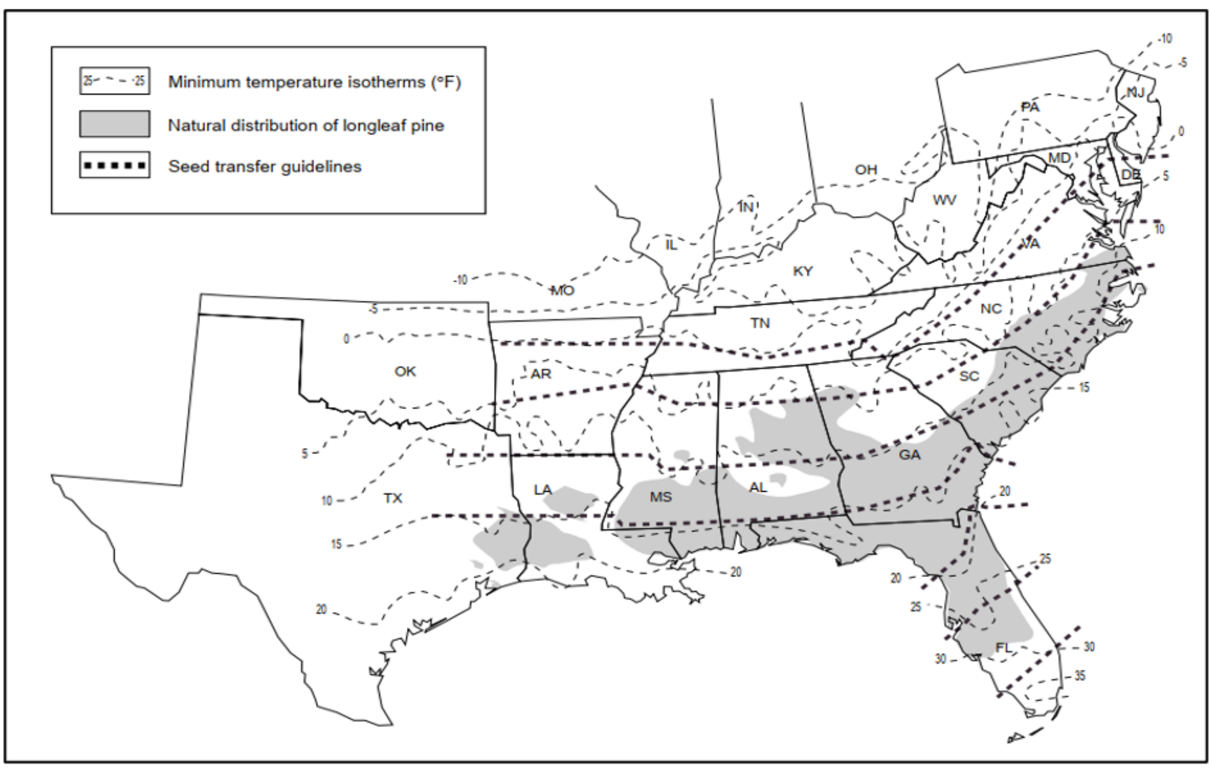

Figure 2: *Map showing the natural range of longleaf pine and associated longleaf pine seed transfer boundaries. Seed source zone and selection rules are important when choosing a longleaf pine seed source. Source (Schmidtling 2001).*

METHODS

Five study sites located on former old-field and cutover sites were selected for installation of longleaf pine seed source trials. Study areas were located in south central and southeastern Georgia in the Lower and Upper Coastal Plain regions (Figure 3). The 12 seed sources available from International Forest Company (IFCO) from 2010 through 2012 are listed in Table 1. All seed sources came from a specific location (seed orchard) or county except for the Georgia/Florida improved source. This source consisted of seed collected from a seed orchard that was grafted with first-generation selections. Improved denotes that seed collection was not from wild stands/seed production areas. Seed orchard trees were clones that were collected from superior phenotypes in natural stands from southern Georgia and northern Florida. Degree of improvement was expected to be minimal since seeds were collected from better phenotypes and placed in a bulk mix. Progeny testing by IFCO has not been completed for this source.

Starting from west to east, two of the study sites were located in Tift County, Georgia. The Prostko (seven-acre) and Brumby (11-acre) sites were located on privately owned, former old-field sites on moderately well drained to somewhat poorly drained uplands. Information on site history, soils, site preparation, seed sources planted, plantation spacing, release operations, and follow-up measurements can be found in Table 2. The third study area was located at the University of Georgia Vidalia Onion and Vegetable Research Center (VOVRC) in Toombs County, Georgia. This site was an 11-acre former pine progeny test site and Bermuda grass field on a moderately well-drained upland. Details on site history and management are presented in Table 2. The fourth study area was located on privately owned land (Dekle site) in Bulloch County, Georgia. This cutover site was four acres and consisted of poorly to moderately well-drained soils (Table 2). The fifth and most eastern site was located on private property (Toohollie site) in Screven County, Georgia. This cutover, nine-acre site was located on a well-drained upland (Table 2).

All seed sources were planted as 1-0 stock containerized seedlings grown at IFCO's nursery near Moultrie, Georgia. Site assessments were made between ages five and eight depending on location (Table 2). Because of differences in site ages, annual increments will be presented for diameter at breast height (dbh), total height, and per tree volume index (vi=dbh^2 (inches) * total height (feet)). Also, an estimate of average volume index per acre per year is presented (Volume Index/Acre = (Trees Per Acre at Stand Establishment * Current Average Survival Rate by Seed Source *Average Per Tree Volume Index by Seed Source) / Stand Age). Survival rates were also assessed. In addition, presence of a defect and defect types were recorded including: forks, ramicorn branches, cankers, branch whorls (five or more branches originating from the same height on the trunk), broken top, sweep (greater than three-inch shift from vertical in a 16 feet trunk segment), and lean (greater than 5° from vertical).

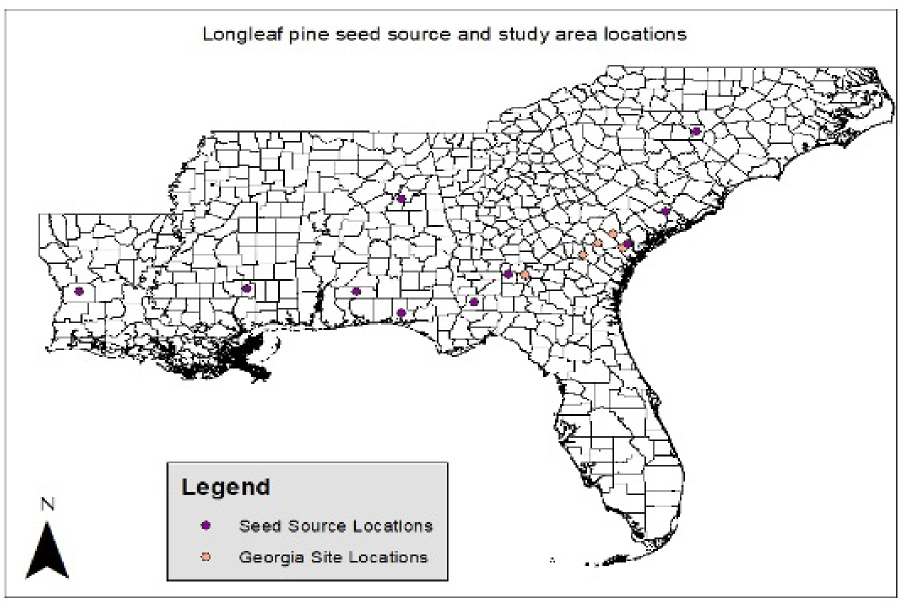

Figure 3: *Location of 12 seed source locations from throughout longleaf pine's native range and five seed source trial locations in south central and southeastern Georgia.*

Table 1: International Forest Company (IFCO) seed sources available during 2010-2012 and their availability as of November 2020.

Seed Source	IFCO 2020 Availability
Decatur County, GA	Discontinued
Dorchester County, SC	Discontinued
Dougherty County, G	Discontinued
Escambia County, AL	Available
Georgia/Florida Improved	Available
Lamar County, MS	Discontinued
Richmond County, NC	Available
Talladega County, AL	Available
Rincon, GA (Union Camp)	Discontinued
Vernon Parish, LA	Available
Walton County, FL	Discontinued
Worth County, GA	Discontinued

Table 2: Site characteristics and management history for the five sites across south central and southeastern Georgia included in the longleaf pine seed source study. All study areas were hand planted using hoedads or dibble bars.

Site	Acres	Soil Series	CRIFF* Classification	Site History	Site Preparation			Seed Sources Planted	Date Planted	Planting Spacing (ft)	Herbaceous Weed and Woody Plant Control	Prescribed Fire History	Measurement Dates(s)
					Burn	Mechanical	Chemical						
Prostko Tift Co.	7	Leefield and minor Alapaha inclusions	B	Old-Field	No	Disk	Glyphosate (3.5 qts/ac) during Oct. 2012	Decatur; Dorchester; Escambia; GA/FL Improved; Lamar; Richmond; Union (Rincon, GA); Vernon; Walton; Worth	Dec. 2012	7 x 10	Yes (5 first and second- year applications)	None	March 2018 (stand age 5)
Brumby Tift Co.	11	Clarendon and Ocilla	E and B	Oldfield and former Christmas tree farm	Yes (fall 2012)	No	No	GA/FL Improved; Lamar; Talladega; Vernon; Walton	Dec. 2012	7 x 10	No	Two burns	March 2018 (stand age 5)
VOVRC Toombs Co.	11	Tifton and Irwinton	E	Old-field	Yes (Nov. 2012)	Yes-2 pass rip to 18-inch depth during summer 2012	YesPolaris AC (imazapyr) @24 oz/ac + 4 qt/ac Razor Pro (glyphosate) during Sep. 2012	Dorchester; Dougherty; Escambia; GA/FL Improved; Lamar; Richmond; Union Camp (Rincon, GA); Vernon; Walton; Worth	Dec. 2012	6 x 9 and 6 x 10	Yes-Envoy Plus (clethodim) in plots with Bermudagrass during second growing season	None	March 2019 (stand age 6)
Dekle Bulloch Co.	4	Pelham and Stilson	B and F	Cutover	No	No	YesPolaris SP (imazapyr) + glyphosate Oct. 2011	Decatur; Dorchester; Escambia; GA/FL Improved; Lamar; Richmond; Talladega; Vernon; Walton; Worth	Jan. 2012	7 x 10	No	None	March 2018 (stand age 6)
Toohollie Screven Co.	9	Blanton	F	Cutover	Yes (fall 2011)	Yes-root rake and windrow summer 2011	No	Decatur; Dorchester; Escambia; GA/FL Improved; Lamar; Richmond; Talladega; Vernon; Walton; Worth	Jan. 2012	9 x 10.5	Yes- basal bark application of hardwoods in Feb 2012; foliar glyphosate spot sprays on hardwoods Oct. 2012, and understory and midstory hardwood control with hack and squirt application summer 2019	Yes-burns at stand ages 4 and 6	Feb. 2020 (stand age 8)

*CRIFF-Cooperative Research in Forest Fertilization-University of Florida soil classification system based on soil texture, drainage class, soil texture depths, and presence/depth of an argillic and/or spodic horizon for the Coastal Plain region of Florida and Georgia.

RESULTS

The 12 longleaf pine seed sources differed in survival rate, average annual DBH and height growth, and annual per tree volume increment. Site differences did not exist for survival rate, indicating that survival rates and success of stand establishment efforts were similar across the five study sites, but sites differed in annual DBH, height and per tree volume index growth indicating site productivity differences likely due to soils and varying land-use histories.

Seed source survival was greatest in the Escambia, Union Camp, and Lamar seed sources (88-91%) (Figure 4) and least in the Walton, Worth, and GA/FL Improved seed sources (61-67% survival) (Figure 5). Annual DBH increment was greatest with the Union Camp and GA/FL Improved seed sources (each 0.52 inches per year; Figure 6) and least in the Vernon and Lamar seed sources (each 0.45 inches per year) (Figure 7). Diameter growth tended to be greatest at old-field sites (Prostko) and the former slash pine progeny test stand and bermudagrass field (VOVRC) that received chemical site preparation and at least partial herbaceous weed control (Figure 8), and average annual DBH growth was least on cutover sites that did not receive chemical site preparation. Annual height increment was greatest with the Dougherty and GA/FL Improved seed sources (2.6 feet per year) and least with the Lamar, Union Camp and Vernon seed sources, which all averaged 2.3 feet per year (Figures 9 and 10). Site effects and trends were similar between annual DBH increment and annual height increment with the Prostko and VOVRC sites having the greatest average annual increments (Figure 11). Annual per tree volume increment by seed source was greatest in the GA/FL Improved (35.4 ± 2.4), Union Camp (32.4 ± 2.2) and Walton (31.3 ± 1.8) sources and least with the Lamar (20.6 ± 1.7) and Vernon (20.6 ± 1.4) seed sources (Figures 12 and 13). The VOVRC site (49.2 ± 2.1) had the greatest average per tree volume increment while the Brumby site (14.4 ± 0.9) had the smallest average per tree annual volume increment (Figure 14). The volume index per acre per year analysis revealed no statistical differences among seed sources. The Dougherty County, Georgia and Union Camp (Rincon, Georgia) seed sources had the greatest average volume index. Escambia County, Alabama and the GA/FL Improved seed sources also performed well, while the Talladega seed source had the smallest volume index per acre per year average increment (Figure 15).

The Talladega and Vernon seed sources had the greatest defect-free rates of the seed sources tested at these early stages of stand development (87.0 and 85.3%, respectively). The Dougherty seed source had the lowest defect-free rate (62.7%) and was followed closely by the Escambia (73%) and Worth (74%) seed sources. Ramicorn branches, or high-angled branches that are at least one-third of the trunk diameter, were the most commonly observed defect and were found in as many as 19.3% (Table 3) of all Dougherty County, Georgia seed source trees. Forks were the second most commonly observed defect and occurred in as many as 11.3% of Dougherty County, Georgia trees. Branch whorls were the least common defect observed across all seed sources (Table 3).

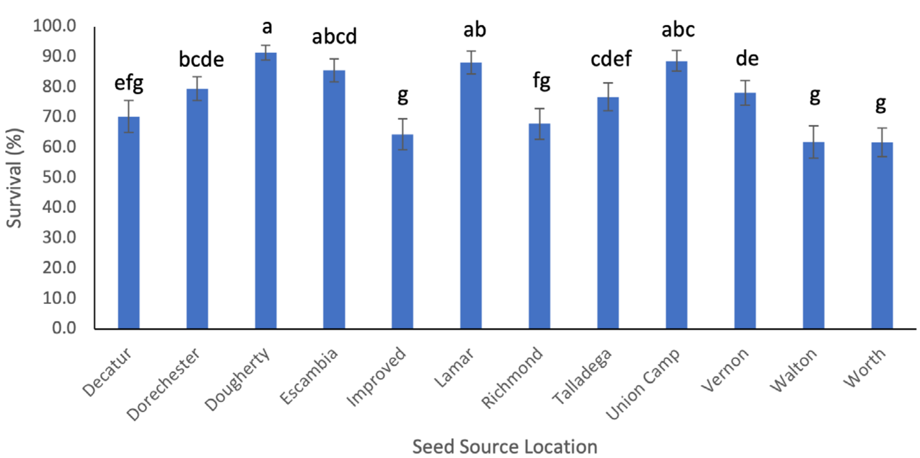

Figure 4: *Longleaf pine average survival rate by seed source across five sites in south central and southeastern Georgia. Bars within columns represent standard error. Seed sources that do not share a letter differ statistically (p = 0.05).*

Figure 5: *The Dougherty County, Georgia seed source had the highest survival rate (91%) of the 12 seed sources tested. This photo from July 2020 shows the Dougherty County, Georgia, seed source at the University of Georgia Vidalia Onion and Vegetable Research Center (VOVRC).*

Figure 6: *The Union Camp (Rincon, Georgia seed orchard) seed source tied with the Georgia/Florida Improved seed source for the greatest average annual diameter growth. This photo from July 2020 shows the Georgia/Florida Improved seed source at the Prostko site near Tifton, Georgia.*

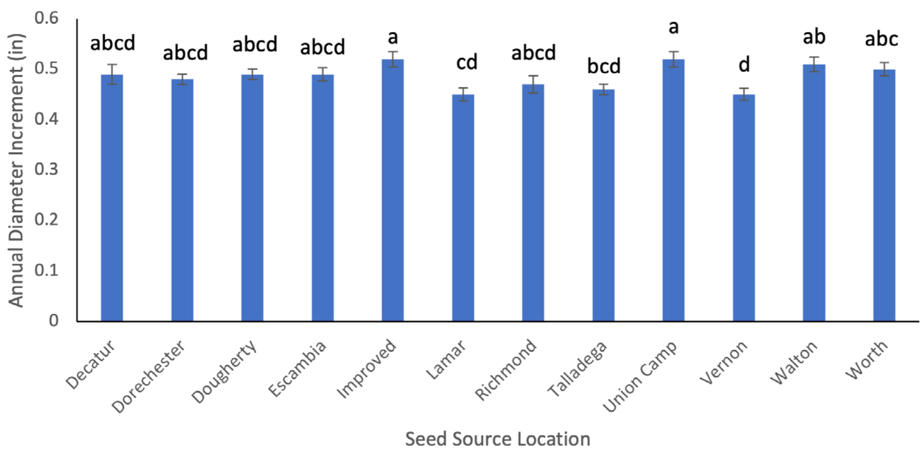

Figure 7: *Longleaf pine average annual diameter at breast height (DBH) growth by seed source across five sites in south central and southeastern Georgia. Bars within columns represent standard error. Seed sources that do not share a letter differ statistically (p = 0.05).*

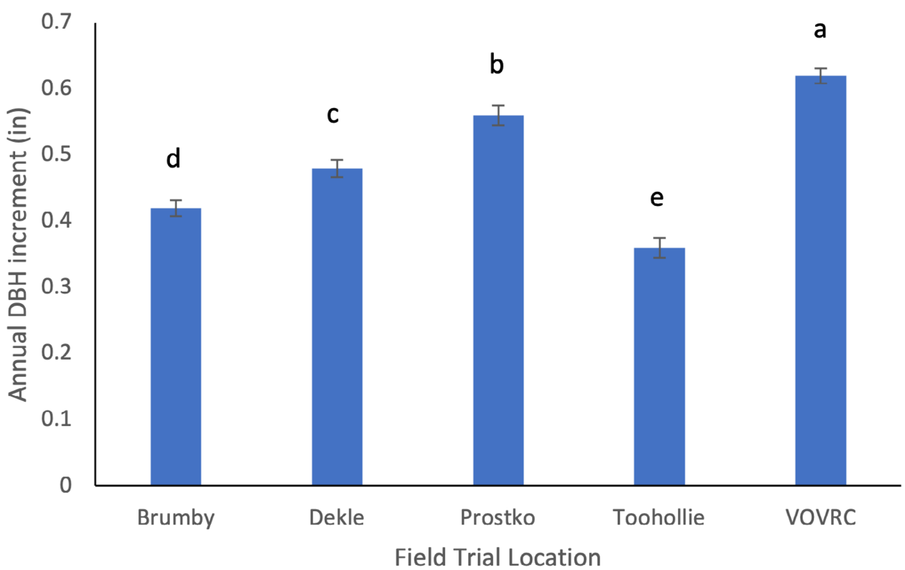

Figure 8: *Longleaf pine average annual diameter at breast height (DBH) growth by site in south central and southeastern Georgia. Bars within columns represent standard error. Sites that do not share a letter differ statistically (p = 0.05).*

Figure 9: *The Georgia/Florida Improved seed source tied with the Dougherty County, Georgia, seed source for the greatest average annual height growth increment. This photo from July 2020 shows the Georgia/Florida Improved seed source at the Brumby site near Tifton, Georgia.*

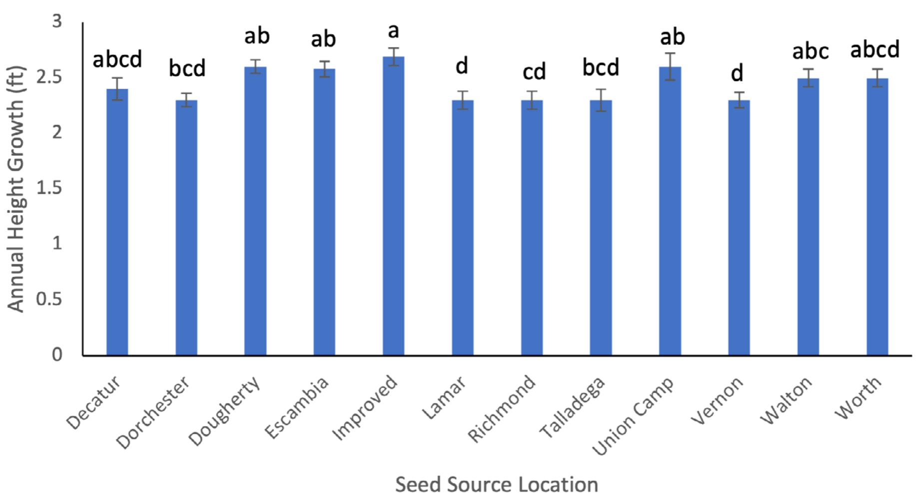

Figure 10: *Longleaf pine average annual height growth by seed source across five sites in south central and southeastern Georgia. Bars within columns represent standard error. Seed sources that do not share a letter differ statistically (p = 0.05).*

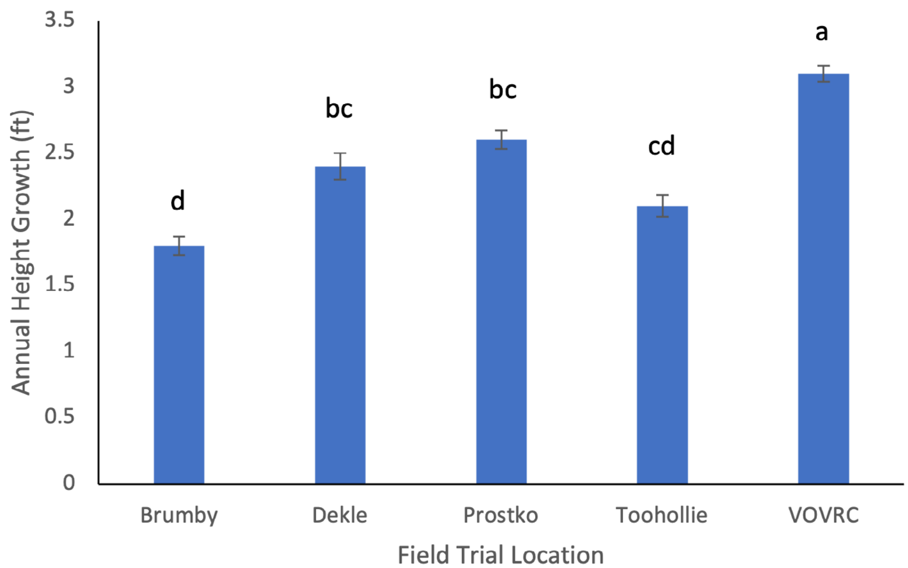

Figure 11: *Longleaf pine mean annual height increment by site in south central and southeastern Georgia. Bars within columns represent standard error. Sites that do not share a letter differ statistically (p = 0.05).*

Figure 12: *The Walton County, Florida, seed source had statistically similar average per tree volume index as the Georgia/Florida Improved and Union Camp (Rincon, Georgia seed orchard) sources. This photo is from July 2020 at the University of Georgia Vidalia Onion and Vegetable Research Center (VOVRC).*

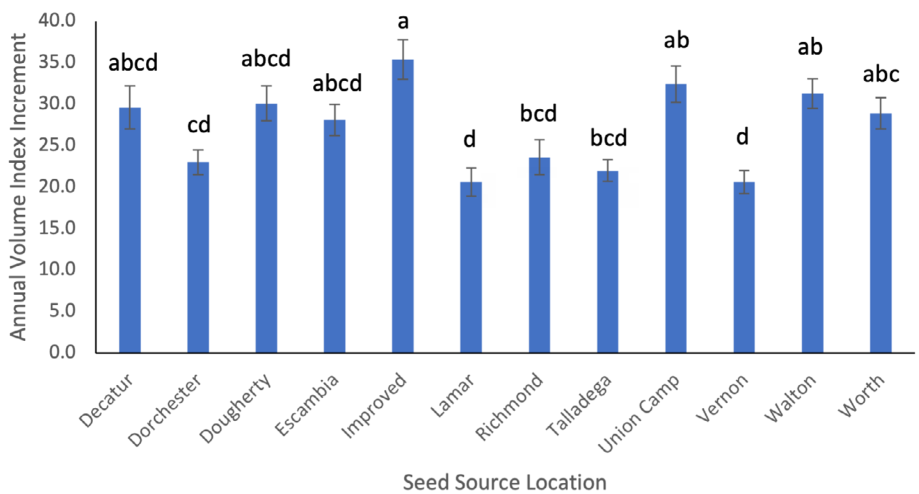

Figure 13: *Longleaf pine average per tree volume index by seed source across five sites in south central and southeastern Georgia. Bars within columns represent standard error. Seed sources that do not share a letter differ statistically (p = 0.05).*

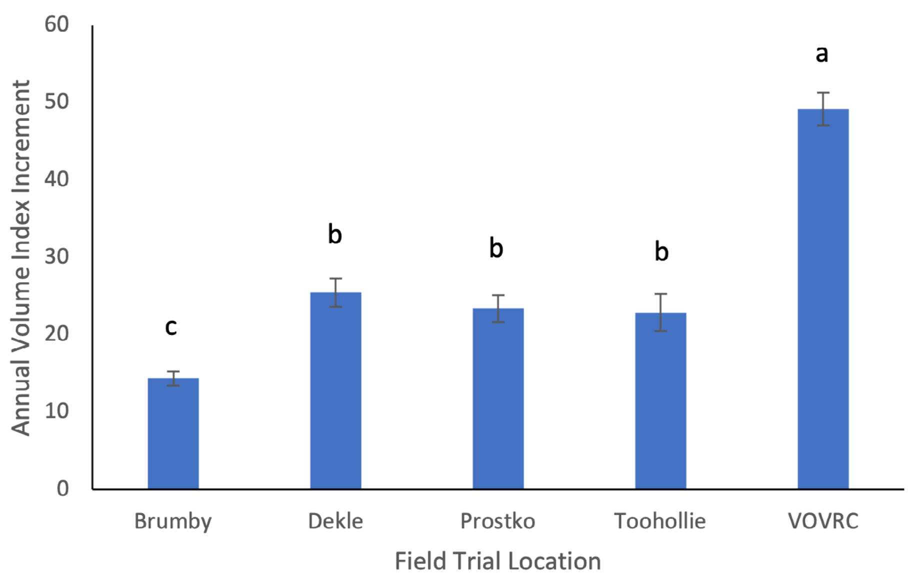

Figure 14: *Longleaf pine mean annual per tree volume index increment by site in south central and southeastern Georgia. Bars within columns represent standard error. Sites that do not share a letter differ statistically (p = 0.05).*

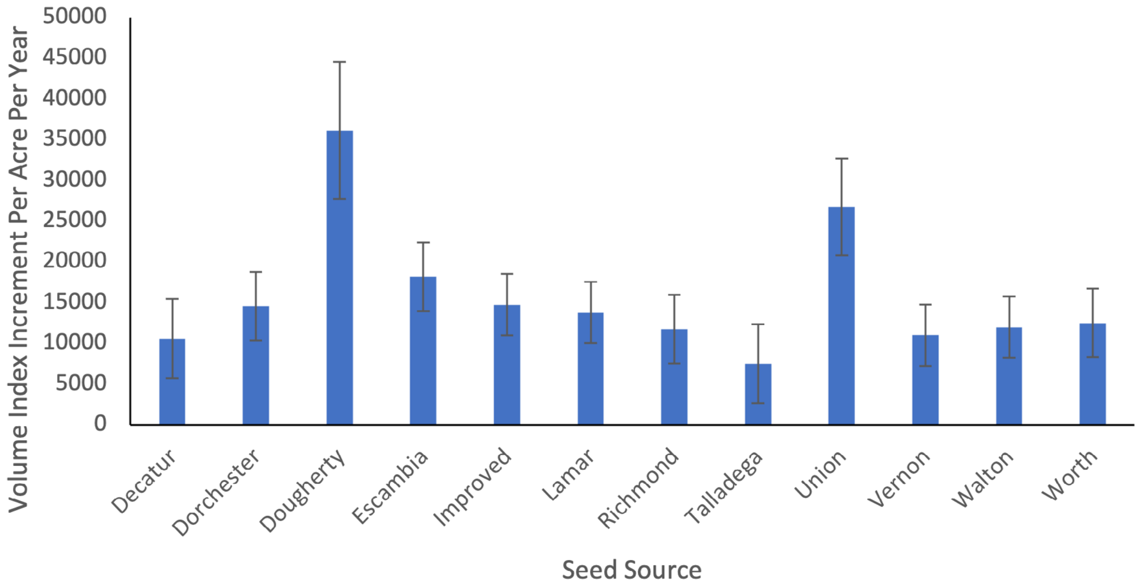

Figure 15: *Results of the average volume index increment per acre per year analysis across sites for the longleaf pine seed source study. Bars within columns represent standard error. No significant differences existed among seed sources (p = 0.19).*

Table 3: Stand age five- to eight-year defect rates by defect type and seed source across five longleaf pine seed source study sites in south central and southeastern Georgia. Values highlighted in bold indicate a significant relationship between defect type and seed source (p = 0.05).

	Broken Top	Canker	Fork	Lean (>5°)	Ramicorn Branch	Sweep	Branch Whorl (5 or more branches)	Defect Free
	% Defect Rate							
Decatur	0	1.0	7.5	**4.0**	10.1	1.5	0	75.9
Dorchester	0.3	2.5	5.5	0	13.4	0	0	78.3
Dougherty	0	4.7	**11.3**	0	**19.3**	2.0	0	62.7
Escambia	0.6	**5.0**	5.3	0.8	**14.5**	0.8	0	73.0
Improved	0.4	3.1	5.1	0.9	9.6	1.6	0	79.3
Lamar	0	1.8	3.2	0.7	10.1	1.6	**0.7**	81.9
Richmond	0.3	1.7	6.1	1.4	**6.6**	2	0	81.9
Talladega	0	0.8	3.4	0	8.8	0	0	87.0
Union	**0.9**	**4.3**	2.4	0	10.0	0.5	0	81.9
Vernon	0	0.7	4.8	0.4	7.4	1.4	0	85.3
Walton	0	1.4	4.3	**2.0**	12.1	0.7	0	79.5
Worth	0.2	2.4	**9.2**	1.4	10.2	1.9	**0.7**	74.0

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Similar to larger, former longleaf pine seed source studies and trials from throughout the species' native range (e.g. Lantz and Kraus 1987; Wells and Wakeley 1970), Central Gulf Coast (southern Alabama, Florida Panhandle, and southwestern Georgia) seed sources such as the GA/FL Improved, Escambia, and Walton sources had the greatest adaptability and performed best (survival and growth) in the regions of Georgia where test sites were established in this study. The Union Camp source, though not from the Central Gulf Coast region, also performed well in most categories. It should be noted that the Union Camp seed source was planted at only two of the five study sites (VOVRC and Prostko), while the Dougherty source was only planted at the VOVRC site. Both of these sites were old-field sites that received chemical site preparation and herbaceous weed control. Management history likely contributed to the greater average volume index increment per acre per year results observed at these sites in Figure 15. Average volume index increment per acre per year results for these two seed sources should be interpreted cautiously.

Longleaf pine seedlings from the Central Gulf Coast have been reported to perform well as far west as central Louisiana and eastward to central Georgia. In addition, seed sources from this region perform well up to 150 miles north of where they originated (Wells and Wakeley 1970). Seed sources from more western regions of longleaf pine's range (e.g. Lamar and Vernon) had moderate to good survival rates, but growth rates tended to lag behind Central Gulf Coast seed sources. Northern seed sources including Talladega, Richmond, and Dorchester had intermediate survival and growth rates compared to western and Central Gulf Coast seed sources located closer to the field trial sites.

Four of the five seed sources that had greater than 80% defect-free rates were from more northern or western seed sources. The Union Camp seed source had an 81.9% defect-free rate, and it was the only seed source from Georgia. This phenomenon could be partially explained by faster growth rates of seed sources from in or near the Central Gulf Coast region as faster growth rates have been associated with higher defect rates in other pine species such as loblolly pine (Xiong et al. 2010). If high value timber products (e.g. sawtimber and poles) are a management objective, slower growing seed sources that tend to have fewer defects may be an important consideration for landowners and managers.

Only five of the 12 seed sources tested in this study were available from IFCO as of November 2020. Of these five available seed sources, Escambia, AL, may be the best option if long-term timber objectives are important to a landowner or manager. Compared to the GA/FL Improved source, the Escambia seed source survival rate was 21.2 percentage points greater and annual height and dbh growth increment differences were negligible through stand ages five to eight years (0.1 feet per year and 0.03 inches per year, respectively). The stem defect-free rate was only 6.3 percentage points lower in the Escambia seed source compared to the GA/FL Improved source. The large difference in survival between these two seed sources may justify choosing the Escambia County, Alabama, seed source for planting in the Coastal Plain region of Georgia.

Shopping for longleaf pine seedlings, like other tree seedlings, should begin well over a year in advance of an expected planting date. This will ensure that the best seed sources are available or can be requested from a nursery (if this option is available). When choosing longleaf pine seedlings, select containerized stock if available and sites in the Coastal Plain of Georgia should be planted with longleaf pine seed sources from the Central Gulf Coast region if the nursery you shop with has seed source options for customers. Work with your nursery representative to select the best seed source possible for your new longleaf pine stand.

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