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# Five-year 1-0 versus 2-0 stock containerized longleaf pine performance on a cutover site - Middle Coastal Plain of Georgia

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## INTRODUCTION

Artificial regeneration through planting continues to be the most important method for restoration of longleaf pine (*Pinus palustris*) forest types throughout the Southeast (Potter et al. 2024). Either bareroot or containerized stock types are used for planting. When a bareroot or containerized seedling has a 1-0 stock type, this means that seed was planted in early spring (usually mid- to late March) and seedlings were lifted from nursery beds the fall or winter of the same year. Usually, 1-0 stock seedlings are grown no more than eight or nine months in the nursery. The second most commonly encountered bareroot or containerized stock type is 2-0 seedlings. Seed for these trees is sown at the same time as 1-0 trees, but the trees are allowed to grow in their original nursery bed for 20 to 22-months, so seedlings are lifted during the fall or early winter the year after they were sown. Two-year-old seedlings are not available every year from all longleaf pine nurseries. They are typically only available during years where not all seedlings were sold that were sown the year prior, or buyers were not able to pick up and plant trees during the growing season they were expecting to plant. One nursery in Georgia that exclusively sells containerized longleaf pine reported that their inventory of 2-0 stock longleaf seedlings can range from zero trees in a given year to more than one million with most years having 300,000 to 500,000 2-0 stock containerized longleaf seedlings available for purchase. Typically, 2-0 trees do not cost more than 1-0 trees (mainly because 2-0 seedling availability year to year is unknown), although it costs the nursery more to continue fertilization, herbicide, pest control and irrigation for another year.

Currently, longleaf pine seedlings are almost exclusively sold as containerized stock due to large performance improvements over bareroot stock. Survival improvements with containerized stock tend to increase as sites become harsher (South et al. 2005). As would be expected, trees that are grown for more than one year in a nursery bed typically have larger root systems and root collar diameters (rcd) on average than trees that are grown for one year before being lifted. This extra seedling size has been shown to result in greater early survival and quicker growth out of the grass stage (Lauer 1987; Dumroese and Owstin 2003; Dickens et al. 2018a). Previous work has shown that a larger rcd can be an important indicator of expedited stem height growth out of the grass stage and improve seedling tolerance to prescribed fire during the grass stage (Wahlenberg 1946; Knapp et al. 2018). Longleaf pine seedling morphology has been shown to be related to field performance. Lauer (1987) conducted a test on a cutover site in Florida with different longleaf pine seedling rcd sizes to determine

how this trait impacted survival, growth out of the grass stage, and height growth. After two growing seasons, results indicated that survival progressively increased as planted seedling rcd increased from 0.18 in (82%) to 0.8 in (92%), but survival began to decrease once rcd exceeded 0.8 in. The same trend was observed for percentage of seedlings out of the grass stage two years after planting (15% of 0.18 to 0.31 in rcd seedlings out of the grass stage versus 95% of 0.75 to 0.8 in rcd seedlings). Height growth rate also was greater for larger rcd seedlings (Lauer 1987). In most cases, larger average rcd seedlings are associated with 2-0 stock seedlings, and performance gains over 1-0 stock seedlings would be likely on most sites given proper seedling storage, handling, and planting techniques are combined with suitable site preparation and post-planting vegetation control.

The objective of this study was to compare survival, initiation of height growth out of the grass stage by tree age, total tree height and diameter growth of 1-0 and 2-0 stock containerized longleaf pine seedlings on a Middle Coastal Plain cutover site.

## STUDY AREA AND METHODS

The study area was located in the Tifton Upland section of the Middle Coastal Plain physiographic region in Wilcox County, Georgia on a 395-acre cutover site that was formerly a loblolly pine plantation 18-years prior (Craul et al. 2005). Soils on the site were from the Ailey series (Web Soil Survey 2025), which according to the University of Florida's Cooperative Research in Forest Fertility (CRIFF) soil classification guide is a CRIFF F soil (Jokela and Long 2018). These soils are well drained to somewhat excessively drained and have an argillic or Bt horizon deeper than 20 inches in the profile. The site developed into a pine-hardwood mixture over the 18-year period that it sat idle prior to establishment of this trial. A woody vegetation inventory completed during April 2019 on the site found an average of 5,076 ± 976 tree and stem shrubs per acre greater than one-foot tall prior to chemical site preparation. When considering potential chemical site preparation prescriptions, the landowner wanted to preserve a substantial natural wiregrass (*Aristida stricta*) component that was dispersed throughout the site. Chemical site preparation was applied aerially via helicopter on July 4, 2019 with a tank mix consisting of 40 oz/ac of a 6.3 lb ester triclopyr (Forestry Garlon® XRT), 12 oz/ac of a 4 lb acid equivalent imazapyr (Polaris® AC), 4 oz/ac of 60% active ingredient metsulfuron methyl (Escort® XP), and 19.2 oz/ac penetrant spreader with methylated seed oil (RRSI Sunrise) in 15 gallons of water per acre (Figure 1). During September 2019, the site was drum chopped (two pass) to knock down and crush all standing dead hardwoods, pines and shrubs (Figure 2). No site preparation prescribed fire was conducted. The site was hand planted on January 9, 2020, at a 6 x 12 ft spacing (605 trees per acre). Weather information was recorded during planting (Table 1). Precipitation for the area totaled 19.03 in from December 1, 2019, to Feb 29, 2020, while the historical average (1938 to 2016) for these three months is 12.56 in (UGA Weather Network 2025). No post-plant herbaceous weed control or prescribed fire were applied through the 5th growing season.

After mechanical site preparation was completed, 16 36 x 36 ft plots were established so that each plot would contain 24 planted longleaf pine seedlings. A total of 384 trees were assessed throughout the study. Plots were randomly assigned 1-0 or 2-0 stock seedlings for planting and each stock type had eight replications. Plots were arranged so that they were not close to any stand edges, to reduce the chances of edge effects on development. Seedlings were marked at planting with color coded pin flags to represent 1-0 or 2-0 stock. Prior to planting, 58 randomly selected 1-0 and 2-0 seedlings were weighed and measured for root collar diameter. Analyses revealed the 2-0 seedlings weighed significantly ($p<0.001$) more than the 1-0 seedlings (2.68 versus 2.29 oz) and 2-0 seedlings had larger root collar diameters ($p<0.001$) on average than 1-0 seedlings (0.531 versus 0.394 in), and no sampled seedlings had root collar diameters less than the 0.187 in, which is considered the minimum rcd for planting of newly lifted seedlings as suggested by Wakeley (1954). Seedlings were assessed for survival after the first growing season (2020) and no trees had emerged from the grass stage. At the end of the second growing season, trees were assessed for survival, tally of trees that had emerged out of the grass

stage, and height for trees that had begun stem growth. After the third growing season, the same assessments were completed, and root collar diameter of each seedling was measured. The final measurement was made after the fifth growing season (November 2024). Survival, height, diameter at breast height (dbh) measured at 4.5 ft, and root collar diameter (for trees less than 4.5 ft tall) were recorded. No trees were still in the grass stage after five growing seasons. Data were analyzed using analysis of variance and a significance level of p=0.05.

## RESULTS

Survival decreased the most during the first growing season, yet there was no difference between 1-0 and 2-0 stock seedlings (Table 2; Figure 3). Survival continued to decrease through five growing seasons. Survival of the 1-0 stock seedlings dropped 8.4 percentage points across five growing seasons while the 2-0 stock seedling survival dropped 9.9 percentage points (Table 2). Survival after five growing seasons was 62.5 ± 3.5% for the 2-0 seedlings and 58.3 ± 3.6% for the 1-0 seedlings. It should be noted that survival was expected to decrease more after the age five measurements due to damage caused by Hurricane Helene on September 27, 2024 (Figure 4). Storm damaged (primarily uprooted or stem breakage at groundline) trees ranged from 0 to 20% of surviving trees across replications with an average of 6.9% of trees exhibiting damage for 2-0 stock and 8.4% for 1-0 stock trees.

After the second growing season, 31.6 ± 7.1% of 2-0 trees had begun height growth out of the grass stage, while only 23.1 ± 3.6% of 1-0 trees had emerged from the grass stage, yet these differences were not statistically significant (p = 0.331) (Figure 5). Height growth of seedlings out of the grass stage averaged 5.7 ± 0.3 in and 5.0 ± 0.3 in (p = 0.095) for 2-0 and 1-0 seedlings after the second growing season, respectively. Heights after the 3rd growing season averaged 17.1 ± 0.9 in for the 2-0 seedlings and 15.6 ± 0.9 in for the 1-0 seedlings (p = 0.315) (Figure 6). This same inventory revealed that only 5.6 ± 1.5% of 1-0 seedlings were still in the grass stage while 2.2 ± 0.8% of 2-0 seedlings were in the grass stage. Root collar diameter of 2-0 seedlings averaged 1.41 ± 0.03 in and 1-0 seedlings averaged 1.37 ± 0.02 in (p = 0.392). By the end of the 5th growing season, height growth had increased substantially since the age three-year assessment though there still was no significant difference between 2-0 and 1-0 stock (p = 0.386). The 2-0 trees averaged 7.3 ± 0.3 ft, while the 1-0 trees averaged 6.8 ± 0.3 ft (Figure 7). For trees taller than 4.5 ft, dbh for the 2-0 trees averaged 1.9 ± 0.1 in and 1-0 trees 1.7 ± 0.01 in. About 20 to 25% of trees were less than dbh height with 24.6 ± 6.4% and 20.4 ± 3.3% (p=0.584) of 1-0 and 2-0 stock trees less than 4.5 ft tall after five growing seasons.

**Table 1. Weather conditions recorded on site during planting with a Kestrel® 5500FW Fire Weather Meter Pro on January 9, 2020. Skies were clear on January 9, 2020.**

| Plant time | Temperature (°F) | Relative humidity (%) | Wind speed (mph) | Wind direction |
|---|---|---|---|---|
| Start (0900 hr) | 71.5 | 38.5 | 1.2-6.7 | NW-NE |
| Finish (1150 hr) | 72.6 | 31 | 1.2-6.7 | NW-NE |

**Figure 1:** *The study area was an 18-year-old pine hardwood mixture that developed naturally after the previous loblolly pine stand was clearcut. Chemical site preparation had to be applied aerially due to the large size of the regenerating vegetation. Vegetation in these photos is showing herbicide symptoms approximately 1.5 months after application.*

**Figure 2:** *Drum chopping was completed during late September 2019 to flatten and chop (right photo) deadened hardwoods and pines from the aerial chemical site preparation treatment completed on July 4th. This form of mechanical site preparation has minimal impact on the soil, and it is very useful for facilitating hand planting on cutover sites with high stem densities.*

**Table 2. Containerized longleaf pine seedling survival by stocktype after the 1st, 2nd, 3rd, and 5th growing seasons.**

| Stock Type | Year 1 (p=0.629) Estimate ± SE (%) | Year 2 (p=0.671) Estimate ± SE (%) | Year 3 (p=0.646) Estimate ± SE (%) | Year 5 (p=0.716) Estimate ± SE (%) |
|---|---|---|---|---|
| 1-0 | 66.7 ± 0.3 | 66.2 ± 0.3 | 59.4 ± 3.6 | 58.3 ± 3.6 |
| 2-0 | 72.4 ± 0.3 | 71.0 ± 0.3 | 64.6 ± 3.5 | 62.5 ± 3.5 |

**Figure 3:** *1-0 stock seedling mortality in progress at the end of the second growing season.*

**Figure 4:** *Aerial image with four replications of the study at the end of the 5th growing season. Note the scattered lean, broken and uprooted trees throughout the stand that suffered windthrow associated with Hurricane Helene approximately 4.5 months prior to this photo.*


**Figure 5:** *Examples of 1-0 (photo a) and 2-0 (photo b) seedlings emerging from the grass stage at the end of the second growing season. Photo c shows the predominance of herbaceous weeds and grasses present at the site.*

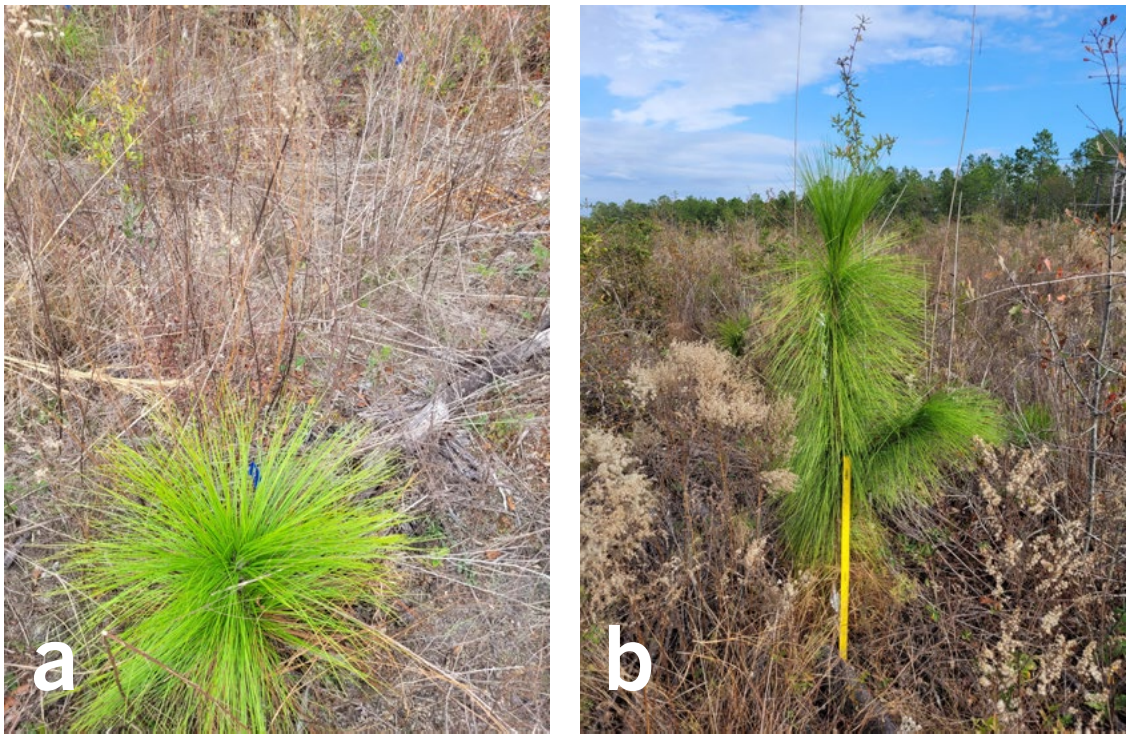


**Figure 6:** *Photo a depicts a 1-0 seedling starting to emerge from the grass stage after the third growing season (December 2022). Photo b depicts an above average 2-0 seedling following the 3rd growing season.*

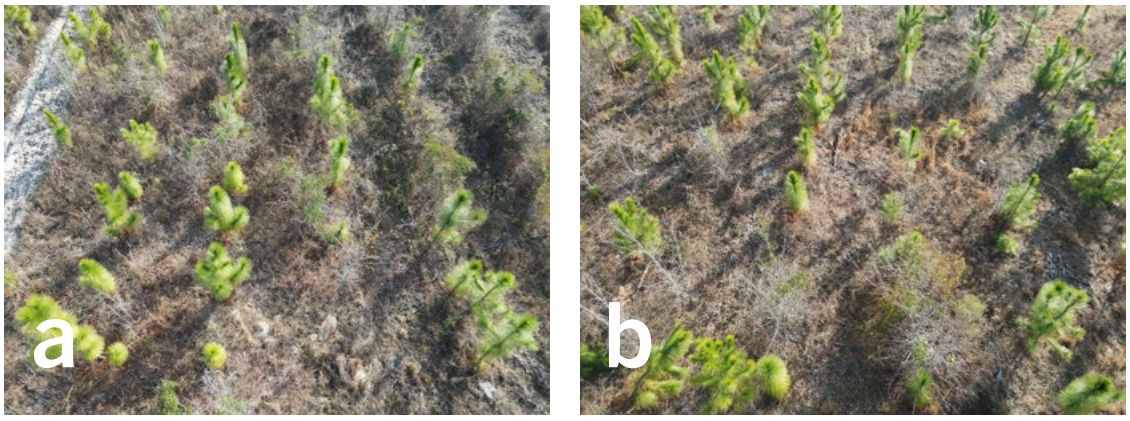


**Figure 7:** *Photo a is a 2-0 stock plot while photo b is a 1-0 stock plot at the end of the 5th growing season.*

## DISCUSSION AND CONCLUSIONS

Results through five years from this trial indicated that planting 2-0 stock longleaf pine may not offer an appreciable advantage over 1-0 stock seedlings on cutover sites. Survival, percentage of seedlings out of the grass stage, rcd (and later dbh), and height growth differences were statistically non-significant between the two stock types through the early stages of this study. Previous published trials comparing 1-0 and 2-0 stock longleaf pine performance have mostly occurred on old-field sites (Dickens et al. 2018a). In these trials, 2-0 stock trees (87 to 91% survival) generally had a 9 to 18 percentage point gain in survival over 1-0 trees (69 to 82% survival) in trials ranging from six to seven years post-planting. Height gains for 2-0 versus 1-0 seedlings generally ranged from 0.2 to 0.3 ft/yr in these old-field trials (Dickens et al. 2018a). In comparison, survival ranged from 58.2 to 62.5% for 1-0 and 2-0 stock trees in this trial after five years. In the old-field trials, diameter growth averaged 0.33 and 0.37 in/yr, while height growth averaged 1.4 and 1.3 ft/yr for 2-0 and 1-0 stock trees, respectively. The old-field trials likely had less limiting soil conditions and competing vegetation. Longleaf pine survival and growth on cutover sites is typically less and slower than growth on old-field sites due to less soil fertility (attributable to soil amendments on former agricultural sites), poorer soil tilth as well as greater levels of woody competing vegetation (Campbell and Morris 2018; Dickens et al. 2018b; Ostertag and Robertson 2007), though after five growing seasons at least 75.4 to 79.6% of surviving 1-0 and 2-0 trees in this trial had reached the 'bottlebrush' or 'rocket' stage of development when more rapid height and diameter growth often occurs (Wahlenberg 1946). In this trial, time in the grass stage could likely have been shortened and growth rates could have been accelerated through more intensive post-planting management. If first year herbaceous weed control using labeled herbicides for longleaf pine herbaceous vegetation control (e.g., Clabo and Dickens 2022; Minogue et al. 2023) had been applied and/or prescribed fire (e.g., Brockway et al. 2006; Knapp et al. 2018) had been used to promote growth of grass stage seedlings over herbaceous and some resprouting woody vegetation longleaf pine growth rates in this trial might have more closely resembled old-field sites. Though 2-0 stock seedlings had no significant survival or growth advantages over 1-0 stock seedling on this cutover site, the slight survival and growth advantages they had through five years and the same cost as 1-0 seedlings may make them more attractive for purchase during years they are available.

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