Bareroot vs. Containerized Stock Types: Shortleaf Pine Growth Comparison on a Planted Stand in Bahama, North Carolina

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Abstract

Shortleaf pine (Pinus echinata) is a native species of ecological and economic value, yet it has declined across much of its historic range. This project examined the performance of bareroot and containerized shortleaf pine seedlings after a prescribed burn at the Umstead Research Station in Bahama, North Carolina. The goal was to evaluate the effects of seedling stock type and a prescribed burn treatment on survival, diameter growth, and height growth after eight years of growth. The working hypothesis was that there would be no statistically significant difference in survival, and diameter and height growth between the two seedling stock types. Field data were collected from 861 seedlings and statistically analyzed using Chi-square tests, Welch t-tests, and two-way ANOVA with Tukey HSD post-hoc comparisons using R via RStudio (2024.12.1 Build 563). While survival was slightly higher for bareroot seedlings (52%) compared to containerized (47%), the difference was not statistically significant ($p = 0.13$). However, survival was significantly higher for seedlings planted in burned plots than in unburned plots ($p < 0.001$), with bareroot seedlings achieving 61% survival and containerized seedlings 57% survival in burned areas. Bareroot seedlings also had a significantly larger mean diameter (2.52 in) than containerized seedlings (2.37 in; $p = 0.04$). The prescribed burn had a highly significant effect on both diameter and height ($p < 0.001$): burned seedlings exhibited greater diameter and height regardless of seed stock type. No significant interaction was found between seed stock type and burn status, indicating that burn effects were consistent across seedling types.

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Bareroot vs. Containerized Stock Types: Shortleaf Pine Growth Comparison on a Planted Stand in Bahama, North Carolina

Purpose

The purpose of this project was to identify the effects of two forms of seedling stocks, bareroot (seedlings grown in nursery beds and lifted without soil) and containerized (seedlings grown in containers with their root system enclosed in a soil plug), on the height and diameter growth of shortleaf pine (*Pinus echinata* Mill.) on a planted forest stand at Umstead Research Station (UF_26) in Bahama, North Carolina (Durham County). Results from this analysis can be used to determine differences between the two stocks and whether there is an advantage to planting one over the other. My hypothesis is that there is no statistically significant difference in survival, and diameter and height growth between the seedling stocks, as previous studies have shown inconsistent performance advantages in growth between bareroot and containerized seedlings.

Two previous studies have occurred on the test site. The first study by Olanin (2017) established the seedlings on the test site and conducted a survival and growth analysis after the first year. The second study by Chirico (2019) analyzed the growth and survival of shortleaf pine seedling stocks (bareroot and containerized) after the presence of fire on the stand. This project has continued to build off the work of Olanin (2017) and Chirico (2019), with more focus geared toward overall growth (diameter and height growth) between the two seedling stocks and whether there is a significant difference after over 8 years of growth. This study will hopefully provide justification as to which seedling stock customers should buy to save money when establishing a new plantation stand or restocking after a harvest.

Introduction to Shortleaf Pine

Shortleaf pine is one of the most important commercial conifers in the southeastern United States (Lawson 1990). With its current natural range spanning 22 states from southern New York to eastern Texas (over 440,000 square miles) shortleaf pine is considered one of the most widespread pine species in the eastern United States (Lawson 1990). Shortleaf pine-dominated forests are estimated to occupy only about 6 million acres today, compared to an estimated 5.2 million acres for longleaf pine (*Pinus palustris*) and about 29 million acres for loblolly pine (*Pinus taeda*) (Sutter 2019, Baker and Langdon 1990, The Nature Conservancy 2025). Although it does not cover the most total land area, the shortleaf pine distribution may suggest that there has been successful adaptation to a range of environmental conditions (e.g., soil types, average annual temperatures [40 to 70-degree F], total precipitation [40 to 60 inches], and elevations [up to 3,000 feet]) and that the species has high genetic diversity and fire adaptation (Pickens 2019).

Shortleaf is considered a medium to large tree, reaching 80 to 100 feet tall and 24 to 36 inches in diameter over a lifespan of up to 200 years (Pickens 2019). It expresses an excurrent growth pattern with excellent stem form, moderate growth rates, notable drought tolerance, high resistance to fusiform rust, and yields valuable sawtimber for structural materials (i.e., bridges, docks, factories, homes, and warehouses), plywood, and pulpwood (Hossain et al. 2021). Shortleaf can be distinguished from other southern yellow pine species by its 1.75- to 4.5-inch slender and flexible needles in clusters of 2 (sometimes 3) and cones that average from 1.5 to 2.5 inches long, with an ovoid to conical shape (Glasgow 2019).

Shortleaf pine has decreased in both its abundance and natural range in recent history (Sutter 2019). East of the Mississippi River, shortleaf pine has lost over 50% of its former area over the last 40 years. From 1980 to 2013, shortleaf pine-dominated forests in North Carolina have decreased 45% due to changes in timber management practices, altered fire regimes, disease, and land use changes. This rapid decline has also been linked to forest pest outbreaks, such as the southern pine beetle (*Dendroctonus frontalis*), in poorly managed stands (Sutter 2019).

Containerized vs. Bareroot Seedlings

Bareroot and container seedlings are the two most common stock types used in forest planting and restoration programs (Grossnickle and El-Kassaby 2015). Bareroot seedlings are normally grown in open field nurseries where the soil is removed from the root system during harvest (i.e., the lifting process), while containerized seedlings are grown in either open nursery compounds or in a controlled greenhouse environment with the root/media plug retained during all steps from the nursery through planting in the field (Grossnickle and El-Kassaby 2015). However, studies involving stress resistance and nutrition found no conclusive evidence that either stock type has a performance advantage (Grossnickle and El-Kassaby 2015).

Studies have shown that bareroot seedlings are more sensitive to handling practices such as lifting, storage, transport, and planting, and can negatively affect their growth and survival performance (Grossnickle, 2005). To avoid the risks that bareroot seedlings have in the planting process, containerized seedlings are an option for foresters to use since they can have a higher level of field survival, which is related to their increased drought avoidance potential and shock resistance during the planting process (Grossnickle and El-Kassaby 2015). However, studies have shown that bareroot and container seedlings have comparable survival rates on sites with minimal planting stress, especially if sound planting practices are implemented to establish the seedlings (Brissette and Barnett 1989).

Barnett et al. (1989) suggested that containerized seedlings have a higher advantage due to increased survival and growth and have an extended planting season, which is one of the best advantages to using containerized seedlings. Brissette and Barnett (1989) conducted an experiment and found that containerized seedlings had slightly higher survival than bareroot stock during their first growing season with a survival rate of 98.3% and 96.9%, respectively. Although differences in survival were not significant, the greater field performance in containerized seedlings is attributed to their larger root systems and better shoot-to-root balance before being planted (Brissette and Barnett 1989). According to Gwaze et al. (2006), although containerized seedling survival was greater, bareroot seedlings exhibited greater growth when compared to the containerized seedlings. After taking into account the above-mentioned studies, it is still debatable whether containerized seedlings, despite having higher survival rates, are necessarily better than bareroot seedlings regarding growth.

Why Use Containerized Seedlings? Pros and Cons

There is evidence to suggest that human beings have been using containerized seedlings for more than 2,000 years (South 2015). According to South (2015), it wasn't until the 1960s and 1970s that commercial use of containerized seedlings became widespread throughout the southeastern United States. Now, more than 180 million containerized seedlings are produced every year in the southeast (Harper et al. 2013). So, what are the advantages to using containerized seedlings over bareroot seedlings?

According to Barnett et al. (1986), some advantages include: (1) the ability to quickly produce seedlings year-round; (2) an extended planting season using containerized seedlings; (3) improved performance of the tree species; (4) better outcomes on adverse sites; (5) more efficient use of limited seed stock; and (6) greater uniformity in seedling size and shape. The uniform shape of the plugs, which are seedlings removed from their containers before planting, makes hand and machine planting easier (Texas A&M Forest Service 2023). Also, containerized seedlings may be planted 9 to 10 months of the year, assuming that soil moisture is adequate (South 2015).

However, containerized seedlings also have disadvantages. It takes more care (i.e., time, money) to grow containerized seedlings than bareroot seedlings; the seedlings are often much smaller than bareroot seedlings; and the containers are bulky and more expensive to transport (South 2015; Texas A&M Forest Service 2023). Also, growing techniques require more attention to moisture and temperature regimes than is required for producing bareroot seedlings (Barnett et al. 2016).

Comparison of Cost for Containerized and Bareroot Seedlings

There is an obvious cost difference between bareroot seedlings and containerized seedlings. It is very difficult to find private tree nurseries in North Carolina that sell shortleaf pine seedlings. The North Carolina Forest Service has the only nursery service in North Carolina that offers both bareroot and containerized seedlings for sale. As of April 2025, shortleaf pine containerized seedlings are listed at $60 per 334 seedlings ($0.18 per seedling), while bareroot seedlings are listed at $37.50 per 500 seedlings ($0.08 per seedling). This does not include the $60 charge per unit for UPS shipments by the NC Forest Service (NC Forest Service 2023). The Virginia Department of Forestry offers bareroot seedlings at $0.12 per seedling with the purchase of 1,000 seedlings; containerized are $0.20 per seedling only with the purchase of 334 seedlings at a time (Virginia Department of Forestry 2023). Containerized costs could be offset by planting fewer containerized seedlings per acre, expecting a greater percentage to survive (South 2016).

It is difficult to obtain prices from private tree nurseries, but a recent South Carolina Arborgen seedling price guide has recently been published online. According to Arborgen's Taylor Nursery 2022-2023 SCFC Seedling Price Guide, both loblolly pine coastal OP: AG-88 (66-A-A) and loblolly pine piedmont OP: AG-757 (98-A-A) are priced at $33, $49, and $70 for 100, 500, and 1000 seedlings per unit, respectively. Bareroot shortleaf pine is also priced at the same unit price. The only containerized pine species for sale from the Taylor Nursery is longleaf pine at 250 containerized seedlings for $50 per unit box (SC State Commission of Forestry 2023).

Foresters initially thought that containerized seedlings would cost less to plant than bareroot stock (Mann 1977). This was based on the assumption that small containerized seedlings could be planted more quickly than bareroot seedlings. But the number of seedlings a planter can carry has decreased as the size of containerized seedlings has increased over time (South 2016). Hand planting a containerized seedling costs an estimated $0.14 while the cost for bareroot planting was $0.11 per seedling (Dooly and Barlow 2013). This 27.3% price difference can increase establishment costs as the planting acreage increases and the cost of planting is subject to increase (and has increased) over time (Cappelletti 2025).

Methods

Site History

The study site is a 41-acre (16.6 hectare) stand located in the Umstead Research Farm (UF_26) in Bahama, North Carolina (Durham County) with elevations ranging from 410 to 420 feet above sea level. UF_26 was historically an agricultural field up until 1963 when it was converted to a planted loblolly pine stand (Olanin 2017). In 2007, the site was commercially thinned to approximately 4.64 square meters (50 square feet) of basal area with the removal of the stand's hardwood components. In 2013, the entire 41-acre stand was commercially clearcut (Olanin 2017). In August 2014, the site was chemically treated to prepare for planting (Olanin 2017). The proceeding herbicide mixture was applied aerially at a rate of 56.8 liters per acre: 5.68 liters (6 quarts) of Accord Concentrate or equivalent: (53.8% glyphosate); 0.59 liters (20 oz) Arsenal AC or equivalent: (53.1% Isopropylamine salt of Imazapyr(2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid)*; 0.089 liters (3 oz) Oust XP or equivalent: (75% Sulfometuron methyl {Methyl 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]-carbonyl]amino] sulfonyl]benzoate}; 0.59 liters (20 oz) low-use Methylated Seed Oil surfactant; and 49.8 liters (13.16 gallons) of water (Olanin 2017).

Soil Description

According to Web Soil Survey (2023), the soil within the test site is Mecklenburg loam 2 to 6 percent slopes (MuB) (Figure 1). Mecklenburg loam is described as a fine, mixed, active, and thermic Ultic Hapludalf ("MECKLENBURG SERIES", 2022). The Mecklenburg series consists of very deep, well drained, slowly permeable soils that formed in residuum weathered from intermediate and mafic crystalline rocks of the Piedmont uplands with slopes ranging from 2 to 25 percent ("MECKLENBURG SERIES" 2022). The mean annual precipitation is 45 inches, the mean annual temperature is 59 degrees near the soil-type location, and the site index for shortleaf pine is 64 ft (base age 50 years) ("MECKLENBURG SERIES" 2022).

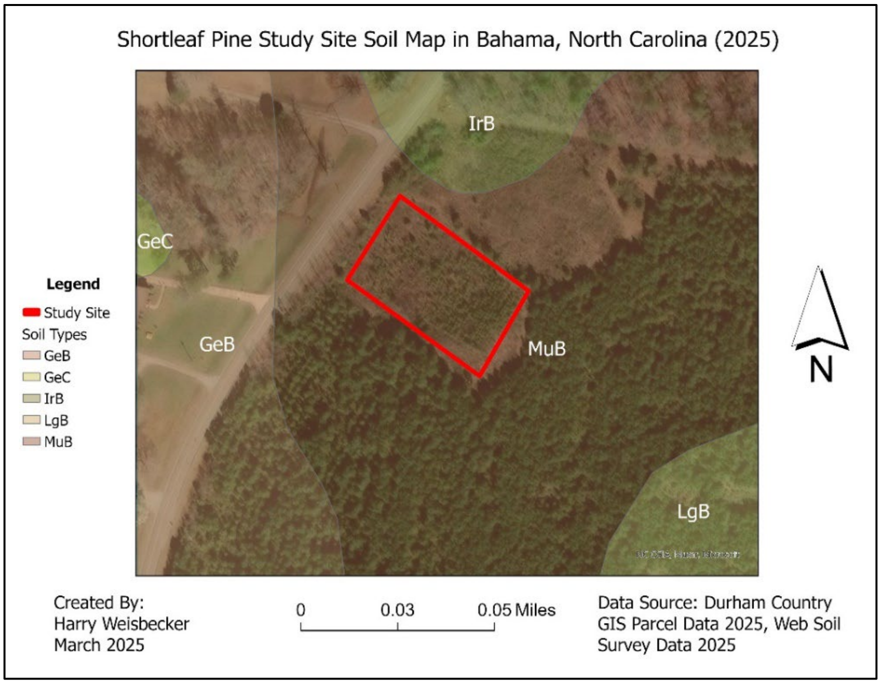

Figure 1. Soil map of the study site (including surrounding soil series in the general area.)

Seedling information

The seedlings were planted in early March 2016. The containerized and bareroot stock used were 1-year-old seedlings produced from the same seed lot, which was an orchard mix produced from selections original to western North Carolina. The seedlings were grown and cared for at the North Carolina Forest Service's Claridge Nursery in Goldsboro, North Carolina. The containerized seedling plugs were 3.81 cm in diameter and 11.43 cm in length. Containerized and bareroot dibble bars were used to plant both seedling types (Olanin 2017).

Experimental Design

The design of this experiment was to measure the difference between stock types with the experimental unit being the seedling. The original experiment consisted of n=861 seedlings planted in a 5 by 5-foot (1.52 by 1.52-meter) grid. The first row began with a sequence of 10 bareroot followed by 11 containerized seedlings making a total distance of 100 feet (30.5 meters); the second row was 10 containerized and 11 bareroot (Olanin 2017). The rows ranged from 20 to 21 seedlings per row (Chirico 2019). This alternating planting pattern continued for 41 total rows for a total experimental area of 0.46 acres (0.186 hectares), and each seedling was labeled with a numbered aluminum tag (Olanin 2017). Additionally, pin flagging of two different colors was placed next to each planted seedling for easier identification of stocking type and to serve as a place holder for the numbered tags (Chirico 2019).

Prescribed Burn

A prescribed burn was conducted on May 2, 2018, with assistance from the North Carolina Forest Service. A controlled backing fire was implemented to burn rows 1 to 23 to compare growth and survival of seedlings in two separate areas: burned (0.32 acres) and unburned (0.24 acres) (Figure 2). In January 2019, seedling measurements (in both areas) and a survival survey were conducted to record mortality and post-burn response. Diameter was measured in millimeters using a micrometer, and height was recorded in centimeters with a meter stick. For multi-stemmed seedlings, only the tallest stem was measured (Chirico 2019).

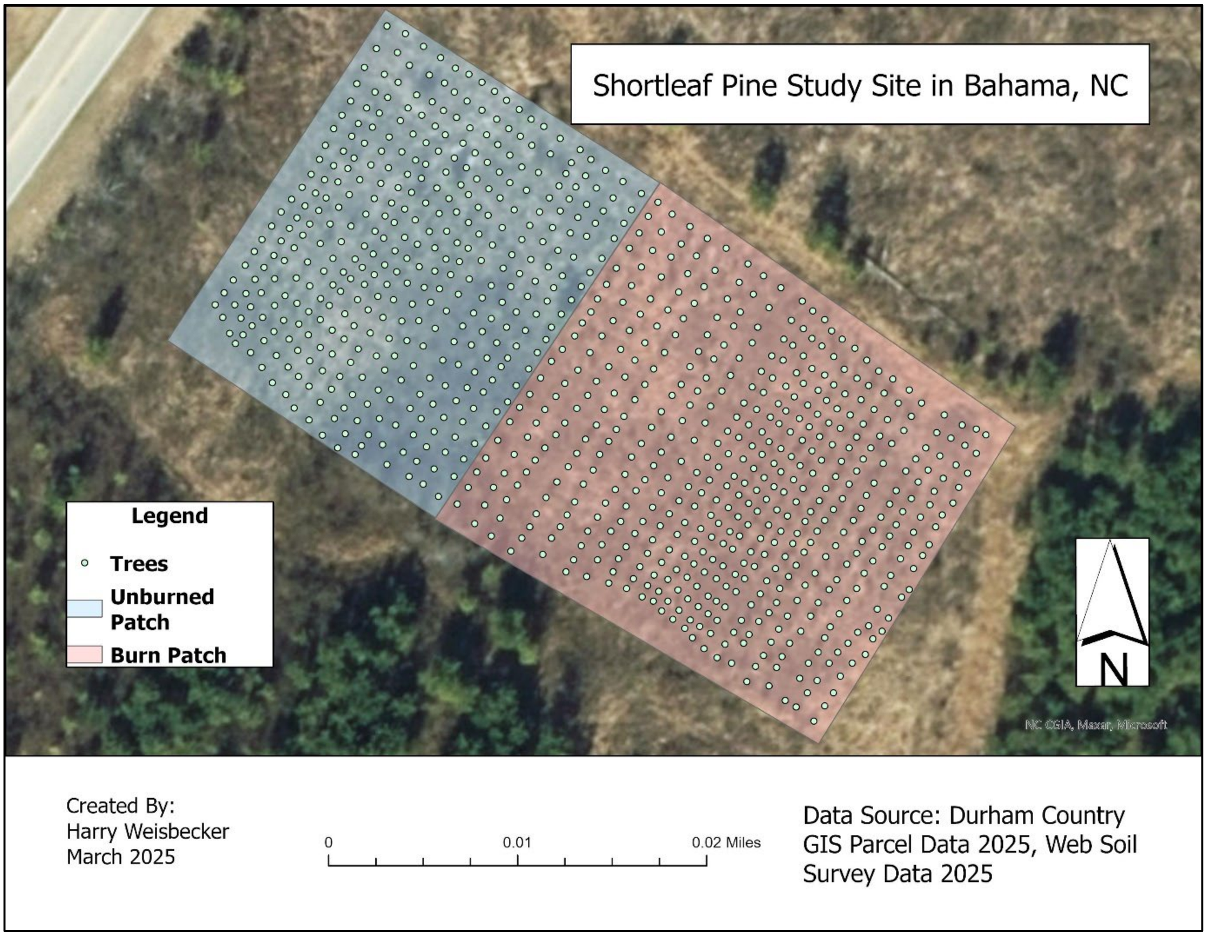

Figure 2. Map of the study site with polygons indicating the burn area (0.32 ac) vs. the unburned area (0.24 ac). Rows start from right (row 1) to left (row 41).

Measurements

In January 2024, the shortleaf pine stand was measured again (Figure 3). I cruised the stand almost entirely alone and recorded data on paper. The site was brushy, and each tree location was located by pacing while using a machete to get through blackberry thorns. The entire cruise took approximately 11 days to finish. Diameters were recorded (in inches) using a diameter tape at breast height (4.5 feet above ground). Heights were measured with an extendable height pole, allowing for accurate readings of total tree height from the base to the terminal leader. Each tree's condition was recorded as either alive (A) or dead (D). Additionally, the crown class was noted for each tree as dominant (D), co-dominant (CD), intermediate (I), or suppressed (S), based on its position in the canopy. If a tree could not be located at the flagged/tagged location, it was recorded as dead (D). Measurements were taken systematically across the stand to ensure as much consistency and accuracy as humanly possible.

Figure 3. Photo taken from the field of measurements being conducted.

Statistical Analysis of Data

Data were downloaded into Excel and saved as a .csv file for further analysis. All statistical analyses were conducted in R via RStudio (2024.12.1 Build 563) to evaluate differences in seedling survival and growth across the seed stock type and burn area (R Core

Team 2024). Packages used included “dplyr” for data organization (Wickham et al. 2023), “ggplot2” and “ggpubr” for visualization (Wickham 2016 and Kassambara 2023), and “knitr” for generating summary tables (Xie 2024). Independent two-sample t-tests were used to compare mean diameter and height between the seedlings. Chi-squared tests were applied to assess differences in survival proportions across seed types and burn conditions. For a more detailed comparison of seedling growth across both seed stock type and burn area, a two-way analysis of variance (ANOVA) was conducted to test effects on diameter and height, followed by Tukey’s honestly significant difference (HSD) post-hoc tests when significant differences ($p < 0.05$) were detected.

Results

Survival

A Chi-square test revealed no statistically significant difference in survival between 8-year-old bareroot and containerized seedlings ($\chi^2 = 2.34$, df = 1, $p = 0.126$). While the statistical result was not significant, the raw survival data shows a small difference in outcomes between the two types. Bareroot seedlings had a slight survival advantage, with 52% alive and 48% dead, compared to 47% alive and 53% dead for containerized seedlings (see Table 1). Although numerically different, these proportions do not reflect a statistically meaningful difference in survival.

Table 1. Survival outcomes for Bareroot and Containerized seedlings, showing the count and percentage of seedlings/trees classified as alive or dead.

Seed Type Survival		
Condition	Bareroot	Containerized
Alive	223 (52%)	203 (47%)
Dead	204 (48%)	231 (53%)

Diameter

An independent two-sample Welch t-test revealed a significant difference in mean diameter between bareroot and containerized seedlings ($t = 2.06$, $df = 416.69$, $p = 0.040$). The 95% confidence interval for the difference in means ranged from 0.007 to 0.291 in, indicating a small but statistically significant advantage for bareroot stock.

The mean diameter of bareroot seedlings was 2.52 inches (SD ± 0.73 in), while containerized seedlings averaged 2.37 inches (SD ± 0.75 in) (Figure 4). Figure 5 illustrates the distribution of seedling diameters by stock type. Bareroot seedlings had a slightly higher median diameter (2.5 in), with a maximum diameter just over 5 in. Containerized seedlings had a median diameter of approximately 2.3 in and a maximum just under 4 in.

Table: Diameter and Height Summary by Seed Type

Seed.Type	Mean_Diameter	SD_Diameter	Mean_Height	SD_Height
B	2.516290	0.7312547	14.11031	2.759101
C	2.367488	0.7518473	13.62118	2.956968

Figure 4. Summary table for diameter and height by seed stock type.

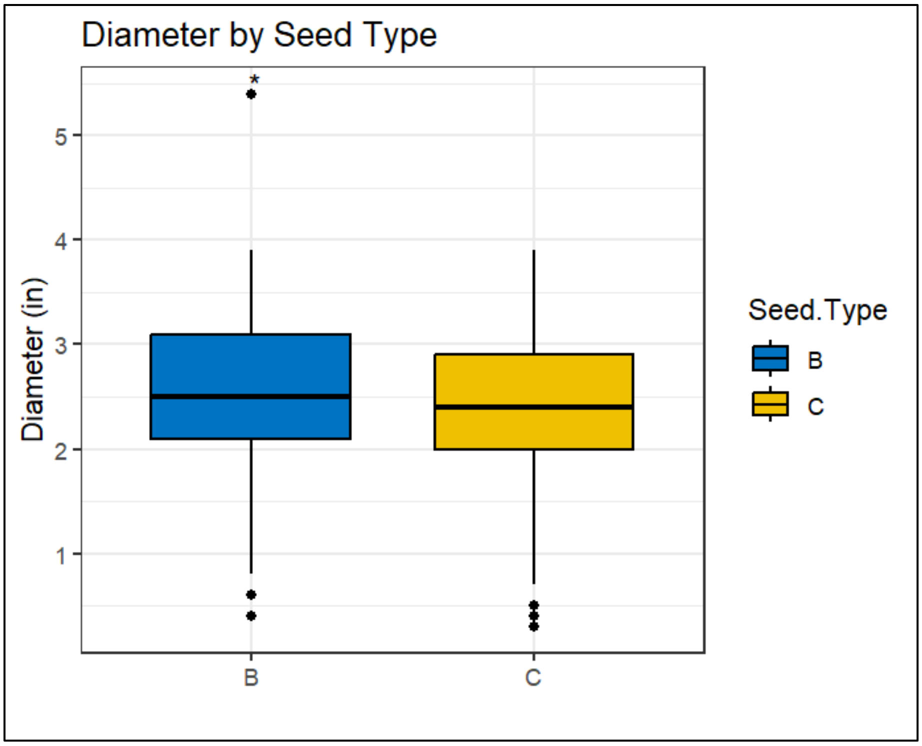

Figure 5. Plot comparing the diameter range for both bareroot (B) and containerized (C) seedling stock types.

Height

The same Welch t-test found no statistically significant difference in seedling height between the two stock types (t = 1.76, df = 413.02, p = 0.079). The 95% confidence interval ranged from -0.06 to 1.04 feet, suggesting the observed difference in mean height is likely due to random variation.

The mean height of bareroot seedlings was 14.11 ft (SD ± 2.76 ft), while containerized seedlings averaged 13.62 ft (SD ± 2.96 ft) (Figure 4). Median heights for both groups were similar (roughly 14.3 ft for bareroot and 14 ft for containerized) (Figure 6). Bareroot seedlings reached a slightly higher maximum height (just over 20 ft).

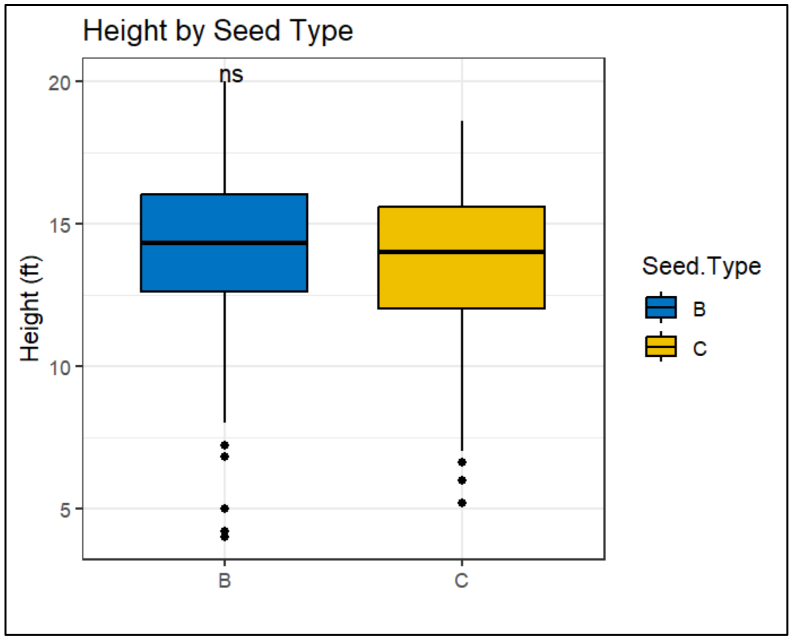

Figure 6. Plot comparing the height range for bareroot (B) and containerized (C) seedling stock types.

Burned vs. Unburned Results:

Survival:

A Chi-square test revealed a statistically significant difference in seedling survival between burned and unburned plots ($\chi^2 = 40.06$, df = 1, $p < 0.001$), indicating that burn treatment had a strong influence on survival outcomes. In the burned patch, 287 seedlings survived and 199 died, while in the unburned patch, only 139 survived and 236 died (Figure 7). This demonstrates a clear survival advantage in the burned areas, regardless of seed stock type.

Table: Survival Counts by Burn Status and Condition

	A	D
B	287	199
UB	139	236

Figure 7. Survival of seedlings on the burn patch (B) vs. the unburned patch (UB) (regardless of seed stock type).

Survival rates by both burn treatment and seed type were noticeable (Figure 8). Bareroot seedlings in the burned treatment had the highest survival rate at 61%, followed closely by containerized seedlings in the burned group at 57%. Survival rates dropped in the unburned treatments: bareroot seedlings had a survival rate of 41%, while containerized seedlings showed the lowest survival rate at 33%.

Table: Survival Counts and Rates by Burn Status and Seed Type

Burned.Unburned	Seed.Type	A	D	Survival_Rate
B	B	147	94	0.6099585
B	C	140	105	0.5714286
UB	B	76	110	0.4086022
UB	C	63	126	0.3333333

Figure 8. *Survival of seedlings on the burn patch (B) vs. the unburned patch (UB) (factoring in bareroot (B) and containerized (C) seed stock type).*

Diameter:

A two-way ANOVA was conducted to examine the effects of seed stock type and burn treatment on seedling diameter. The results showed a significant effect of seed stock type ($F = 4.62$, $p = 0.0321$) and a highly significant effect of burn treatment ($F = 36.59$, $p < 0.001$). However, the interaction between seed type and burn status was not statistically significant ($F = 0.73$, $p = 0.395$), suggesting that the effect of burn was consistent across both stock types.

Tukey's HSD post-hoc comparisons supported this, showing that bareroot seedlings had significantly larger diameters than containerized seedlings (mean difference = 0.15 in, $p = 0.032$), and burned seedlings had significantly greater diameter than unburned seedlings (mean difference = 0.45 in, $p < 0.001$). Among the groups, burned bareroot seedlings (B:B) had significantly larger diameters than both unburned bareroot seedlings (B:UB) and unburned containerized seedlings (C:UB). Containerized burned seedlings (C:B) also had significantly greater diameter than both unburned groups. However, the difference between C:B and B:B was not statistically significant (p = 0.49), indicating similar diameter performance under burned conditions for both stock types (Figure 9).

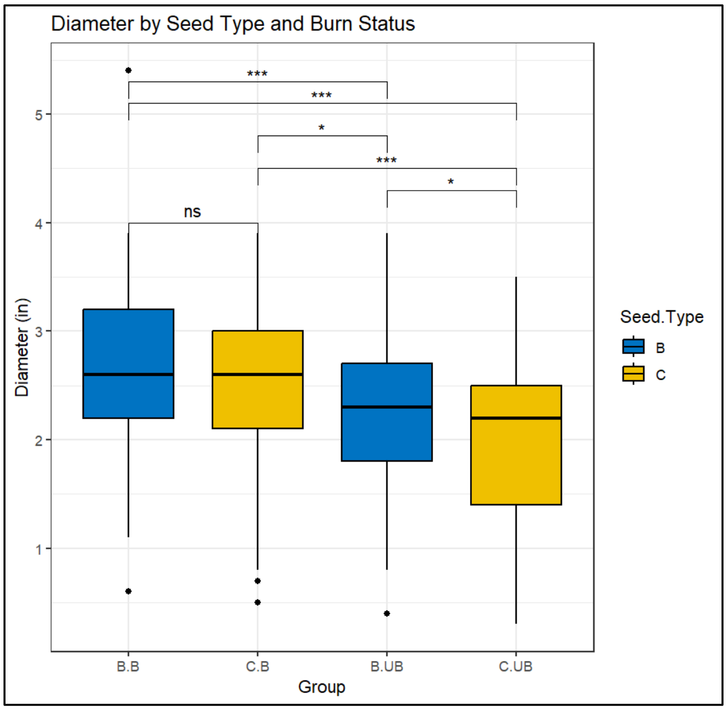

Figure 19. Plot comparing the diameter range for both bareroot (B) and containerized (C) seed stock types (considering burn status: burned [B] vs. unburned [UB]).

B:B had the highest median diameter at 2.6 in, followed by C:B at 2.5 in (Figure 10). Median diameters dropped in unburned plots: B:UB at 2.3 inches, and C:UB at 2.0 in. Summary statistics show that bareroot seedlings in burned plots had a mean diameter of 2.65 in (SD ± 0.70 in), compared to 2.26 in in unburned plots. Containerized seedlings had a mean diameter of 2.53 in in burned plots, and 2.01 in in unburned plots.

Table: Diameter and Height Summary by Seed Type & Burn Status

Seed.Type	Burned.Unburned	Mean_Diameter	SD_Diameter	Mean_Height	SD_Height
B	B	2.646259	0.6969869	14.79796	2.453303
B	UB	2.258108	0.7337288	12.78026	2.845629
C	B	2.527143	0.6929078	14.33143	2.667445
C	UB	2.012698	0.7614697	12.04286	2.977427

Figure 10. Summary table for diameter and height by seed stock type based on burn status.

Height

Another two-way ANOVA was performed to assess the effects of seed stock type and burn treatment on seedling height. The analysis revealed a highly significant effect of burn treatment ($F = 59.97$, $p < 0.001$), indicating that burned seedlings were significantly taller than unburned ones. The main effect of seed stock type was not statistically significant ($F = 3.55$, $p = 0.0603$), and the interaction between seed stock type and burn treatment was also not significant ($F = 0.24$, $p = 0.626$), showing that burn effects on height were consistent across seed stock types.

Tukey's HSD test showed that both B:B and C:B seedlings were significantly taller than their unburned counterparts ($p < 0.001$). However, there was no significant difference in height between B:B and C:B ($p = 0.45$), nor between the two unburned groups ($p = 0.37$). These results suggest that burning had a stronger influence on seedling height than seed stock type.

Graphical comparison support these statistical findings (Figure 11). Bareroot seedlings in burned plots (B:B) had the tallest median height at 15 ft, with some reaching over 20 ft. Containerized burned seedlings (C:B) followed with a median of approximately 14.5 ft. In contrast, unburned bareroot seedlings (B:UB) had a median of 13.5 ft, while unburned containerized seedlings (C:UB) had the lowest at 13 ft. Summary data (Figure 9) show that bareroot seedlings in burned plots had a mean height of 14.8 ft (SD ± 2.45 ft), compared to 12.78 ft in unburned plots. Containerized seedlings averaged 14.33 ft in burned plots and 12.04 ft in unburned plots.

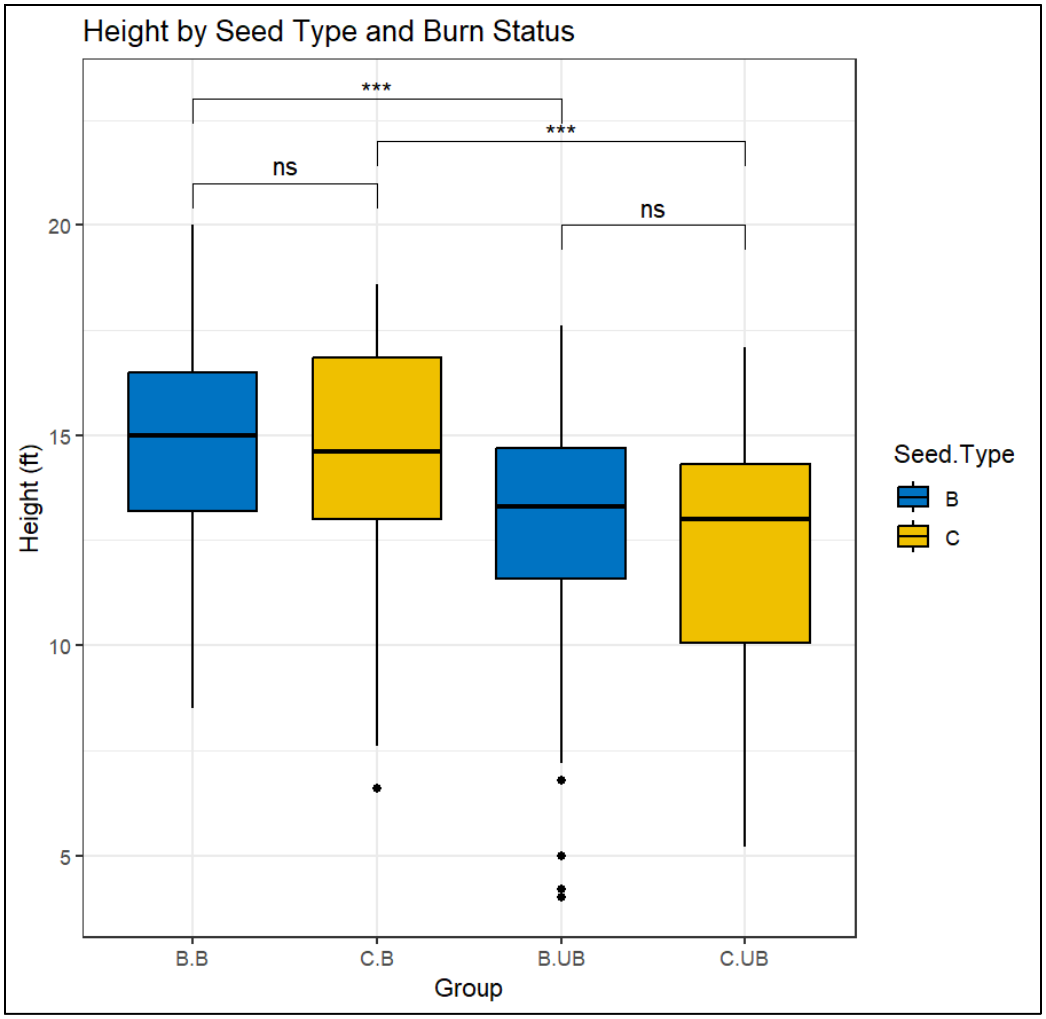

Figure 11. Box plot comparing the height range for both bareroot (B) and containerized (C) seed stock types (considering burn status: burned [B] vs. unburned [UB]).

Discussion:

Comparison of Results from Previous Studies:

The results of my study can both compare and enhance the previous work by Olanin (2017) and Chirico (2019) conducted on the same site (Table 2). Olanin found that containerized seedlings showed the highest early survival of 97%, with a stronger early growth average in height (16.2 cm) than the average diameter growth (2.02 mm vs. 2.24 mm for bareroot). Chirico's results also highlighted higher pre-burn survival for containerized stock (93%) than bareroot (87%), although post-burn survival was greater in bareroot seedlings (70%) compared to containerized (61%). This could be attributed to the larger size of bareroot (an average of 6.1 mm in diameter and 46.6 cm in height) when compared to the containerized seedling (5.1 mm in diameter and 42 cm in height).

Table 2. Comparison table for results from Olanin (2017), Chirico (2019), and Weisbecker (2024). Please note that the "" indicates results from the burn patch within the study site.*

Shortleaf Pine Seed Stock Study Period Comparison Table			
Variables	Olanin (2017)	Chirico (2019)	Weisbecker (2024)
Pre-burn Survival (Containerized)	97%	93%	N/A
Pre-burn Survival (Bareroot)	92%	87%	N/A
Post-Burn Survival (Containerized)	N/A	61%*	57%*
Post-Burn Survival (Bareroot)	N/A	70%*	61%*
Diameter Growth (Containerized)	3.23 mm -> 5.25 mm; Avg growth: 2.02 mm	5.1 mm (burned)*	2.01 in (unburned); 2.53 in (burned)*
Diameter Growth (Bareroot)	4.7 mm -> 7.12 mm; Avg growth: 2.24 mm	6.1 mm (burned)*	2.25 in (unburned); 2.65 in (burned)*
Height Growth (Containerized)	12.2 cm -> 28.4 cm; Avg growth: 16.2 cm	42.0 cm (burned)*	12.04 ft (unburned); 14.33 ft (burned)*
Height Growth (Bareroot)	24.70 cm -> 38.7 cm; Avg growth: 14 cm	46.6 cm (burned)*	12.78 ft (unburned); 14.80 ft (burned)*

In my study, the post-burn survival trend again favored bareroot seedlings (61%) over containerized (57%), which aligns with Chirico's findings. Burned bareroot seedlings also showed higher average growth in both diameter (2.65 in) and height (14.80 ft), surpassing containerized seedlings, which reached an average diameter and height of 2.53 in and 14.33 ft, respectively. Even in the unburned patch, bareroot seedlings showed an advantage over containerized seedlings in both metrics. These results suggest that while containerized stock may provide an initial survival advantage in undisturbed conditions (i.e., no prescribed fire), bareroot seedlings demonstrate higher resilience and post-fire growth. The enhanced growth and survival observed in burned plots may be partly attributed to reduced competition for light, water, and other resources, as fire likely eliminated competing vegetation. Overall, these findings support the idea that seed stock type selection should be matched to site management objectives, particularly in systems where prescribed fire plays a role in regeneration and competition control.

Conclusion:

This study tested the hypothesis that there would be no statistically significant difference in survival, diameter growth, or height growth between bareroot and containerized shortleaf pine seedlings. While overall survival was slightly higher for bareroot seedlings (52%) compared to containerized seedlings (47%), this difference was not statistically significant ($p = 0.13$). However, a statistically significant difference in seedling survival was found between burned and unburned plots ($p < 0.001$), with bareroot seedlings in burned areas exhibiting the highest survival rate (61%), followed by containerized seedlings in burned plots (57%). Survival rates declined in unburned plots, with bareroot seedlings at 41% and containerized seedlings at 33%.

In terms of growth, bareroot seedlings had a significantly larger mean diameter (2.52 in) than containerized seedlings (2.37 in; $p = 0.04$). Bareroot seedlings in the burned patch achieved the highest average diameter (2.65 in) and height (14.80 ft), compared to containerized seedlings in the burned patch (2.53 in diameter, 14.33 ft height). A two-way ANOVA indicated a highly significant effect of prescribed burn treatment on both diameter and height ($p < 0.001$), meaning that seedlings in burned plots exhibited greater growth regardless of seed stock type. However, neither seed stock type nor burn status alone produced a statistically significant difference in seedling height ($p > 0.05$). No significant interaction was found between seed stock type and burn treatment for either diameter or height, suggesting that both bareroot and containerized seedlings responded similarly to fire.

These results suggest that bareroot seedlings may offer a more cost-effective option compared to containerized seedlings given that bareroot seedlings had slightly higher growth, while also being more affordable. By demonstrating clear performance advantages in burned conditions regardless of seedling type, this study provides practical guidance for landowners and managers seeking to optimize survival and growth while reducing costs when establishing new plantations or restocking after harvest.

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