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Research Article

Initial Seedling Survival and Growth of Western Coast and Mexican Pine Species in East Texas

Alexandria Cook, Brian P. Oswald*, K. Rebecca Kidd, Hans M. Williams, Anusha Shrestha

Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, USA

ABSTRACT

The southeastern United States produces almost a quarter of the world's timber, and a potential shift in growing conditions influencing tree survival and growth could be ecologically and economically detrimental. Changing climates has prompted concern as droughts are becoming more severe and frequent, and in East Texas, non-native species adapted to predicted conditions might be considered. Loblolly (*P. taeda*) with two western United States pine species (ponderosa, *Pinus ponderosa* and Jeffrey pine *P. jeffreyi*) were planted in 2021 and shortleaf (*P. enchinata*) pine with Mexican pine species (Caribbean, *P. caribaea*, Durango, *P. durangensis*, and Mexican weeping *P. patula*) seedlings were planted in 2023. Survival and growth were evaluated at four sites between 2022 and 2024. Of the seedlings planted in 2021, loblolly pine had the greatest survival. Mexican pine seedlings planted in 2023 had low survival rates, with shortleaf having the greatest survival. The native loblolly and shortleaf pines had the greatest diameter and height growth. Ponderosa pine had the greater survival and growth of the non-native 2021 species and the Mexican Weeping pine of the 2023 species.

Multiple contributing factors influenced the survival and growth of the seedlings. Drought during the summers of 2022 and 2023 and below average growing season precipitation limited available soil moisture. Competition from understory vegetation could have lessen chances for species establishment. Differences in soils compared to native range soils may also have influenced our results. The timing of planting followed east Texas approach, rather than at native sites, and could have impacted seedling success.

Keywords: Survival; Growth; Seedling; Western pines; Drought; Climate change

INTRODUCTION

The presence of Euro-Americans has altered the natural landscape across the United States, with conversion of forests to urban development and infrastructure, introduction of exotic species, and removal of habitat. In addition, climate change has impacted weather patterns and seasonal weather events, which has contributed to the increased occurrence of severe wildfires and droughts. Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (NO_0), and Ozone (O_3) make up a portion of the greenhouse gases and have been linked to climate change [1,2]. These gases can both directly and indirectly affect water and nutrient utilization of species on individual, community, and ecosystem levels, composition and species ranges can potentially shift as a result [3,4]. The effects of climate change have begun to have an impact on the vegetation communities across the United States, and current adaptations of the plant communities may not reflect the new climate and may potentially result in new plant composition [5-7]. Dryer and hotter climates are predicted in East Texas as overall precipitation will decrease with an increase in the frequency of extremely intense, short-duration precipitation events [6].

In East Texas, trends in the fluctuations of temperature and precipitation may negatively affect loblolly pine (*Pinus taeda*) and shortleaf pine (Pinus echinata) future regeneration and growth, and these changes could have a significant impact to the East Texas timber industry [8]. Loblolly pine is the most highly used species by the timber industry, and shortleaf pine is increasingly used due to its adaptability to variable site conditions. With climate conditions potentially changing, the use of introduced species more adapted to dryer and warmer climates may be important for future timber production. Ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) are western United States species that have evolved in more droughty conditions than currently found in East Texas, and may do well here under future climates. In addition, Durango pine (*Pinus durangensis*), Caribbean pine (*Pinus carribaea var. hondurensis*), and Mexican Weeping pine (*Pinus patula*) may be potential species due to similar site conditions where they are currently found.

Correspondence to: Brian P. Oswald, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, USA, E-mail: oswaldbrian0@gmail.com; boswald@sfasu.edu

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Ponderosa pines southwestern varietal, found in Arizona and New Mexico, is found on coarse textured soils with a pH ranging from acidic to strong alkaline [9]. Jeffrey pine is located in the southwestern corner of Oregon, in the Sierra Nevada Mountains in California, the western edge of Nevada, and south to the Baja peninsula of Mexico. It is cold hardy, drought tolerant, and is a prominent species on sites with low nutrients. This species is often found on soils containing low levels of nutrients with relatively higher pH [10-12]. Durango pine is a close relative of ponderosa pine and is found in northwestern Mexico, [13-16]. The soils are often shallow and rocky, but it grows well in deeper soils. Durango pine is not drought tolerant and favors wet and cooler climates [17]. Mexican Weeping pine is found in the eastern part of Mexico, and grows well on well-drained, deep fertile clay soils along with sandy loam soils; however, this species can grow on a wide range of soil types and land formations [15,16,18]. Caribbean pine is found in the southern Yucatan in Belize, Honduras, Guatemala, and Nicaragua; varietals of Caribbean pine can be found in Cuba and the Bahamas on deep well-drained loam or sandy-loam soils that are mildly acidic [14-16,19]. Caribbean pine is moderately drought tolerant and moderately fire resistant, but does not tolerate frost shown in Table 1 [20].

These western and Mexican pine species compared to the two east Texas native pines to evaluate seedling survival and height and diameter growth over the first and second year post-planting.

MATERIALS AND METHODS

Site description

The Pineywoods ecoregion spans the states of Texas, Louisiana, Arkansas, and Oklahoma, characterized as semi-humid, with annual precipitations ranging from 120-140 cm. Soils are deep and fertile with a sandy loam texture. Soils found here can be slightly to moderately acidic, with pH ranging from 4.5 to 6.5, with occasional alkaline soils [21,22].

Four sites utilized for this study were located in Houston and Cherokee Counties, Texas, shown in Figure 1. Each site was a recently clearcut loblolly pine or shortleaf pine plantation, with varying soil series, topography, and post-harvesting vegetation composition. The Hickory site is located 27.3 kilometers East of Crockett, Texas on Laneville (Fine-silty, siliceous, active, thermic Fluvaquentic Eutrudepts) and Ozias (Fine, smectitic, thermic Aeric Dystraquerts)-Pophers (Fine-silty, siliceous, active, acid, thermic Fluvaquentic Endoaquepts) soil series [23,24]. The Arbor site is located 2.5 kilometers East of Crockett on Lovelady (Loamy, mixed, semiactive, thermic Arenic Glossudalfs) and Fuller (Fine-loamy, siliceous, superactive, thermic Albic Glossic Natraqualfs) soils. Lovelady soils are well-drained; Fuller is a fine sandy loam that is poorly drained. These soils contain similar soil composition in the subsoils, and are mostly used as pasture or woodland and support both loblolly pine and shortleaf pine [25,26]. Located 5.7 kilometers Southeast of Lovelady, Texas, the Maxwell site is on Fuller, Herty (Fine, smectitic, thermic Oxyaquic Vertic Hapludalfs), and Kurth (Fine-loamy, siliceous, semiactive, thermic Oxyaquic Glossudalfs) soil series. The site is dominated by the Herty soil series, a moderately well drained loam soil with low permeability. This soil often has shrink-swell clays in the subsoil that can impact tree form. The Kurth soil series is a fine sandy loam [27,28]. The Swink site is located 9.6 kilometers from Rusk, Texas on Lilbert (Loamy, siliceous, semiactive, thermic Arenic Plinthic Paleudults) soil series, well-drained loamy fine sand [29].

2021 field plot and planting design

Table 1: Silvical summary of the species utilized in this research.

Common name	Scientific name	Native range	Elevation (m)	Temperature (°C)	Precipitation (cm)	Soil texture
Loblolly pine	*Pinus taeda*	Southeast and Mid-Atlantic	150-365	13-21	101-142	Silt loam
Shortleaf pine	*Pinus echinata*	Southeast and Mid-Atlantic	3-910	9-21	114-140	Deep well-drained sandy loam soils
Ponderosa pine	*Pinus ponderosa* var. scopulorum	Southern Rocky Mountains	150-2,200	5-21	25-127	Loam and sand
Jeffery pine	*Pinus jeffreyi*	Interior California	150-2,900	5-21	58-111	Sandy loam and coarse loamy sand
Durango pine	*Pinus durangensis*	Northwestern Mexico	2,000-2,700	NA	60	Well-drained rocky soils
Caribbean pine	*Pinus carribaea var. hondurensis*	Caribbean Islands and Southern Mexico	100-700	22-28	60-400	Deep well- drained loam or sandy-loam soils
Mexican Weeping pine	*Pinus patula*	Eastern Mexico	1,500-3,000	9-23	100-220	Deep fertile clay soils and sandy loam soils

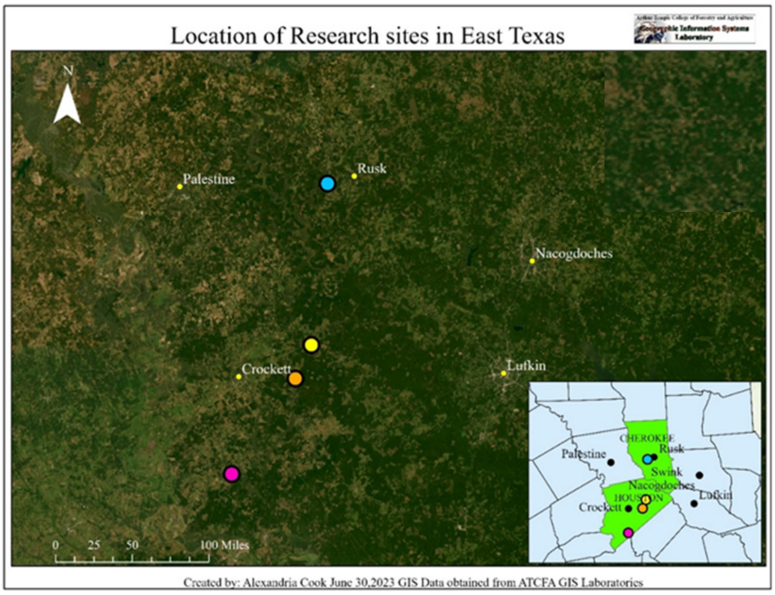

Figure 1: Location of the four research sites in East Texas. **Note:** ( ) Cities; ( ) Swink; ( ) Arbor; ( ) Hickory; ( ) Maxwell.

Planting at the Hickory, Maxwell, and Arbor sites occurred in November of 2021 on a 2.1 × 2.1 m spacing in 14 rows, for 196 seedlings per plot. The open pollenated West Coast species were purchased from New Mexico State University's John T. Harrington Forestry Research Center. Along with one variety open pollenated West Gulf Coast loblolly pine seedlings obtained from IFCO, two different ponderosa pine location sources (designated airport and mountain by New Mexico State University) and single sourced Jeffrey pine were planted in randomly assigned plots. In addition, a fifth plot with a randomly assigned mix of the four species was established.

Competition control for herbaceous vegetation was performed post planting during the growing season using a mixture of 140 milliliters per hectare of Velpar LVU and 9.57 milliliters per hectare of Oust XP. Manual removal of voluntary pine seedlings was performed as needed at an intermittent basis. Seedlings were planted early in the morning at a depth up to 20 centimeters and the soil compacted around each seedling.

2023 field plot and planting design

Seeds of Durango, Caribbean, and Mexican Weeping pines were purchased from Sheffield Seed Co. Following their instructions for seed scarification and stratification, seeds were placed in individual containers in Scotts® planting medium and grown in a greenhouse on the Stephen F. Austin State University campus and watered twice a day for a total of two hours each day for two years using an overhead misting system. At each site, four plots with the same spacing as in 2021 were established; one plot of open pollenated West Gulf Coast shortleaf pine with nine seedlings per row in nine rows, and one plot of either Durango pine, Caribbean pine, and Mexican Weeping pine with 10 seedlings per row in 10 rows. Seedlings were also to a depth up to 20 centimeters, and the soil compacted around each seedling.

Competition control for herbaceous vegetation was performed after seedlings were planted during the growing season using a mixture 114.8 milliliters per hectare of Velpar LVU and 5.38 milliliters of Oust XP per hectare at the smaller plots at the Swink, Hickory, and Arbor sites. Manual removal of voluntary pine seedlings was also performed as needed.

Field measurements

Survival was tracked over the entire study time period. Sites were visited two months after planting to obtain initial baseline heights and ground line diameters measurements to determine individual seedling growth over time. The heights were measured from bare mineral soil to the top of needles to the nearest 0.1 centimeter using a ruler, and diameters recorded at the base of the stem with digital calipers to the nearest 0.01 millimeter. Measurements were collected again in December of 2022 and 2023. Mortality, heights and diameters were also recorded and survival was assessed during the growing season. All data collection occurred over two dormant and growing seasons for the seedlings planted in 2021 and one dormant and growing season for the seedlings planted in 2023.

Statistical analysis

To compare the results without any edge effects, the outer rows on each plot were classified as buffer rows and data not collected from those rows. Analysis was performed using RStudio©. The Shapiro-Wilks test was utilized to test for normality. Analysis of Variance (ANOVA) was used to test both the effects of the sites on the species using heights and diameters, and to determine significant differences (p=0.05) between the species across sites and years, and a Tukey post-hoc test then performed. Survival was quantified as percent survival of each species at each site and year.

RESULTS

Survival

While all species planted in 2021 had high initial survival, by the end of July in 2021, Arbor had the greatest survival of all species; Maxwell had almost no survival, and Hickory survival was predominantly loblolly pine. Due to the substantial mortality at the Hickory and Maxwell sites, survival and growth were only assessed at Arbor for the remainder of the study. After the first growing season, the Arbor site loblolly pine survival was 69%, with ponderosa air at 49% and Ponderosa Mountain at 41%. After two years, loblolly pine had 44% survival, with the two ponderosa pine varietals having similar survival (4% and 5%), and Jeffrey pine had 1% survival. The Swink site had the lowest and the Hickory site the highest baseline survival of seedlings planted in 2023. By the end of July, no survival of Caribbean and Durango pines occurred at Swink, and no Caribbean pine survived at Hickory. After one year, shortleaf pine had 77.9% survival, with Mexican Weeping pine survival at 7.8%, but only at the Arbor and Hickory sites shown in Table 2.

Growth

For the 2021 planted seedlings, baseline heights and baseline diameters by site were significantly different (p-value<0.001), with Arbor having the greatest heights. After 1 year, loblolly pine heights were greater than ponderosa pine, and the airport location ponderosa pine had a greater height than the mountain location; after two years' loblolly pine heights continued to the be greater than ponderosa and Jeffrey pine; Loblolly pine diameter and height growth was significantly greater than the other 2021 planted species shown in Tables 3-5.

There were no significant differences in initial height and diameter at the site level for the 2023 planted species shown in Table 4. After one-year, shortleaf pine had greater height and diameter than Mexican Weeping pine at Hickory, which was the only site with any other species besides shortleaf pine. At the end of the first year, shortleaf pine showed significantly greater growth than Mexican Weeping pine, confounded by the low number (5) surviving Mexican Weeping pine seedlings shown in Table 5. Loblolly pine diameter and height growth was significantly greater than the other 2021 planted species, as was shortleaf compared to those planted in 2023.

Table 2: Survival of seedlings planted in 2021 and 2023. Measurements of seedling survival taken one month after planting, during the growing season and again during the dormant season.

Site	2021					
	Species	Baseline initial survival	First Mid- summer growing season survival	First year survival	Second Mid- summer growing season survival	Second year survival
Arbor	Loblolly pine	98	46	54	31	4
	Ponderosa pine (air)	99	81	66	61	44
	Ponderosa pine (mnt)	98	41	41	30	5
	Jeffrey pine	97	0	2	0	0.5
Hickory	Loblolly pine	98	8	*	*	*
	Ponderosa pine (air)	100	73	*	*	*
	Ponderosa pine (mnt)	98	1	*	*	*
	Jeffrey pine	100	2	*	*	*
Maxwell	Loblolly pine	98	1	*	*	*
	Ponderosa pine (air)	98	1	*	*	*
	Ponderosa pine (mnt)	98	0	*	*	*
	Jeffrey pine	91	0	*	*	*
Site	**2023**					
Arbor	Caribbean pine	7	0	0		
	Durango pine	79	61	46		
	Mexican Weeping pine	31	20	0		
	Shortleaf pine	31	11	0		
Hickory	Caribbean pine	4	0	0		
	Durango pine	93	79	77		
	Mexican Weeping pine	93	14	0		
	Shortleaf pine	73	50	7		
Swink	Caribbean pine	0	0	0		
	Durango pine	77	77	58		
	Mexican Weeping pine	93	37	0		
	Shortleaf pine	0	0	0		

Note: Survival was not gathered from the Hickory and Maxwell sites from the 2021 planting due to high mortality of the western pines. Survival for 2023 was only collected for one year.

Table 3: Mean diameters (mm) and heights (cm) with standard deviations in parentheses of loblolly pine, two location ponderosa pines, and Jeffrey pine seedlings at the Arbor, Hickory, and Maxwell sites. Ponderosa pine (air): Airport source; Ponderosa pine (mnt): Mountain source. Different letters within a column by site represent significant differences (p-value<0.05).

Site		Baseline		One year		Two years	
		Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)
Arbor	Jeffrey pine	3.99 (1.1)[a]	10.2 (3.5)[c]	7.33 (0)[a]	16.5 (0)[b]	29.9 (0)[c]	14.8 (0)[c]
	ponderosa pine (air)	5.6 (1.5)[b]	15.9 (3.9)[b]	7.1 (1.5)[a]	23.2 (6.0)[b]	12.4 (3.0)[b]	43.3 (8.2)[b]
	Ponderosa pine (mnt)	5.07 (1.3)[b]	16.7 (5)[b]	7.79 (1.8)[a]	22.2 (9.6)[b]	12.1 (2.6)[b]	36 (9.5)[b]
	Loblolly pine	3.79 (.8)[a]	28.4 (4.6)[a]	7.48 (2.1)[a]	45.1 (6.6)[a]	19 (6.2)[a]	94.4 (22.7)[a]
Hickory	Jeffrey pine	4.07 (.7)[a]	11.9 (7.6)[c]	-	-	-	-
	ponderosa pine (air)	5.63 (1.2)[b]	16.7 (4.3)[b]	-	-	-	-
	Ponderosa pine (mnt)	5.12 (1.1)[b]	19.6 (5.3)[b]	-	-	-	-
	Loblolly pine	4.03 (.8)[a]	26.3 (7.5)[a]	-	-	-	-
Maxwell	Jeffrey pine	3.37(.7)[a]	9.58 ± 1.67[c]	-	-	-	-
	ponderosa pine (air)	5.16 (1.1)[b]	18.4 (3.2)[b]	-	-	-	-
	Ponderosa pine (mnt)	4.86 (1.1)[b]	17.5 (3.9)[b]	-	-	-	-
	Loblolly pine	4.19 ± 2.5[a]	28.6 ± 3.6[a]	-	-	-	-

Table 4: Mean diameters (mm) and heights (cm) with standard deviation in parentheses for seedlings planted in 2023 at Arbor, Hickory, and Swink sites. Due to mortality, Caribbean pine and Mexican Weeping pine were removed after baseline measurements. Different letters within a column by site represent significant differences (p-value<0.05).

Site		Baseline		One year	
		Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)
Swink	Durango pine	10.2 (3.9)[a]	2.25 (.5)[b]	NA	NA
	Shortleaf pine	4.62 (1.2)[b]	25.2 (4.7)[a]	16.1 (5.9)	46.3 (8.7)
Arbor 2	Caribbean pine	2.73 (.24)[c]	33.2 (5.9)[c]	NA	NA
	Durango pine	2.24 (.65)[b]	9.93 (2.4)[b]	NA	NA
	Shortleaf pine	4.43 (1.6)[a]	26.7 (3.4)[a]	12.7 (0)	41 (9.7)
	Mexican Weeping pine	2.33 (.9)[c]	19.3 (6.2)[c]	NA	NA
Hickory 2	Caribbean pine	3.46 (0)[c]	31.2 (5.6)[c]	NA	NA
	Durango pine	2.22 (.5)[bc]	9.13 (2.8)[bc]	NA	NA
	Shortleaf pine	4.15 (.8)[a]	25.2 (3.95)[a]	11.3 (0)[a]	46.4 (10)[a]
	Mexican Weeping pine	2.79 (3.6)[c]	15.8 (5.2)[c]	8.04 (0)[b]	36.5 (14.2)[b]

Table 5: Growth in heights (cm) and diameters (mm) with standard deviation in parentheses of seedlings planted in 2021 and 2023 Ponderosa pine (air): Airport source; Ponderosa pine (mnt): Mountain source. Different letters within a column by site represent significant differences (p-value<0.05). For each of the calculated years of growth, n represents the number of seedlings alive.

	2021									2023		
	Year one growth			Second year growth			Two year growth			Year one growth		
Species	n	Height (cm)	Diameter (mm)	n	Height (cm)	Diameter (mm)	n	Height (cm)	Diameter (mm)	n	Height (cm)	Diameter (mm)
Loblolly pine	120	17.41 (11.10)^{a}	3.48 (2.64)^{a}	79	48.47 (26.17)^{a}	11.37 (6.92)^{a}	79	65.88 (23.70)^{a}	14.85 (6.40)^{a}	-	-	-
Ponderosa pine (air)	88	6.28 (7.07)^{b}	1.63 (1.94)^{c}	15	12.35 (12.18)^{c}	5.14 (3.72)^{b}	15	18.63 (9.93)^{b}	7.04 (3.18)^{b}	-	-	-
Ponderosa pine (mnt)	74	4.32 (8.14)^{b}	2.78 (2.11)^{c}	9	21.9 (12.14)^{b}	4.53 (3.61)^{c}	9	26.22 (9.01)^{b}	7.31 (2.94)^{b}	-	-	-
Jeffrey pine	4	6.45 (5.55)^{b}	3.25 (1.66)^{b}	1	-1.7 *	22.85*	1	4.2*	26.10*	-	-	-
Caribbean pine	-	-	-	-	-	-	-	-	-	-	-	-
Durango pine	-	-	-	-	-	-	-	-	-	-	-	-
Mexican Weeping pine	-	-	-	-	-	-	-	-	-	5	19.7 (14.56)^{b}	5.39 (3.83)^{b}
Shortleaf pine	-	-	-	-	-	-	-	-	-	91	19.25 (8.78)^{a}	8.71 (5.24)^{a}

Note: *= No significance letter was assigned to Jeffrey pine after the first year of growth due to low survival.

DISCUSSION

Survival

It was initially anticipated that ponderosa pine would have a higher survival than what was recorded due to its drought tolerance. For the 2023 species, the same was thought for Caribbean pine, mainly because the climate in East Texas is close to what this species experiences in its native range.

Based on seasonal trends, a "Triple-Dip" event occurs, which is categorized as cooler than average Pacific waters occurring multiple years in a row. The current event started back in 2020 and continued through 2023 [30]. Due to the mechanics of the La Nina cycles, drier and warmer air conditions during the winter and summer months are often seen [31]. Precipitation from May through August in both 2022 and 2023 was lower than the historical growing season amounts shown in Table 6 [32,33]. Major droughts having occurred over the last 20 years, with the last major drought from 2010 to 2013 shown in Figure 2. During the study period, temperatures were above average compared to the historical records from 1975 to 2023; these conditions would have greatly influenced both survival and growth in this study shown in Table 7 [30].

Competition played a huge role in seedling survival for the two western pines, particularly Jeffrey pine, during 2022; shrubs, grasses, and other understory vegetation competed for the same available moisture, leading to poor survival of Jeffrey pine. Even though an herbicide application was performed, the growth of competing species could have removed some of the available soil moisture. The understory "Southern Rough" form of competition is dramatically different than that found in ponderosa and Jeffrey pines ecosystems. Another potential cause for seedling mortality for Jeffrey pine could have been caused by the herbicide application. At certain stages of growth and time of year, herbicides can negatively impact this species [34]. While soil textures were compatible with many of the species' requirements, a potential reason for seedling mortality for Caribbean pine could have been other soil parameters. Alfisols, Inceptisols, Ultisols, and Vertisols all support all the species studied except Caribbean pine, which is often found on Oxisols.

Seedling survival could have also been influenced by inconsistent planting techniques. The volunteer planters had a range of experience using a dibble bar, and improper use of the bar could have allowed air pockets surrounding the roots, shallower than required planting depths, or root damage. Seedlings from an established nursery planted in 2021 had well established root systems with a nominal shoot to root ratio. Seedlings for the 2023 planting grown in the greenhouse had lower than optimal shoot-root ratios.

Growth

The western pines planted were from a climate that receives less rainfall than the East Texas region, and while they had ground line diameters greater than loblolly pine, grew slower. One reason for this could be that resources are often allocated to root development during droughts or periods of reduced soil moisture in the upper soil horizons.

Both western species enter dormancy based on photoperiod timing and temperature. Because temperatures usually do not reach below freezing in East Texas, temperatures triggering dormancy did not occur, and the photoperiod trigger did differ. Growth of ponderosa and Jeffrey pine do not have continuous growth pattern compared to loblolly and shortleaf pine, but rather a periodic growth. For the western pines to flush out, favorable temperatures required to produce more branches may not be obtained in east Texas [35].

Comparing the received rainfall for the East Texas region to the average precipitation the Mexican pine species receive, the values were within the normal range of what is seen in the regions the pine species is native. Since the seedlings were initially grown in a greenhouse, variables such as temperature, soil moisture, soil parent material, and sunlight were a constant for all of these seedlings prior to planting in 2023.

Table 6: Precipitation values from the Crockett, Texas and Overton, Texas weather stations for the summer months from 2022 to 2023 compared with the historical average from 1968 to 2021.

Month	2022 PPT (cm)	2023 PPT (cm)	Historical PPT (cm)
Apr	13.5	30.5	10
May	10.6	6.5	11.9
Jun	3.3	4.7	10.9
Jul	1.3	7.6	6.9
Aug	19.6	2.3	6.1
Sept	0.9	8	8.9
Total PPT	49.2	59.6	54.9

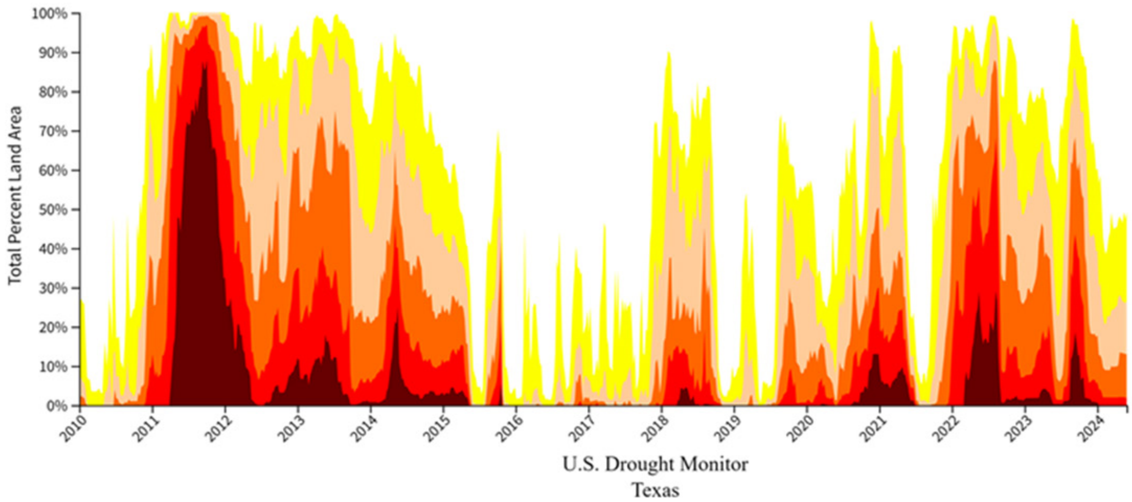

Figure 2: NOAA NIDIS U.S. Drought Monitor from 2010 to 2024 showing the intensity of across the state of Texas. Five categories were used to indicate the severity of drought. DO: Abnormally dry; D1- D4: Levels of severity with 1 being less severe and 4 being extremely severe. **Note:** ( ) D0; ( ) D1; ( ) D2; ( ) D3; ( ) D4.

Table 7: Mean temperatures, with maximum and minimums, per month at Crockett, Texas and Overton, Texas weather stations from 2022 to 2023 with the historical average for each month from 1975 to 2023. Temperatures represents the average temperature for the whole month, but does not show the event of record-breaking highs recorded for any day in the month.

Month	2022 Mean Max./Min. Temp (°C)	2023 Mean Max./Min. Temp (°C)	Historical Mean Max./Min. Temp (°C)
Jan	15.3/1.1	17.3/6.2	14.7/2.3
Feb	14.7/1.2	17.8/6.9	16.8/4.2
Mar	20.8/6.0	22.2/10.3	21.33/8.6
Apr	25.7/13.7	22.5/12.2	25.2/12.3
May	30.1/19.4	27.9/18.1	28.9/17.3
Jun	34.2/23.0	33.0/22.3	32.8/21.3
Jul	36.2/24.1	35.9/24.3	34.6/23.1
Aug	34.1/23.2	38.6/24.8	35.1/22.5
Sept	31.9/19.1	33.5/21.3	31.8/18.8
Oct	26.7/11.8	26.3/14.5	26.3/7.5
Nov	18.7/8.2	18.5/8.5	20.4/7.5
Dec	16.2/5.9	17.4/4.8	16.2/3.3

CONCLUSION

While survival was low for all of the introduced species, they still could provide future alternatives to current native species. Obtaining varietals of these species that more closely match our conditions could potentially increase survival and growth. Competing vegetation could have also played a role in the survival and growth of the species as the vegetation composition in East Texas is ecologically different than where introduced species are found. Different and more intense competition control, mirroring expected levels of competition found in their native ranges, may improve success of these species.

While the climate in East Texas has not reached a point in which we can no longer support our native pine species, future development and research of other non-native species should still be pursued as we anticipate ecological stress on the current native ecosystems.

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AUTHOR CONTRIBUTION

Alexandria Cook contributed with the majority of the field work, data analysis, and writing of the initial draft document. Brian P. Oswald initiated the idea and supervised the overall project. Hans Williams, Kathryn Kidd and Anusha Shrestha reviewed the proposal and final document.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

COMPETING INTERESTS

None.

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