LINKAGE BETWEEN LONGLEAF PINE SEEDLING MORPHOLOGY AND GRASS STAGE EMERGENCE

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EXTENDED ABSTRACT

While the early survival of planted longleaf pine (*Pinus palustris* Mill.) is anticipated, the juvenile growth of longleaf pine may be hindered by grass stage duration, which is variable and may extend for several years (Crouch and others 2020, Haywood 2007). Variable grass stage duration causes irregular tree size and underutilizes site resources, representing setbacks to maximum economic return after planting. Interest in the dual purpose of restoring longleaf pine ecosystems and producing longleaf pine timber will increase when length and variation of the grass stage are minimized.

Positive correlation between grass stage emergence and seedling growth measured by root collar diameter is well documented (Knapp and others 2018, Wahlenberg 1946). Not only does root collar diameter represent overall seedling growth, but it also reflects the potential for root system acquisition of water (Grossnickle 2012). We proposed that sustained early growth and rapid, uniform grass stage emergence are tied to morphological relationships favoring water uptake. Our objective was to assess the growth and grass stage emergence of four types of greenhouse-grown longleaf pine seedlings. We hypothesized that root variables linked to water uptake are associated with grass stage emergence.

One longleaf pine seed source each from Alabama (AL) and Florida (FL) were grown for 7 months in two commercial cavity types in 2019 by the International Forest Company in Moultrie, GA. Six seedlings from each of the four seedling types were randomly chosen for pre-plant measurements. Twenty seedlings per seedling type were planted in 22.5-L pots, 50 cm deep, containing commercial peat-vermiculite medium and randomly placed on greenhouse benches. Seedlings were grown for 52 weeks under ambient conditions, watered twice per week, and fertilized once with 40 g Osmocote Plus 15-9-12 in September 2020. By the end of March 2020, 10 percent seedling mortality was attributed to *Fusarium* root disease and in April 2020, Root Shield Plus+ WP was applied as a root drench to remaining live seedlings. Seedlings were harvested in November 2020.

Among the pre-plant and harvested seedlings, root collar diameter (RCD) and root and shoot dry mass were measured and total dry weight (TDW) and root-to-shoot ratio (R:S) were calculated. Seedlings were further analyzed for stem length and number of sinker roots having a diameter >2 mm at the end of the taproot. Proximal ends of sinker roots were severed from the taproot and distal ends of sinker roots were severed at a 2-mm diameter. Taproot and sinker root top and end diameters and lengths were measured, top

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and end areas were calculated, and volumes (cm^3) were estimated by the conical frustum equation (1):

$$\frac{\pi h}{3}\left(r_1^2 + r_2^2 + r_1 r_2\right) \tag{1}$$

where

h (cm) is length, r_1 (cm) is top radius, and r_2 (cm) is end radius. Sums of sinker root top and end areas and volumes by seedling were calculated.

Means and standard deviations of pre-plant seedling RCD, tissue dry weights, TDW, and R:S were determined. Two-way factorial analyses of variance using a completely randomized experimental design were conducted on harvested seedling RCD, tissue dry weights, TDW, R:S, stem length, and sinker root (number, total and maximum lengths, total volume, top and end areas) and taproot (volume, top and end areas) variables. Main effects were seed source (AL, FL) and cavity type (1, 2). Statistical significance was established at an alpha-level of 0.05 for means comparisons with the Tukey-Kramer test.

Before potting, RCD and TDW of AL Type 2 seedlings were 17 and 11 percent greater, respectively, than means among the AL Type 1 and FL Type 1 and 2 seedlings. Across cavity types, the R:S of AL seedlings was 28 percent greater than that of FL seedlings.

Twelve months after potting, seedling RCD and TDW responses to seed source and cavity type differed from pre-plant values. The RCD of FL seedlings was significantly greater than that of AL seedlings, and the TDW of FL Type 2 seedlings was significantly greater (67 percent) than that of the other three seedling types (table 1).

Twelve months after planting in 22.5 L, deep pots, the pre-plant seed source effect on R:S was no longer apparent, and R:S increased 72 percent across all seedling types. This validates the need for a favorable planting environment to optimize longleaf pine root system development. Despite this observation, lower pre-plant R:S among the FL seedlings compared to the AL seedlings preceded a post-potting dry mass investment strategy that benefitted both the shoot and root system of FL seedlings compared to AL seedlings.

One year after potting, seedling stature was greater among the FL Type 2 seedlings compared to both types of AL seedlings and the FL Type 1 seedlings. We speculate that early growth of the FL seedlings was accelerated, in part, by a R:S that favored foliage mass. As greenhouse growth progressed, greater carbon fixation by the FL seedlings enhanced overall growth. The subsequent influence of cavity type on FL seedling taproot and sinker root growth led to superior root system development of the FL Type 2 seedlings. While the number of sinker roots emerged from the taproot end did not differ across the four seedling types, total volume and length as well as maximum depth of sinker roots were generally greater among the FL Type 2 seedlings and were positively related to taproot end area and volume.

In September 2020, 10 months after potting, 25 and 64 percent of FL Type 1 and 2 seedlings, respectively, had initiated height growth, whereas only 6 percent of AL Type 1 seedlings and none of the AL Type 2 seedlings had initiated height growth. Two months later, stem lengths indicative of grass stage emergence were observed in 36 percent of FL Type 2 seedlings but only 7 percent of the AL Type 1 seedlings and none of the FL Type 1 or AL Type 2 seedlings. Linkage between taproot and sinker root development and grass stage emergence are being investigated further.

Table 1—Mean longleaf pine seedling morphological variables 12 months after potting and placement in a greenhouse

Variable	AL seed source		FL seed source	
	Cavity type 1	Cavity type 2	Cavity type 1	Cavity type 2
Root collar diameter (mm)[a]	19.9 ± 1.1 b[b]	19.5 ± 0.8	21.0 ± 0.9	24.0 ± 0.7
Root dry weight (g)[c]	40.7 ± 5.4 b	29.5 ± 2.9 b	40.9 ± 3.8 b	64.3 ± 5.3 a
Shoot dry weight (g)[c]	40.5 ± 6.0 b	30.2 ± 2.9 b	42.7 ± 3.8 b	60.8 ± 5.3 a
Total dry weight (g)[c]	81.1 ± 11.2 b	59.7 ± 5.3 b	83.7 ± 7.4 b	125.1 ± 9.6 a
Root-to-shoot ratio[e]	1.04 ± 0.04	1.01 ± 0.06	0.97 ± 0.06	1.10 ± 0.06
Stem length (cm)[a]	4.2 ± 0.7	3.3 ± 0.3 a	5.2 ± 0.4	6.5 ± 0.8
Taproot top area (cm^2)[a]	3.3 ± 0.4	3.1 ± 0.2	3.6 ± 0.3	4.6 ± 0.3
Taproot end area (cm^2)[c]	1.1 ± 0.2 ab	0.6 ± 0.1 c	0.9 ± 0.1 bc	1.4 ± 0.2 a
Taproot volume (cm^3)[c]	20.4 ± 2.5 b	21.2 ± 1.7 b	24.0 ± 2.0 b	36.6 ± 2.2 a
Number of sinker roots[d]	1.9 ± 0.1 a	1.7 ± 0.2 a	1.4 ± 0.2 a	1.9 ± 0.2 a
Total sinker root top area (cm^2)[c]	0.9 ± 0.2 ab	0.5 ± 0.1 b	0.8 ± 0.1 ab	1.2 ± 0.2 a
Total sinker root end area (cm^2)[e]	0.07 ± 0.01	0.07 ± 0.01	0.05 ± 0.01	0.08 ± 0.02
Total sinker root volume (cm^3)[c]	24.1 ± 6.2 a	9.0 ± 1.2 b	17.4 ± 2.7 ab	31.1 ± 4.7 a
Total sinker root length (cm)[c]	97 ± 14 ab	64 ± 9 b	66 ± 8 b	106 ± 11 a
Maximum sinker root length (cm)[c]	57 ± 7 ab	40 ± 2 b	48 ± 3 b	66 ± 5 a

Note: Two seed sources, Alabama (AL) and Florida (FL), were grown in one of two cavity types for 7 months in a nursery before potting.

[a] Seed source *P*-value < 0.05, FL greater than AL.

[b] Standard error.

[c] Seed source x cavity type *P*-value < 0.05; means within a row followed by a different lower case letter are significantly different by the Tukey-Kramer test at the 0.05 level.

[d] Seed source x cavity type *P*-value < 0.05; means not significantly different by the Tukey-Kramer test at the 0.05 level.

[e] No significant main or interaction effects.

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