THICKNESS AND ROUGHNESS MEASUREMENTS FOR AIR-DRIED LONGLEAF PINE BARK

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Abstract--Bark thicknesses for longleaf pine (*Pinus palustris* Mill.) were investigated using disks collected from trees harvested on a 70-year-old plantation. Maximum inner bark thickness was relatively constant along the tree bole whereas maximum outer bark thickness showed a definite decrease from the base of the tree to the top. The minimum whole bark thickness followed the same trend as the inner bark thickness while maximum whole bark thickness followed the same trend as the outer bark thickness. Greater bark thicknesses were observed along the northern face of the tree bole. Minimum/maximum whole bark thickness ratios, used as a measure of bark roughness, were fairly constant from the base of the tree up to a relative height near 60 percent; increasing values further up the bole reflected decreasing bark roughness. Comparisons of the data from the northern and southern faces suggested asymmetries in bark roughness around the circumference. Altogether, results demonstrate intriguing aspects of longleaf pine bark variability along the tree bole and in the four cardinal directions.

INTRODUCTION

The barrier properties imparted by tree bark to seal in moisture and protect against external damaging agents (e.g., fire, insects) are primarily served by the essentially dead outer bark (rhytidome). Particularly for the pines, the inner bark (phloem) contributes to the chemical and physical barriers formed via exudation of protective resins. Together, the outer bark and inner bark provide a complex and multifunctional system essential for secondary growth. Adding to the complexity of the outer bark is the presence of fissures that form as the girth of the tree bole expands. Since a fissure presents a zone of thinner outer bark, it would appear that minimum whole bark thickness may be more relevant than maximum whole bark thickness when speculating on the functionality of bark as a barrier. Although these fissures provide concealment for arthropods (Hanula and Franzreb 1998, Hooper 1996), the extent that they are a conduit to insect attack has yet to be clearly established. To date, whole bark thicknesses for longleaf pine (*Pinus palustris* Mill.) have been suggested to impact insect populations (Hanula and others 2000) and resistance to mortality from fire (Hare 1965, Martin 1963, Wang and Wangen 2011).

Measurements of bark thickness on the standing tree are also of interest from the perspective of utilization. Bark yields for the southern pines are roughly 10 percent along the bole (Cole and others 1966) and up to 60 percent for small branches (Phillips and others 1976). Given ongoing longleaf pine restoration efforts, a renaissance in longleaf pine harvesting (Landers and others 1995) will afford bark residues for utilization. Taking into consideration the functionality of bark on the living tree and its potential to be an actively-managed forest biomass resource, longleaf pine inner bark and outer bark maximum thicknesses were reported using fresh tree disks collected at five different sampling heights (Eberhardt 2013); in the present study, measurements were taken from these disks after drying under ambient conditions. In addition, minimum and maximum whole bark thicknesses in the air-dried state were measured on the complete set of tree disks taken every 0.61 m along each tree bole. These data are discussed in the context of the functionality of longleaf pine bark on the living tree.

MATERIALS AND METHODS

Fifteen 70-year-old longleaf pine trees were harvested in the summer (July 6 through July 25) from the J.K. Johnson Tract of the Palustris Experimental Forest located in the Kisatchie National Forest, LA. The felled trees were measured and then sectioned to afford 2-inch-thick disks every 0.61 m from the stump cut (0.15 m above ground level). Disks taken at approximately 0.15, 5, 10, 15, and 20 m, that had been measured for inner and outer bark thicknesses in the fresh state (Eberhardt 2013), were measured again after drying for 2 months under ambient conditions. One measurement for each thickness was taken with a digital caliper from each of the four quadrants designated on each disk: southwest, southeast, northwest, and northeast. Remaining disks (i.e., those not taken at the five above-specified

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heights) were allowed to dry before taking any bark thickness measurements. Maximum and minimum whole bark thickness measurements were taken from all air-dry disks. Microsoft Excel 2010 was used to conduct two-sample paired *t*-tests to test for differences between measurements from neighboring quadrants (e.g., northeast and northwest) and averages of values for each semicircle representing opposing cardinal directions (i.e., north vs. south, east vs. west). Since none of the comparisons between the eastern and western faces were significant, probabilities are only shown for comparisons of the northern and southern faces. It is acknowledged that handling of the tree disks may have unavoidably resulted in some losses of very loose outer bark layers.

RESULTS AND DISCUSSION

Trees used in this study had a wide range of growth rates with values for diameter at breast height ranging from 14.7 cm to 45.5 cm (Eberhardt 2013). Total heights ranged from 17.6 m for the most suppressed tree to approximately 29 m for dominant trees. Using the values for total tree height and the height at which each disk was taken, values for relative height were calculated. Maximum inner and outer bark thicknesses were previously reported for the fresh tree disks (Eberhardt 2013); figure 1 shows the corresponding plot using the data from the disks after air-drying. Since the trends are unchanged, data plots for the air-dried disks could be extrapolated to estimate values for fresh disks after accounting for bark shrinkage; air-dried disks are easier to process in that they are not constrained by timely measurements as are fresh disks. The caveat would be accounting for any variability in shrinkage around the circumference of the tree. Calculating values for shrinkage using thickness values for the fresh and air-dried disks suggested greater shrinkage for the northern face compared to the southern face (Eberhardt 2013). After drying, the differences in the inner and outer bark thicknesses between the northern and southern faces were more subtle (table 1) when compared by two-sample paired *t*-tests (inner bark, $P = 0.0139$, outer bark $P = 0.0184$); prior to drying, the differences were highly significant (inner bark, $P = 0.0009$, outer bark $P = 0.0002$). Thus, while variability in moisture content has a significant impact on the observed variability in bark thicknesses around the circumference of a tree, other factors (e.g., environment, microclimate) may promote greater bark thicknesses along the northern face. The insulation capacity of bark has been shown to be a function of its thickness and moisture content (Bauer and others 2010). Accordingly, the direction of a fire could be a minor factor for tree survival in instances where there are definite differences in bark moisture content and thickness around the circumference of the tree that would afford different levels of insulation.

Similar to the inner and outer bark thicknesses, the minimum and maximum whole bark thicknesses gave the best fit with logarithmic models when plotted against relative height (fig. 2); however, a better fit was obtained with the minimum bark thickness ($R^2 = 0.7491$, fig. 2) compared to the maximum inner bark thickness ($R^2 = 0.3806$, fig. 1). The plot for the minimum and maximum whole bark thicknesses relative to inside bark radius (fig. 3) was also similar to the previously presented plot for inner and outer bark thicknesses (Eberhardt 2013). Observations showed the minimum whole bark thickness and the maximum inner bark thickness were both relatively constant along the bole of the tree; as for the maximum whole bark thickness and the maximum outer bark thickness, both decreased logarithmically from the base of the tree to the top.

Comparison of the maximum and minimum whole bark thicknesses for neighboring quadrants gave higher values for the northern quadrants relative to the corresponding southern quadrants; comparing the northern face to the southern face showed the maximum whole bark thickness to be greater ($P = 0.0049$) on the northern face (table 2). There was no difference ($P = 0.8850$) between the northern and southern faces for the minimum whole bark thickness. At this juncture, it should be noted that the mean maximum whole bark thickness (6.81 mm) is essentially the same as the corresponding maximum outer bark thickness (6.73 mm). This discrepancy likely resulted from the use of data from five sampling heights in

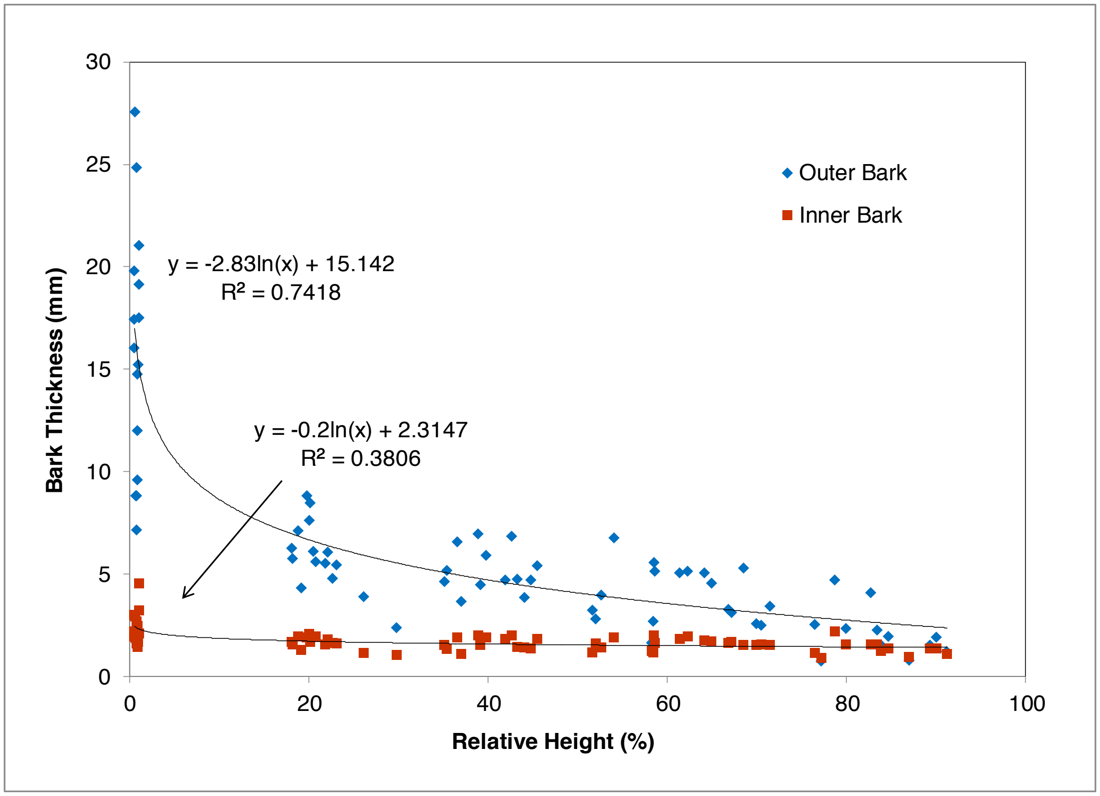

Figure 1--Maximum inner and outer bark thicknesses at relative heights up tree bole.

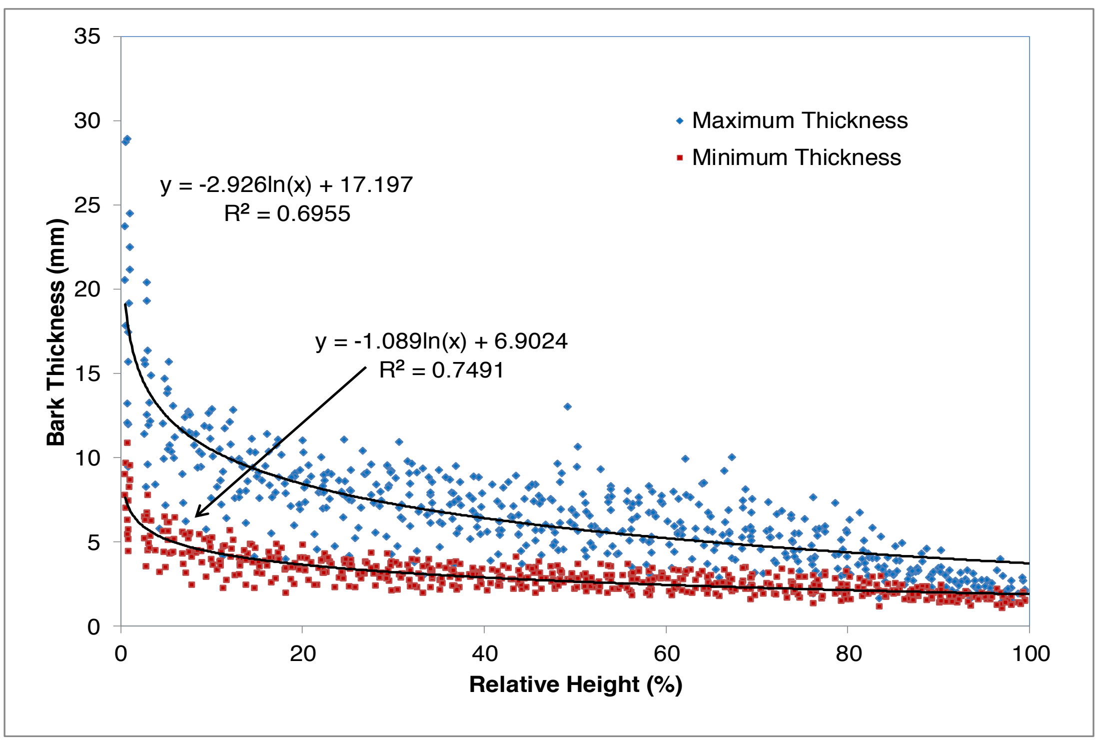

Figure 2--Maximum and minimum bark thicknesses at relative heights up tree bole.

Table 1--Two-sample paired mean analyses of maximum inner and outer bark thicknesses for northern and southern sampling orientations: comparisons for sample measurements taken before and after drying

Analysis	Means compared	Thickness measurement	Timing	Mean	*P* value
				mm	
1	North South	Inner bark	Before drying	2.183 2.013	0.0009
2	North South	Outer bark	Before drying	7.760 6.954	0.0002
3	North South	Inner bark	After drying	1.760 1.683	0.0139
4	North South	Outer bark	After drying	6.966 6.499	0.0184

Table 2--Two-sample paired mean analyses of whole bark thicknesses for northern and southern sampling orientations: comparisons for maximum and minimum bark thickness values

Analysis	Means compared	Thickness measurement	Mean	*P* value
			mm	
1	North South	Maximum	6.888 6.726	0.0049
2	North South	Minimum	3.037 3.035	0.8850

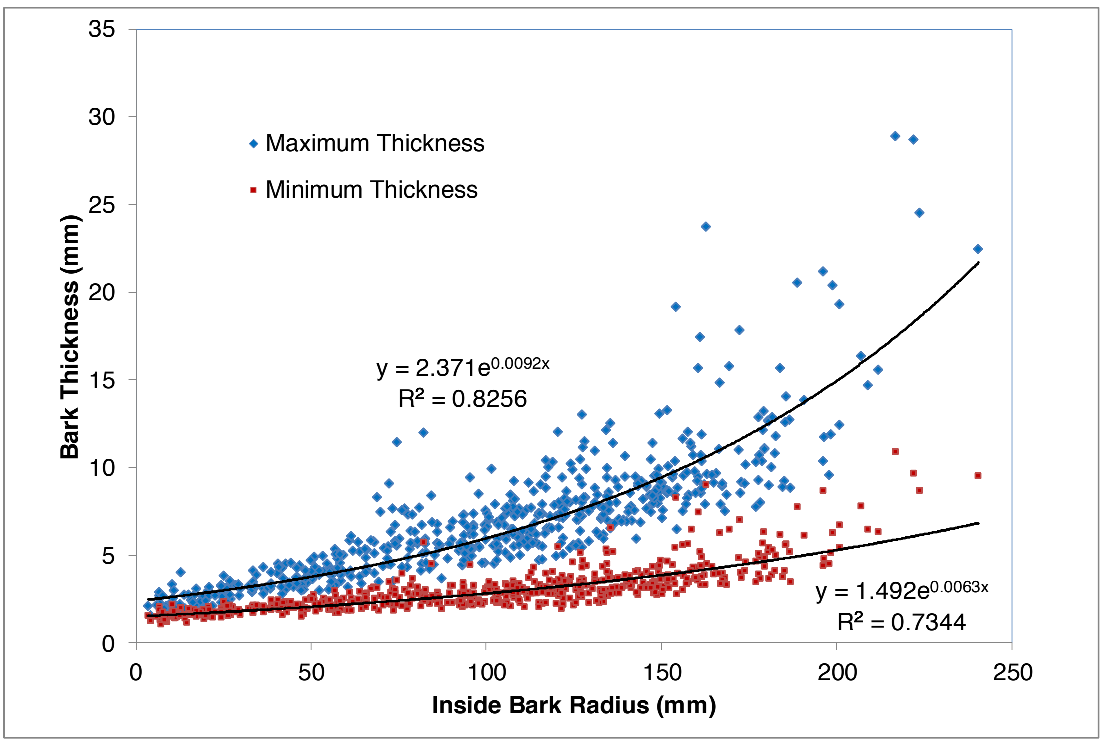

Figure 3--Maximum and minimum bark thicknesses relative to inside bark radius.

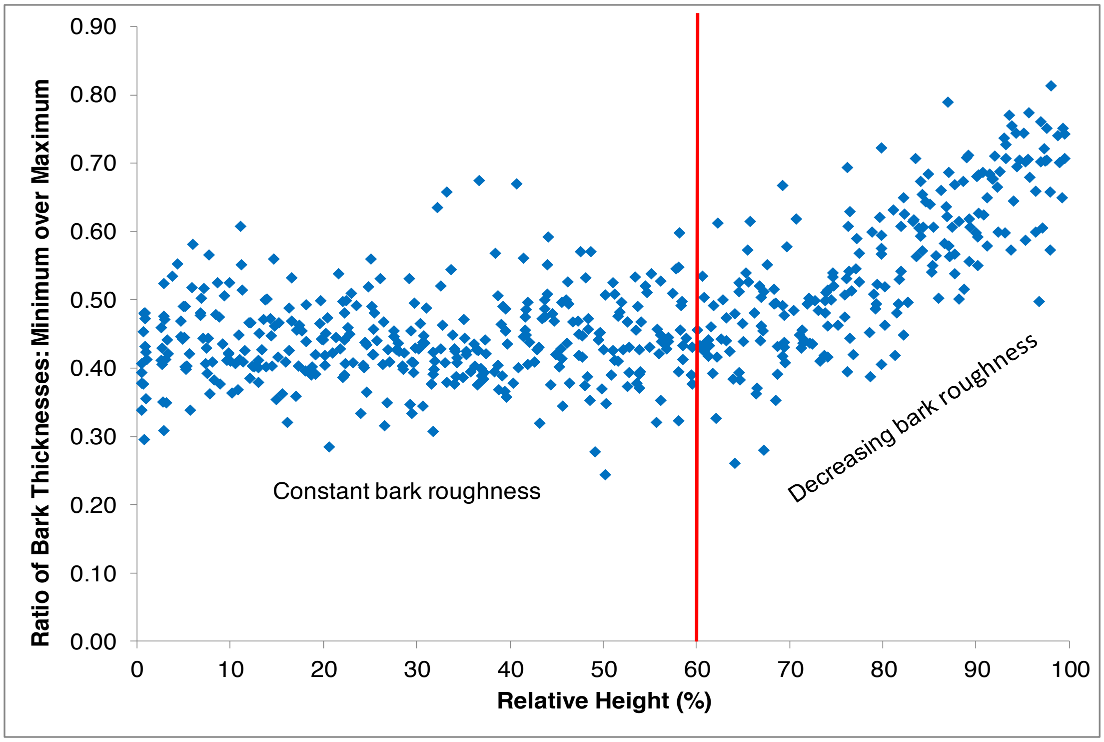

Figure 4--Ratio of bark thicknesses (minimum over maximum) at relative heights up tree bole.

Table 3--Two-sample paired mean analyses of whole bark minimum/maximum thickness ratios for northern and southern sampling orientations: comparisons at different relative sampling height ranges

Analysis	Means compared	Relative sampling height	Mean	*P* value
		%	*mm*	
1	North	0-60	0.4342	0.0077
	South		0.4443	
2	North	60-100	0.5547	0.5943
	South		0.5580	
3	North	0-100	0.4801	0.0261
	South		0.4875	

one case (outer bark thickness) and all sampling heights in the other (maximum whole bark thickness).

Measurement of the minimum and maximum whole bark thicknesses, and calculating a ratio of the two values, provided a crude assessment of the roughness of the bark; thus, dividing the minimum whole bark thickness by the maximum whole bark thickness gives the proportion of the whole bark that provides a continuous barrier around the circumference of the tree. Focusing on the microhabitat provided by bark fissures, more elaborate measures (e.g., bark-fissure index, fissure depth class) describe the fissure depth (MacFarlane and Luo 2009, Michel and others 2011). In the present study, plotting these minimum/maximum whole bark thickness ratios against the corresponding relative heights showed a fairly constant value (approximately 0.45) from the base of the tree up to a relative height near 60 percent (fig. 4). Above that relative height, the difference between the two thicknesses declined as it approached a ratio value of 0.80 at the top; an increasing ratio corresponds with decreasing bark roughness (i.e., decreasing fissure depth relative to the whole bark thickness). While differences in insect populations up the tree bole have been observed (Gargiullo and Berisford 1981, Hanula and Franzreb 1998), any relationships to differences in bark roughness have received limited attention. As with the other measurements of bark thickness, there is a statistically significant difference (table 3) between the northern and southern faces with a lower minimum/maximum bark thickness ratio (i.e., greater roughness) on the northern face along the main bole (relative height = 0 to 60 percent). It would be particularly intriguing if differences around the circumference of a tree could impact bark suitability for insect inhabitation.

CONCLUSIONS

While variability in moisture content impacts the observed variability in bark thicknesses around the circumference of a tree, other factors may promote greater bark thicknesses along the northern face. In longleaf pine, minimum whole bark thickness parallels the maximum inner bark thickness while maximum whole bark thickness parallels the maximum outer bark thickness. Measurement of the minimum/maximum whole bark thickness ratio appears to provide a simple measure of longleaf pine bark roughness asymmetries.

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