HYBRID SWEETGUM VOLUME EQUATIONS FOR A NORTH LOUISIANA AFFORESTED SITE FOLLOWING HERBICIDE APPLICATION

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Abstract—Investigating the suitability of hybrid sweetgum (*Liquidambar formosana* x *styraciflua*) as a biomass feedstock for Western Gulf forest industries requires information on stand yields. Using data from 2-year-old (1-0 seedling stock) hybrid sweetgum trees, equations were developed to estimate stem volume, comprising both wood and bark, on an afforested site in north Louisiana. Dummy variable statistical analyses concluded all data could be pooled across herbicide and varietal treatments to produce a single model system. Eighty-eight trees were measured for stem diameter at 1-foot increments from the groundline, and total stem height was determined from pole measurements. The volume of each section was calculated using Smalian's formula and summed to provide total stem volume. Eighty trees served as a model development set, with eight trees randomly withheld for validation. The square of groundline diameter (D_G^2) alone was determined to sufficiently predict stem volume, which could save managers time and effort when constrained by scarcity of resources at this stage of stand development. The validation set suggested our model over-predicted stem volume of smaller trees and under-predicted larger trees. Mean absolute deviation was 0.003 cubic feet, or 17 percent. Including tree height, form, and/or other variables as age increases will likely improve upon these estimates over time.

INTRODUCTION

Sweetgum (*Liquidambar styraciflua* L.) is a fast-growing hardwood species native to much of the Eastern United States (Martin and Harrell 1957). It is the most populous hardwood species growing on pine (*Pinus* spp.) sites in the South, but it grows fastest on bottomland sites (Koch 1985). Sweetgum quickly colonizes a site following disturbance, both naturally and by artificial regeneration.

Maintaining lumber quality through the drying process precludes sweetgum possessing any significant share of the appearance-grade hardwood marketplace, relegating it more commonly to lower-valued industrial products. Smaller, pulpwood-sized stems have long been a resource suited to pulping, with more limited use for oriented strand board production.

A relatively new practice becoming more commonplace is short rotation woody crop (SRWC) forestry, where the goal is to cultivate a crop of trees as rapidly as possible using techniques needed to improve growth rates (Kaczmarek and others 2012). Sweetgum is being investigated as a SRWC resource, but many questions related to SRWC need answering. Some, such as tolerance to cold and drought, resistance to disease, and fertilization requirements, must be considered prior to establishing a SRWC plantation (Kline and Coleman 2010); estimations of volume are also needed to predict yields in these stands.

The objective of this work was to develop stem volume equations using independent variables measured on an afforested field in north Louisiana. Tree measurements were conducted in a study examining the interactive effects of herbaceous competition control (two treatments) and hybrid sweetgum variety (five varieties) on yields using data from 2-year-old (1-0 seedling stock) hybrid sweetgum (*Liquidambar formosana* x *styraciflua*) trees.

METHODS

The study was located at Louisiana Tech University, South Campus (32° 30' 49.84" N. 92° 39' 11.59" W) in Ruston, LA. The study site was largely on an Angie fine sandy loam soil (Aquic paleudult), with a small portion on a Sacul very fine sandy loam (Aquic hapludult) (USDA NRCS 2019); no significant slope was present. The site had been used for grazing and hay production since 1990. During this time, horse manure was spread over the field occasionally as fertilizer. Prior to 1990, the

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Citation for proceedings: Bragg, Don C.; Koerth, Nancy E.; Holley, A. Gordon, eds. 2020. Proceedings of the 20th Biennial Southern Silvicultural Research Conference. e–Gen. Tech. Rep. SRS–253. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 338 p.

site was the interior of a racetrack dating back to the late 1970s, during which time Christmas trees were periodically grown on the site.

No fertilizer treatment was applied prior to planting because of the site's history of manure fertilization (Scott and others 2004). In preparation for planting, the site was subsoiled (ripped) to a 24-inch depth in late summer. One week before planting, 3 quarts per acre of glyphosate was applied (Accord XRTII® [Dow, Indianapolis, IN]) via backpack sprayer to remove any herbaceous vegetation present.

Prior to planting, containerized seedlings were left outside under a covered awning and watered daily to prevent soil from drying out. Seedlings were planted in late October 2015, by hand. Five hybrid sweetgum varieties were tested (AGHS1, AGHS2, AGHS3, AGHS4, AGHS8). The study was laid out in a split-plot design, with herbicide being the main plot and genotype as the sub-plot. Five replications were installed. Each row of the study was considered one plot, receiving a random herbicide treatment. The rows were divided into sub-plots of eight seedlings of each genotype. The internal six seedlings of each sub-plot were considered the test sub-plot, while the seedling at either end of the sub-plot was considered a border tree and removed from analysis. A total of 640 seedlings was planted. The seedlings were planted 5 feet apart along the row, and rows were 10 feet apart.

The herbicide tested was sulfometuron methyl (Oust XP®). Oust XP® was applied in a 36-inch-wide band using a boom sprayer attached to a tractor at 2 ounces per acre directly over the seedlings. The rate of 2 ounces per acre of Oust XP® was selected in accordance with recommendations for sweetgum based on prior studies (Kushla and Self 2013). In this study two treatments were studied, a no herbicide control and a single application of Oust XP® applied on February 17, 2016. This treatment was in accordance with the chemical company recommendations for Oust XP® to prevent seedling damage while still controlling competing vegetation into the growing season.

Measurements were conducted after two growing seasons in November 2017. To determine if herbicide application and/or variety caused a change in growth characteristics of seedlings after 2 years, seedlings from each block were randomly measured. Height was measured in 1-foot increments using a height pole from the ground level up to the highest living bud present on the seedling. Diameter was measured using calipers at each increment on both the lower and upper ends of the stem section beginning at the groundline. Groundline-diameter (D_G) was measured at ground level unless roots were exposed above the ground, where instead D_G was taken at the root collar. Eighty-eight trees were measured (table 1).

Equations were developed to estimate the amount of standing stem volume using 80 trees as a model development set. Independent variables investigated included D_G, tree height, and additional diameters along the stem (Schlaegel 1984) in various combinations of both linear and exponential form. All variables were natural logarithm (ln) transformed to account for non-constant variance. Prior to final model-fitting, dummy variables were used to see if separate volume equations were needed by herbicide, variety, or herbicide and variety interaction. The results showed that separate equations were not necessary. Thus, all data were pooled across treatments to produce a single model with no dummy variables present at $\alpha = 0.05$. The equations were then evaluated qualitatively to gauge both their statistical (regression F test and coefficient t tests) and practical significance (model R^2). Validation of the final equation used the remaining eight trees from the study.

RESULTS AND DISCUSSION

The relationship between D_G and volume was not altered by genotype or herbicide. This is worthy of tracking over time because resource consistency is desired among manufacturers for predicting yields and conversion efficiencies. The equation we felt most practically

Table 1—Summary statistics for 2-year-old sweetgum trees at an afforested site in north Louisiana

Statistic	Groundline diameter	Volume
	inches	*cubic feet*
Model development set (n = 80)		
Mean	1.35	0.025
Standard deviation	0.32	0.013
Maximum	2.17	0.075
Minimum	0.74	0.006
Median	1.32	0.022
Validation set (n = 8)		
Mean	1.14	0.018
Standard deviation	0.25	0.010
Maximum	1.51	0.031
Minimum	0.67	0.004
Median	1.19	0.018

captured the significant effects that tree size and form had on stem volume was Equation 1 in ln form (fig. 1), or its arithmetic equivalent, Equation 2:

$$\widehat{\ln Vol} = -4.41 + \left(1.06 * \ln D_G^2\right) \quad (1)$$

$$\widehat{Vol} = e^{-4.41+(1.06*\ln D_G^2)} \quad (2)$$

where

Vol is in cubic feet and D_G is in inches.

This single-measurement regression was significant (F = 841.79, p < 0.01), with R^2 = 0.92. The intercept b_0 (t = -166.43, p < 0.01) and slope b_1 (t = 29.01, p < 0.01) coefficients were likewise highly significant. This equation was concluded to be as good (but perhaps not better) a predictor of stem volume than linear forms of diameter at any height and total height. While the inclusion of other independent variables accounted for slightly more variance in stem volume than simply using D_G^2, (D_G^2H and $D_G^2D_3H$, where an additional diameter measurement was taken at height = 3 feet and H is total height, for example), these equations required multiple measurements.

Validation Analysis

Our model system on average under-predicted volume for the validation trees (figs. 2 and 3). Under-prediction appeared greater for larger D_G of the woody stem, but at smaller diameters volume was slightly over-predicted. Perhaps for particular D_G, biomass is more efficiently produced. Including height in the model may be more important in terms of practical significance for prediction of future observations rather than focusing strictly on statistical significance during model development.

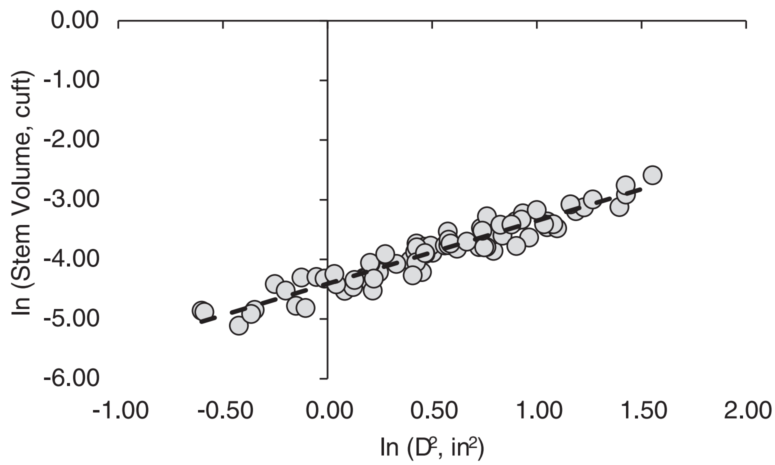

Figure 1—Plot of log-transformed stem volume versus the square of groundline diameter.

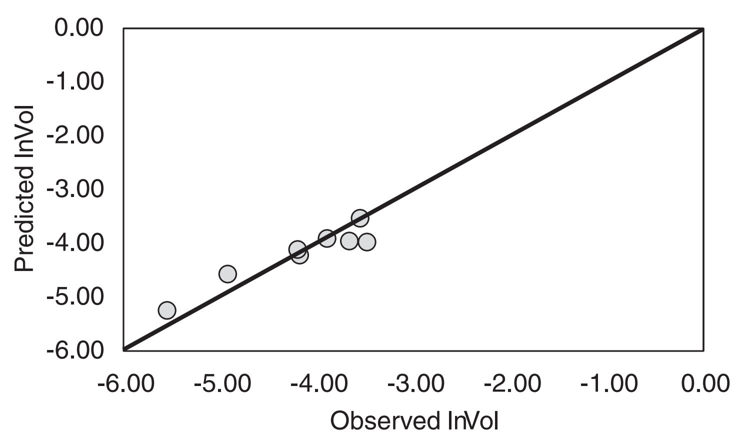

Figure 2—Comparison of predicted versus observed log-transformed stem volumes for the validation set.

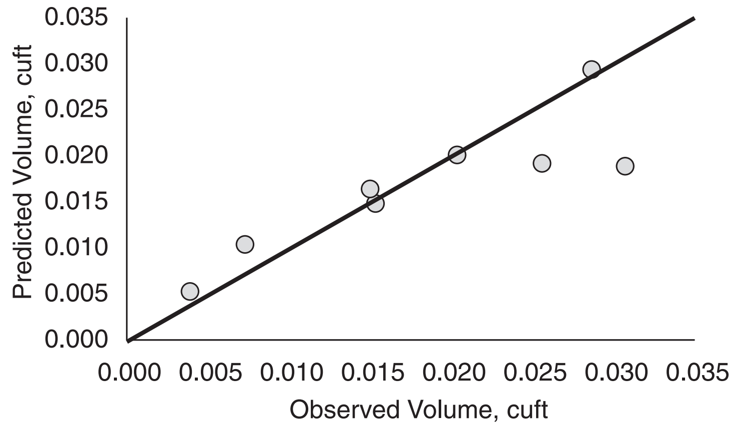

Figure 3—Comparison of predicted versus observed stem volumes for the validation set.

Using the Equation

The volume equation in arithmetic form represents the exponent to which the base is raised. This, however, returns a geometric mean rather than an arithmetic one. A correction factor, $\theta_2 = e^{s^2/2}$ (Flewelling and Pienaar 1981), was applied to adjust for logarithmic transformation bias, where the regression variance, s^2, was equal to 0.0254. We calculated θ_2 as 1.0128.

Suppose one wants to predict the volume of a hybrid sweetgum tree with a D_G of 1.25 inches; the equation would be used as:

$$\widehat{Vol} = e^{-4.41+1.06*ln(1.25^2)} * 1.0128 = 0.0198\,ft^3$$

SUMMARY

Data from 2-year-old (1-0 seedling stock) hybrid sweetgum trees treated with herbicide were pooled across treatment effects to develop stem volume equations on an afforested site in north Louisiana. The efficiency provided by taking a single measurement of D_G to predict hybrid sweetgum stem volume could save managers time and effort, particularly if constrained by scarcity of resources at this stage of stand development. The practicality of a single diameter measurement, coupled with a basic knowledge of spreadsheet applications, can allow most parties interested in sweetgum SRWC—even nonindustrial private forest landowners—to conduct an individual-tree or stand-level assessment using this equation.

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