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Individual Tree Volume Equations for Plantation Grown White Spruce in Northern Minnesota*

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ABSTRACT

Prediction equations for volume of plantation-grown white spruce (Picea glauca [Moench] Voss), both inside and outside bark, were developed from 115 trees. The allometric models $Y = AD^B$ and $Y = AD^B H^C$, where Y is volume, D is dbh, and H is total height were used. The addition of height to the model reduced the standard error for all estimates. Comparison of estimated volumes from these equations to volumes estimated by other equations in the Lake States region and eastern Canada showed that differences were small. Composite volume equations for white spruce in the Lake States region should provide reasonable estimates, regardless of individual tree culture (plantation versus natural) or sample location.

INTRODUCTION

Volume estimates for white spruce (Picea glauca [Moench] Voss) in the Lakes States region are usually determined from standard volume tables for natural stands (Gevorkiantz and Olsen 1955, Honer 1967). Limited data exist for prediction of individual tree volume for plantation-grown white spruce. This paper reports prediction equations for volume of plantation-grown white spruce, based on diameter at breast height (dbh) and total height. Comparisons are made to predictions from other white spruce volume equations developed in the Lake States and eastern Canada.

METHODS

Study plots (1/50 ha) were established in 39 fully stocked white spruce plantations, ranging in age from 19 to 43 years, in the areas of the Chippewa and Superior National Forests in northern Minnesota. Plot selection avoided stands with obvious insect and disease damage, competition from other tree species, and thinnings. Plantations were established from local seed sources. Three trees per stand were selected for sampling, including one dominant tree, one tree near the quadratic mean dbh of live trees on each plot, and one overtopped tree. Trees were not selected if they had abnormal form or were injured or damaged. Sample trees were felled at ground line.

Bolewood volumes were based on measurements from cross section disks removed each meter up the tree. Diameters, inside and outside bark, of each disk were measured. Smalian's formula was then used to determine the volume of each meter section (Husch and others 1982), with summed values resulting in a total above-stump volume, both inside bark (ib) and outside bark (ob) for each sample tree. Individual tree volumes were expressed in cubic meters. Total tree heights were measured to the nearest cm after felling.

Nonlinear least squares regression (Nie and others 1975) was used to determine coefficients for volume equations. Allometric models of the form $Y = AD^B$ and $Y = AD^B H^C$,

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where Y is total above-stump volume in m^3, D is dbh in cm, and H is total height in m, were used to develop the prediction equations. Weighted nonlinear methods were used because of heterogenity of variance (Crow and Laidly 1980). The inverse of the variance of volume, by 2 cm diameter classes, was used as the weighting factor (Husch and others 1982).

Comparisons to estimates for other volume equations often used in the Lake States region (including eastern Canada) were accomplished by predicting volumes for a selected range of diameters and heights. Estimates for English system equations were determined in cubic meters using conversion equations as defined by Demaerschalk (1972).

RESULTS AND DISCUSSION

The 115 sample trees spanned a range in dbh from 1.1 to 32.6 cm ($\overline{X}$=14.9 cm; S.E. = 0.64 cm) and in heights from 2.0 to 17.9 m ($\overline{X}$ = 11.4 m; S.E. = 0.39 m). The standard error of the estimate ($Y_i-\hat{Y}$) for prediction of volume (ib and ob) from dbh was fairly small ($Sy.x/\overline{y}$ = 18%) indicating a reasonable relationship between dbh and tree volume (Table 1).

The addition of height to the model reduced Sy.x for volume predictions by 46% (Table 1). The advantage of adding height to prediction models, however, can only be achieved if height is accurately estimated. In fully stocked plantations, errors associated with height measurements could easily offset the difference in the Sy.x's for the volume equations.

Comparisons of estimates for volume from this study to estimates from other predictive models in the Lake States and eastern Canada (Table 2) demonstrate that differences between locations and tree cultures (plantation versus natural) are so small that sampling errors or model selection may account for most of the variation. The volume estimates for this study were most similar to those based on natural stands across the Lake States (Gevorkiantz and Olsen 1955). This similarity occurred even though the percentage of bark volume for this study (8%) is almost one-half of the 15% reported by Gevorkiantz and Olsen (1955). Study estimates were most dissimilar to those based on natural stands across central and eastern Canada (Honer 1967). Berry's (1980) equations for plantations at Petawawa, Ontario, yield slightly lower estimates than did this study, while Jones' (1966) Lake States estimates were slightly higher. The similarity of estimates for the volume equations supports the original observations of Gevorkiantz and Olsen (1955) that a composite equation for white spruce in the Lake States region should yield reasonable estimates.

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Table 1. Coefficients of volume equations for white spruce of the form $Y = AD^B$ and $Y = AD^BH^C$, where Y is total above-stump stem volume in cubic meters, D is dbh in centimeters, and H is total height in meters.

Form	A	B	C	R^2	n	Sy.x	$Sy.x/\overline{y}$
$Y = AD^B$						(m^3)	(%)
Stem (ib)*	.000081	2.612		.97	115	.025	.185
Stem (ob)*	.000098	2.582		.97	115	.027	.183
$Y = AD^BH^C$							
Stem (ib)	.000047	1.958	.938	.99	115	.013	.100
Stem (ob)	.000058	1.954	.901	.99	115	.015	.103

*ib = volume inside bark, ob = volume outside bark

Table 2. Comparison of selected white spruce volume (outside bark)[a] estimates for individual tree equations using diameter and height as independent variables.

DBH (cm)	Total Tree Height (m)	Harding & Grigal Lake States (MN) Plantation[c]	Gevorklantz & Olsen Lake States Natural[b]	Jones (1966) Lake States (MI) Natural[b]	Berry (1980) Ontario/Petawawa Plantation	Honer (1967) Central & Eastern Canada Natural[b]
		Volume (m^3/tree)[b] — Study Source, Locations, Tree Culture				
10	10.0	.04	.04	.05	.04	.04
15	12.5	.11	.11	.12	.10	.10
20	15.0	.23	.23	.25	.20	.21
25	17.5	.41	.42	.43	.36	.37
30	20.0	.66	.70	.65	.60	.59
35	22.5	1.00	1.06	.93	.91	.89

[a]For Gevorklantz & Olsen (1955) total gross peeled volume plus 15% bark volume.

[b]Estimates for English system equations determined in cubic meters using conversions as defined by Demaerschalk (1972).

[c]Total volume above ground line stump.

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