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The Relationship of Bole Diameters and Crown Widths of Seven Bottomland Hardwood Species

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SUMMARY

Diameters, heights, and eight crown radii per tree were measured on 75 individuals from each of seven bottomland hardwood species in Mississippi. It was determined that the seven species could not be described by a single regression equation. Crown class was tested to see whether it significantly influenced the slope or intercept of the linear relationship. Three of the species were significantly affected. Total height was not a significant predictor of crown width. Regressions of average crown radius on d.b.h. were calculated for each species or species-crown class group. Roundness of crown was not affected by species but average crown radius/d.b.h. was. The crown width/d.b.h. relationship can be applied to competition studies and in predicting d.b.h.'s from aerial photographs.

Additional keywords: Crown diameter, stem diameter, southern hardwoods.

INTRODUCTION

A knowledge of the quantitative relationship between bole diameter (d.b.h.) and crown width is necessary for predicting diameters and volumes from aerial photos and for structuring of competition studies and models. Stocking and spacing studies can also benefit from an understanding of this relationship.

The crown width/d.b.h. relationships for a number of conifer species are given by Minor (1951), Smith and Baily (1964), Wile (1964), Roberts and Ross (1965), and Bonner (1968). The crown width/d.b.h. relationship of tropical hardwoods has also been reported (Dawkins 1963, Curtin 1964, Kwan 1966, Perez 1970). All these studies found a strong relationship between d.b.h. and crown width (R^2 = .6 – .9). In one study, total height was included as a variable. The crown width/d.b.h. relationship in temperate hardwoods has received a little attention. Krajicek and others (1961) found a very strong relationship (r = .98) between d.b.h. and crown width of open-grown white oak (*Quercus alba*), red oaks (Q. *velutina* and Q. *rubra*), and shagbark hickory *(Carya ovata*). They concluded that the relationship was independent of stand age or site quality. From studies on white oak, black oak (Q. *velutina*), Northern red oak (Q. *rubra*), scarlet oak (Q. *coccinea*), and hickory *(Carya* sp.). Minkler and Gingrich (1970) concluded that open-grown and forest-grown trees had the same crown width/d.b.h. relationship and that the relationship for these species appeared to be independent of site, crown class, and species. The crown width/d.b.h. relationship of bottomland hardwood species, the subject of this paper, has not been previously reported.

METHODS

Seven important local species were chosen for study. They were: sweetgum (*Liquidambar styraciflua*), green ash (*Fraxinus pennsylvanica*), sugarberry (*Celtus laevigata*), American elm (*Ulmus americana),* overcup oak *(Quercus lyrata*), Nuttal oak, (*Q. nutallii*), and willow oak (Q. *phellos*). Seventy five trees of each species without disease or major defect were selected for measurement. About one-third of the trees of each species were in the dominant, codominant, and intermediate crown classes. All the trees were growing on the Delta Experimental Forest near Stoneville, Mississippi, a 3,000-acre area covered with a slack-water clay soil currently mapped as the Sharkey series (very fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts).

Table 1.-*Means and ranges of diameter (d.b.h.), height, and average crown radius for seven bottom/and hardwood species*

Species	D.b.h.		Height		Crown radius	
	Average	Range	Average	Range	Average	Range
	····· *Inches* ····		---------------- *Feet*			
Sweetgum	14.9	6.0-28.4	81	56-I 06	13.3	5.4-20.9
Sugarberry	15.0	7.5-25.8	70	46-85	13.9	8.0-I 9.3
American elm	15.4	7.5-27.3	70	45-91	15.3	7.2–26.9
Green ash	15.4	6.0-28.5	78	56-I 00	14.9	6.5–26.9
Willow oak	19.9	8.2-35.9	80	58-99	17.9	7.1-31.2
Nuttall oak	18.8	6.8-35.3	77	55-99	20.8	8.4-33.1
Overcup oak	18.7	8.0–35.4	73	44-93	17.2	7.2-28.5

Each tree was measured for d.b.h., total height, and average crown radius. Crown radius was measured eight times per tree on the directions N., NE., E., SE., S., SW., W., and NW. This was done by stretching a tape from the trunk, compensating for the distance to the pitch, to a point visually located directly under the edge of the crown. The resulting measurements were summed and divided by eight.

Averages and ranges of height, d.b.h. and average crown radius for each species are given in table 1. The coefficient of variation of crown radius was calculated for each tree as an index of uniformity in crown shape (a perfect circle would equal zero percent). A crown/bole index [average crown radius (in feet) divided by d.b.h. (in inches)] was used in comparing species.

Analysis of covariance with dummy variables was employed to test whether a common regression equation could accurately describe the relationship between d.b.h. and crown width of all seven species. Tukey's test (Mendenhalll968) was used to compare ranked means of crown/bole index of the seven species. Species as a source of variation in roundness of crown was tested by the analysis of variance of the coefficients of variation of crown radius. A probability for error (α) of 0.05 was used in all cases. Linear regression models of average crown radius on d.b.h. were calculated for each species. Because crown classes were known, it was necessary to determine whether the relationship between crown radius and d.b.h. differed among crown classes of each species. For each species, each of the three combinations of two crown classes were compared for significant difference of variance, slope, and intercept. Where differences existed, separate regressions for each crown class were calculated.

RESULTS

A comparison of crown/bole indexes of the seven species shows that Nuttall oak had a significantly greater crown/bole index, while the other species varied in two overlapping groups (table 2). Sweetgum, often recognized for its narrow crown, had a crown/bole index about 25 percent smaller than that of Nuttall oak. Coefficient of variation of crown radii, compared by analysis of variance, revealed no difference in species with respect to roundness or uniformity of crown. Average coefficients of variation by species ranged from 20.5 to 24.1 percent.

Table 2.—*Average crown radius (in feet) divided by d.b.h. (in inches) for seven bottom/and hardwood species as compared by Tukey's test (a = 0.05)'*

Measurement	NO	AE	GA	SB	00	WiO	SG
CR/d.b.h.	1.133	1.020	1.012	.963	.955	.907	.903

[1] NO = Nuttall oak; AE = American elm; GA = Green ash; SB= Sugarberry; 00 = Overcup oak; WiO = willow oak; SG = Sweetgum. Lines under values for species indicate no significant difference.

Table 3.-*Linear regression equations, coefficients of determination, and coefficients of variation for seven bottom/and hardwood species*

Species	Regression'	R^2	C.V.
			Percent
Sweetgum	Y = 2.35 t .735X	.75	14.1
Sugarberry	Y = 6.61 t .486X	.61	12.5
American elm	Y = 3.36 t .776X	.81	12.5
Green ash	Y = 3.10 t .771x	.82	14.2
Willow oak	Y = 1.33 t .832X	.87	11.3
Nuttall oak	Y = 3.25 t .931X	.86	13.3
Overcup oak	Y = 3.95 t .709x	.87	11.8

[1] Y = average crown radius in feet; X = tree d.b.h. in inches.

Linear regression models of average crown radius on d.b.h. were calculated for each of the seven species (table 3). Coefficients of multiple determination varied from .87 for overcup and willow oaks to .61 for sugarberry. Contribution of the additional variables, d.b.h. squared and height, were evaluated with the F-test and found to be insignificant. A significant difference in slopes of the regression lines prohibited the use of a single equation to describe all seven species.

Crown classes within each species were tested by analysis of covariance to determine whether separate regression equations were needed within each species.

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Uniform variance and slope were found within the crown classes of all species. However, green ash, Nuttall oak, and overcup oak had at least two combinations of crown classes with different intercepts. New linear regression equations for each of the crown classes within these species are presented in table 4. Because the crown classes in this forest were closely tied to tree size, and thus crown radius and d.b.h. range, R^2 values were considerably reduced.

DISCUSSION

An unexpected result of the crown radius/d.b.h. ratio was that willow oak and overcup oak differed so little from sweetgum and so much from Nuttall oak. The reason is unknown. Although sweetgum and willow oak appear to be more efficient in accumulating more d.b.h. per unit of crown area than Nuttall oak or American elm, nothing is implied about growth rates.

Apparently, for the number of samples taken, no species produced rounder or smoother crowns than others. And evidently, natural hazards, such as storm breakage of limbs, not species differences, were the cause of deviations from roundness of crown.

The conclusion that height used in combination with d.b.h. was an insignificant predictor of crown width agreed with the findings of Cur-tin (1964) for eucalyptus but differed with the results reported by Bonner (1968) for northern conifers. Species may have had something to do with these differences.

The inadvisability of combining the data from different crown classes in three of the seven species indicates differences among crown classes, at least in Nuttall oak, green ash, and overcup oak. Even differences between crown classes within these species was not always consistent. A better comparison might have resulted if a broader range of diameters within each crown class had been sampled. Minkler and Gingrich (1970) reported that crown width/d.b.h. relationships of well stocked, uneven-aged stands of upland oak and hickories were independent of site, crown class, and species.

The crown width/d.b.h. relationship can now be used to predict stem diameters from crown widths on aerial photographs. Although basal area will continue to be used as the principal stocking guide and index of competition, crown width/d.b.h. relationships can be used to refine competition and stocking studies involving crown expansion where d.b.h. is known or can be predicted.

Table 4.-*Linear regression equations, coefficients of determination, and coefficients of variation for regression to predict average crown radius from d.b.h. for three bottom/and hardwood species*

Identification	Regression[1]	R^2	C.V.
			Percent
Green ash			
Dominant	Y = 11.82 + .454X	.41	16.5
Codominant	Y = 1.27 + .963X	.51	17.1
Intermediate	Y = .641 + .852X	.48	24.5
Nuttall oak			
Dominant	Y = 2.41 + .821X	.43	21.6
Codominant	Y = 5.38 + .679X	.41	19.6
Intermediate	Y = 1.27 + .752X	.42	33.3
Overcup oak			
Dominant	Y = .526 + 1.185X	.60	30.7
Codominant	Y = 6.27 + .686X	.41	16.2
Intermediate	Y = 1.76 + .829X	.39	17.5

[1] X = tree d.b.h. in inches; Y = average crown radius in feet.

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