THINNING GUIDELINES FROM CROWN AREA RELATIONSHIPS FOR YOUNG HARDWOOD PLANTATIONS

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Abstract—Crown closure in hardwood plantations signals the first opportunity to apply density control treatments such as thinning or release. The proper timing of these treatments is a function of stocking levels and is generally scheduled within several years after initial crown closure. Predicting crown closure for a plantation provides practitioners with the ability to plan intermediate treatments and is based upon crown development in a stand. Stem diameter and crown surface area relationships coupled with plantation spacing and age can be used to estimate crown closure. This study provides crown area relationships for 7- to 10-year-old free-to-grow *Quercus rubra*, *Q. alba*, *Liriodendron tulipifera*, and *Fraxinus americana* trees that were located in five plantations established over a wide range of site conditions from abandoned farm land to reclaimed surface mine sites in Kentucky. Stem ground line diameter ranged 0.5 to 6 inches and regressions of crown and stem diameters of free-to-grow trees indicated acceptable fit statistics with the majority of the species/site R^2 values $\geq$ 0.80.

INTRODUCTION

The scheduling of initial density control treatments in hardwood plantations can vary widely simply due to the range of planting densities common to hardwood plantings. Density control treatments, typically release or thinning, can be scheduled in naturally regenerating hardwood stands upon canopy closure and the timing of the treatment is relatively predictable based on forest type and site productivity. However, the wide range of planting densities associated with hardwoods, along with differences in growth and development associated with site variables, makes the scheduling of the initial release or thinning less consistent than is normally associated with naturally regenerating stands (Sharma and others 2003a). Regardless, tree to tree competition and the reduction in growth associated with competition will determine the biologic basis for the initiation of density control treatments (Curtis 1970). Generally, crown development and crown closure in an individual stand is an indicator of intra-stand tree competition and crown diameter/d.b.h. relationships have been used to establish guidelines for density control in naturally regenerating stands (e.g., Gingrich 1967). Historically d.b.h./crown relationships were determined for open grown trees and used to develop maximum crown areas, crown competition factors (Krajicek and others 1961), and tree area ratios (Chisman and Schumacher 1940) that were used to assess stand stocking providing recommendations for density control. This early work provided density control guidelines that were generalized by forest type. However, each species has unique crown architecture and crown diameter/d.b.h. relationships (e.g., Lamson 1987). Therefore species specific canopy closure models should be developed for monoculture stands or plantations to improve canopy closure predictions leading to density control prescriptions.

For plantations, the initial planting density, species, site, and environmental factors determine the time required for crown closure. Planting density is especially important because it is a known factor that can be controlled (Sharma and others 2003b). On a given site planting density, adjusted for mortality, can be used in conjunction with species specific crown/stem diameter relationships to predict canopy closure and the first opportunity for silvicultural stand density control.

The objective of this study was to determine crown/stem diameter relationships for young open grown trees of economically important hardwood species for the purpose of developing crown closure estimates for artificially regenerated plantings. Ultimately, this information can be used to predict the timing of density control prescriptions for both monoculture and mixed species plantations.

METHODS

Study Area

Sample trees were selected from hardwood plantations established in two physiographic regions of KY. One set of data was collected from two mixed species plantations established on abandoned agricultural land in Hardin and Grayson Counties in southcentral KY in the Pennyrile physiographic region. The second set of data was collected from three hardwood plantings established on surface mined lands in the eastern coal field (Perry and Knott Counties) lying in the Cumberland Plateau physiographic region of eastern KY. The surface mine site was constructed using loose spoil technology providing relatively uncompacted (1.4 to 1.8 mg/m^3) pH neutral spoil for planting to replace the relatively thin and clay rich naturally occurring soils common to the region. Initial survival and growth in both regions was similar. The temperate climate is also similar in both regions with precipitation averaging 118 cm (46.5 inches) per year. The average annual temperature is 13 °C with an average frost-free period of 180 days.

Hardwood Seedlings

In both regions mixed species hardwood plantations had been established using 1-0 bare-root seedlings. Ages of the plantations sampled ranged from 7 to 10 years and individual g.l.d. (ground line diameters, 1 inch above mineral soil) ranged 0.5 to 6 inches. Initial spacing of the plantations

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ranged from 6 by 6 feet to 12 by 12 feet, (1 200 and 300 trees per acre, respectively). For the purpose of this study only open growing northern red oak (*Quercus rubra*), white oak (*Q. alba*), yellow-poplar (*Liriodendron tulipifera*), and white ash (*Fraxinus americana*) trees were sampled across the range of g.l.d. available at each planting site. A total of thirty open grown trees of each species were sampled on agricultural lands and 135 trees per species were sampled on surface mine lands. Trees were selected for study if they were free-to-grow as indicated by at least two feet of free growing space on all sides of the crown. Trees having evidence of browse, mowing damage to stem or crown, main-stem forking, or dead or dying branches were not sampled.

Crown/Stem Diameter Measurements

G.l.d. was measured to the nearest 0.25 inch and horizontal crown diameters were measured with the aid of an ultrasound remote and transponder on two perpendicular axes. The outer limits of the crown were delineated by the lateral bud located farthest from the stem. Average horizontal crown diameters were used to determine horizontal crown surface areas and well as regressed against g.l.d. by species by plantation. As expected, simple linear regression was found to adequately describe the g.l.d. and horizontal crown diameter relationship for each species. Analysis of variance (ANOVA) was used to determine goodness-of-fit among regression variables (alpha level was set at 0.05). Significance among species was determined by the differences in least square means of the slope for each plantation and species using SAS software. No significant differences in species regression slopes were found among plantations within a region and plantation data were pooled within a region for further analysis.

Crown/stem diameter relations of northern red oak were combined with growth data and horizontal crown surface area and used to provide an example of how crown/stem diameter relations could be used to project crown closure, and thus the projected first entry period for release and/or thinning, in hardwood plantations.

RESULTS AND DISCUSSION

Coefficients of determination (R^2) ranged from 0.7606 to 0.8871 for crown and stem diameter linear regressions across all species and sites. Only northern red oak showed a significant difference in regression slope between regions at the $p \leq 0.05$ level (table 1). Northern red oak on the surface mined land produced a slope of 2.4334 compared to 1.7423 for agriculture land. This difference indicates the surface mine trees have a larger canopy diameter per increment of stem diameter. For example, a 2-inch red oak stem on the agriculture site has a canopy diameter of approximately 4 feet compared to 4.75 feet on the surface mine site. Regression slopes for other species did not differ significantly between regions.

Regression slopes among species on agricultural lands were statistically similar ($p \leq 0.05$) with the exception of white oak and yellow-poplar (p=0.0177) with white oak exhibiting a wider crown than yellow-poplar. While not statistically significant, there was a trend for northern red oak to exhibit a similar pattern. On surfaced mined lands white oak exhibited a significantly lower slope than the other species. Figures 1 through 4 show the individual tree data points and the average simple linear regression equations for all study trees by species providing generic crown/stem relationships. Coefficients of determination for the generic species equations ranged 0.7716 for white ash to 0.8829 for yellow-poplar. It is reasonable that these generic equations could be used by practitioners for developing average site occupancy and crown closure estimates when site specific data is not available. Figure 5 shows plots of the individual species equations for agricultural plantations and figure 6 shows plots for trees on surfaced mine sites. As previously discussed, the data indicate that crown/stem relationship can be affected by site. However, from a practical standpoint these differences

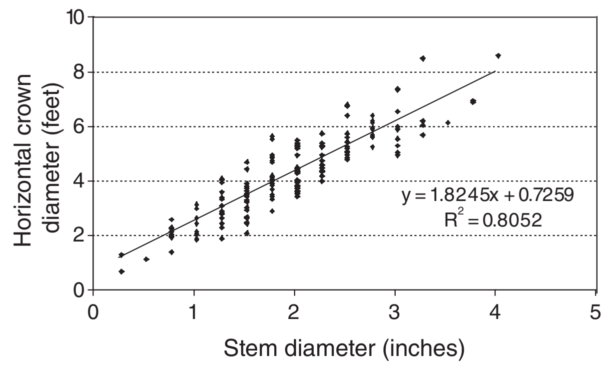

Figure 1—Average crown/stem diameter relationship for white oak (*Q. alba*).

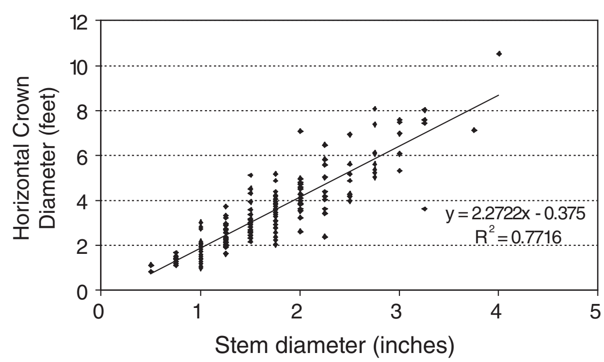

Figure 2—Average crown/stem diameter relationship for white ash (*Fraxinus americana)*.

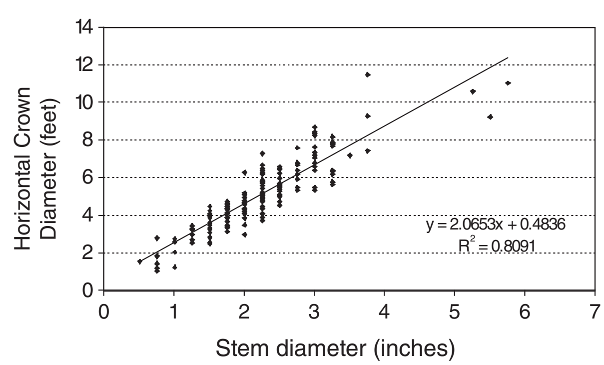

Figure 3—Average crown/stem diameter relationship for northern red oak. (*Q. rubra)*.

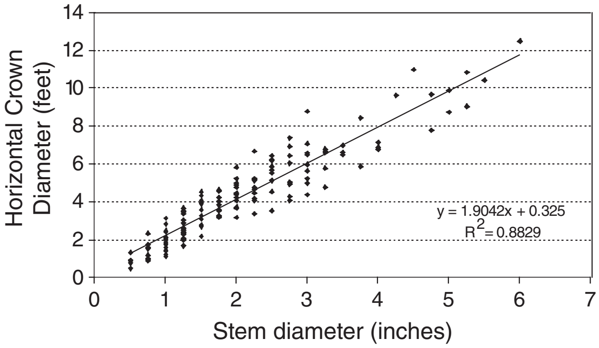

Figure 4—Average crown/stem diameter relationship for yellow-poplar (*Liriodendron tulipifera)*.

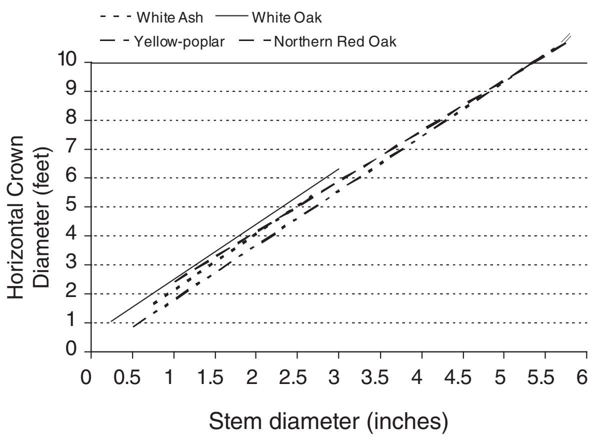

Figure 5—Linear regressions for hardwood plantations on agriculture land.

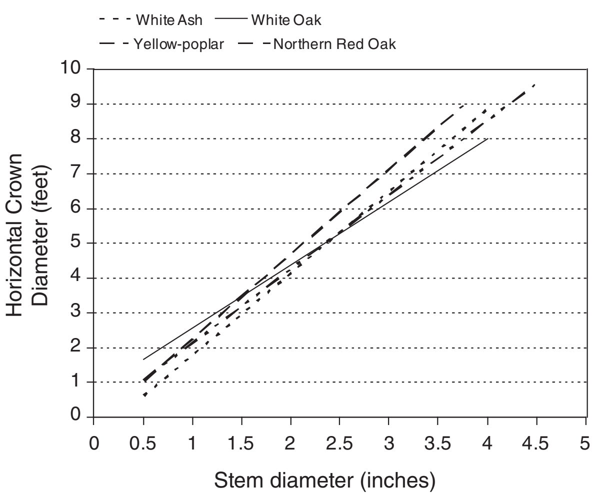

Figure 6—Linear regressions for hardwood plantations on surface mines.

are small and the data can be used to provide reasonable estimates of crown closure over a wide geographical area.

The resulting regressions provide a reasonable means of predicting when crowns will start to touch (crown closure) and when the site is fully occupied by canopy (canopy closure) for varying planting densities. Figure 7 is one example of how this data can be used for predicting site occupancy and

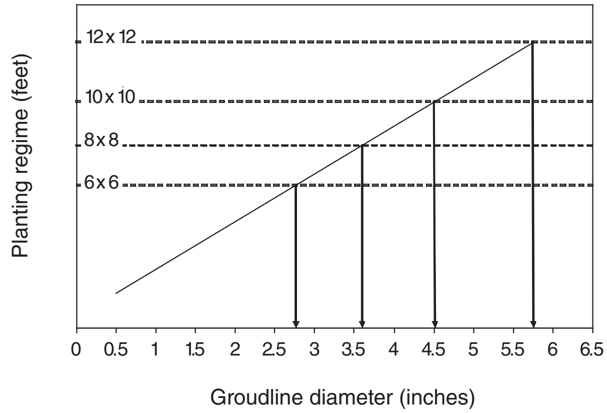

Figure 7—Estimation of ground line stem diameters required for crown closure for northern red oak (*Q. rubra*).

possible thinning regimes at a given planting density. The sloped line is the generic northern red oak regression. The X-axis is the average diameter of trees in the plantation and the Y-axis is the point at which trees at a given spacing would initiate crown closure. The solid horizontal lines indicate the point where crown closure starts for typical spacing's (assuming 100 percent survival). By following the horizontal line of a given spacing to the slope line and following down to the X-axis the practitioner can determine what average ground line diameter is required to achieve crown closure for a given spacing. This assumes 100 percent survival and that the crown/stem diameters for the trees in the planting are similar to ones found in this study. The latter assumption is reasonable given the similarity of relationships among the five dramatically different soils and sites sampled for this study. This method is a quick and easy way to predict future stand level growth parameters for hardwood plantations. Using the equations regenerated in this study, practitioners can determine estimates of site occupancy (ground cover) over time and estimate time required for crown closure of plantings. These estimations will improve their ability to schedule intermediate treatments and improve overall plantation growth and development.

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