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CROWN AND BOLE DIAMETER RELATIONSHIP IN *BRACHYLAENA HUILLENSIS* AND ITS APPLICATION TO SILVICULTURAL INTERVENTIONS

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Among the essential features of a tree's life cycle are some basic aspects of morphological structure and growth in relation to environment. It has been shown that the form of the stem is a function of the crown (Larson, 1963). An understanding of the relationship between the morphological features therefore has a practical bearing on forest management in terms of growth and yield as well as genetic improvement of a tree.

In the evaluation of the possible role of tree morphology and form on growth and productivity, inheritance must be taken into consideration, and it must constantly be borne in mind that all trees are predisposed to assume a certain form. Environmental influences and cultural practices can only modify the basic form which is predestined by heredity. Most variations in stem form may be traced to changes in the size and distribution of the live crown on the stem and to the length of the branch-free bole (Larson, 1963).

Crown diameters bear a definite relation with their bole diameters irrespective of site and age and in some cases irrespective of treatments (Dawkins, 1963). When any kind of definite relation can be discovered between crown diameter and bole diameter, then it is possible to predict the basal-area density of a crop for any given canopy density, and vice-versa. Such relationships have been used in the evaluation of initial espacement of a species (Kwan, 1966), and for stocking control in plantation stands (Suri, 1975 and Mugasha, 1980).

The crown-bole diameter relationship may also be used in defining the ecological and silvicultural behaviour of a species. Among these is the sensitivity to or tolerance of crown density and possibly to basal-area density. The present paper reports on results of an investigation of the relationship between crown diameter and bole diameter of *B. huillensis* and its possible application to stand density control.

MATERIALS AND METHODS

Data Collection

Crown and bole diameters at breast height of 87 trees of *B. huillensis* in Ngong and Karura forests, Kenya, were measured. A wide range of diameters and heights was sampled (Table I). Diameters of the tree boles were measured with a diameter tape to the nearest one-tenth metre by measuring three radii in pre-determined directions. A 2-m rod was used to help the assessor in aligning himself vertically at the edge of the crown. This was facilitated by a second person standing away from the crown and directing the assessor to move in or out with a raised rod to help gain closer alignment with the crown edge. Once at the edge, the assessor was directed to stand still and the radius of the crown taken from that position to the centre of the tree bole at a height of 1.3 m. For each tree, three such measurements were made. The mean of the three radii multiplied by 2 gave an estimate of crown diameter.

Data Analysis

Least square regression (Minitab regression program) was employed in the determination of the relationship between crown and bole diameters. The strength of the relationship was tested by the use of coefficient of determination (r^2).

One problem of determining the growth rate and suitable cutting cycles is the lack of information on expected growth capacity and terminal cutting sizes under growth conditions associated with varying densities in space and time. It is therefore desirable to develop a possible espacement and stocking control which could be used as an operational guide. This was made possible through the use of a regression relationship between crown and bole diameter, developed for *B. huillensis*.

Knowledge of crown-stem diameter relationship, when combined with estimates of canopy closure, enables the stocking and basal area of a stand to be predicted for any given basal area using the relationship:

$$\frac{\text{Unit area (1 ha) X Canopy density}}{(\text{Crown: bole diameter ratio})^2 * \text{Basal area } (m^2/ha)}$$

Theoretical values of crown closure will be 79% for square spacing and 91% for equilateral triangle spacing. However, such regular spacing will never occur in practice, and it must be assumed that crown shape will be sufficiently plastic to accommodate the irregularity of spacing, without altering the crown projection area. This assumption was also made when using crown closures above 91%, which are theoretically impossible for circular crowns.

Crown diameters of various bole diameters were estimated from the developed regression equation and corresponding crown:bole diameter ratios computed from the two parameters. Maximum attainable basal area by a crop of *B. huillensis* of various mean dbh was estimated from the crown closures. Using the derived basal area and canopy density cover, a feasible stocking control was proposed. The range of possible stockings using crown closures of 50%, 90% and 100% were also estimated.

Results and Discussion

The Crown-Bole Diameter Relationship

There was a positive linear relationship between crown diameter and bole diameter, $Y = 0.98 + 0.151x$; $r^2 = 0.76$, where Y is the crown diameter in m and x is the bole diameter in cm. It is possible that the coefficient on x will change with stand density. However, provided that the same crown:stem diameter equation is used throughout, a useful relative index of stand density and crown competition can be developed and monitored. Dawkins (1963) concluded that for intolerant species, neither site quality nor stand density had any significant effect on the relationship. The crowns of other medium tolerant species were affected by stand density, but remarkably less by site quality.

Stana Density Control

To improve production of individual trees, the trees in a stand must have unrestricted continuous freedom for growth. Maximum stand production is achieved at much higher densities than maximum individual tree growth. For a forester to achieve maximum stand production, information on the carrying capacity with time is required. Table II shows estimates of maximum possible carrying capacities in terms of basal area and density per ha for *B. huillensis* growing with its canopy closure maintained at 79%. It is assumed that 79% crown closure will give a first approximation to the conditions for maximum stand growth.

Table I—Diameter and Height Characteristics of Sample Trees

DBH class	No. of trees	Height class	No. of trees
0.0–5.9	4	0.0–2.9	0
6.0–10.9	20	3.0–5.9	6
11.0–15.9	20	6.0–8.9	17
16.0–20.9	21	9.0–11.9	13
21.0–25.9	27	12.0–14.9	26
26.0–30.9	14	15.0–17.9	26
31.0–35.9	3	18.0–20.9	18
36.0–40.9	4	21.0–23.9	5
41.0–45.9	1	24.0–26.9	2
46.0–50.9	1	27.0–29.9	2
51.0–55.9	0	—	—
56.0–60.9	1	—	—

TABLE II—RELATIONS BETWEEN CROWN AND BOLE DIAMETER IN *BRACHYLAENA HUILLENSIS* AND LIMITING STAND DENSITY

dbh (cm)	CD (m)	CD:BD ratio	STAND DENSITY (m^2/ha)	(stems/ha)
5	1.7	34	6.83	3480
10	2.5	25	12.64	1610
15	3.2	21	17.91	1014
20	4.0	20	19.71	628
25	4.8	19	21.88	445
30	5.5	18	24.38	345
35	6.3	18	24.50	255
40	7.0	18	25.80	205
45	7.8	17	26.23	165
50	8.5	17	26.89	137
55	9.3	17	27.54	116
60	10.0	17	28.26	100
65	10.8	17	28.52	86
70	11.6	17	28.85	75
75	12.3	16	29.14	66
80	13.1	16	29.64	59
85	13.8	16	29.97	53

CD = Crown Diameter
BD = Bole Diameter

TABLE III—INTERIM DENSITY CONTROL REGIME FOR *BRACHYLAENA HUILLENSIS* IN PLANTATION

dbh (cm) AT	Basal area (m^2/ha) AT	Density control (stems/ha) BT	AT	Thinning interval (years)	Thinning intensity (%)
		Espacement, 2.0X2.0m			
—	—	= 2500 (stems/ha)		—	—
10	15.7	2500	2000	—	20
12	18.1	2000	1600	5	20
15	21.2	1600	1200	7	25
20	25.1	1200	800	11	33
25	19.6	800	400	11	50
35	24.0	400	250	20	38
45	23.8	250	150	22	40
55	23.9	150	100	22	38

BT = Before thinning
AT = After thinning
Thinning intensity (%) = Basal area removed in terms of percentage of stems

An interesting value in the table is the crown-:bole diameter ratio of 17 at mean bole dbh of 45 to 60 cm. This ratio allows a maximum attainable basal area of about 28 m^2/ha. Other workers have reported values close to 17 for tropical secondary and intermediate light demanding species. Mugasha (1980) working on *Ocotea usambarensis*, obtained a ratio of 20.7 and Kwan (1966) obtained 17.5 as the crown:bole diameter ratio with *Dyera costulata* at the 60 cm dbh. Dawkins (1963) obtained crown:bole diameter ratios ranging from 19–25 with several tropical secondary hard wood species. He concluded from his studies that an average crown: bole diameter ratio of 20 permits tropical hardwood of even-aged crops to attain 19–23 m^2/ha of basal area without serious crown interference. Estimates for *B. huillensis* are slightly outside the range, crown:bole diameter ratio being 17 with maximum basal area at 28 m^2/ha. The lower crown:bole diameter ratio is a reflection of the smaller crown diameter characteristic of the tree. This allows the possibilities of accommodating more crown individuals per unit area and hence a higher maximum limiting basal area. This also implies that while it is more critical to maintain the crown:bole diameter ratio of more wider crowns of most secondary species to avoid crown overlap and possible deterioration, crown development in *B. huillensis* will be less affected by the adjustments of the ratio.

With the available information (Table II), it was possible to develop some density control of the existing as well as the upcoming monoculture wood lots of *B. huillensis*. The observed crown bole diameter ratio suggests that the basal area of a managed *B. huillensis* crop may not exceed 28 m^2/ha without crown overlapping. Since *B. huillensis* is a shade bearer, at least in its early phase of growth, it is possible to maintain some degree of overlap without serious crown deterioration. Computed basal areas for a crop maintained at crown closures of 100, 90 and 50% are presented in Fig. 1 and compare closely with a crop maintained at 79% canopy closure.

It is not yet clear whether a young crop of *B. huillensis* is capable of responding fast to release since present studies suggest low rates of change in crown spread with age, which culminates when the mean tree size is about 45 cm dbh. To be able to silviculturally give attention to the overcrowded monoculture crops of this species, there is need to generate information on density control of a growing crop.

Suggested Interim Density Control Schedule

Considering a case for managing *B. huillensis* in monoculture woodlots, and using information on basal area developed for a crop maintained at 79% canopy closure, Table III was produced to show a possible thinning schedule. The schedule is based on estimated maximum attainable basal areas per unit area and tree size. Similar tables may be produced by assuming other canopy closures.

Control of density is carried out at onset of the maximum basal area to reduce competition, or loss of wood due to creation of excessive spaces. Individual trees standing in the open were highly tapered, short, multi-stemmed and coarsely branched. For this reason and the fact that the conical shape of the tree suggests its ability to stand a relatively high density, first thinning can be delayed to a mean stem size of about 10 cm dbh or even higher. The tree does not root deeply as indicated by many wind-blown individuals and, therefore, density release should be by careful low crown thinning to avoid possible wind throws. Initially, thinning intensity should be kept near the estimated limited basal area capacity until more data on response to release is available. Further density control intervals take care of proper utilization of space.

In the light of the growth rates of *B. huillensis* in natural conditions, a realistic mean bole diameter growth rate of a plantation crop, 0.45 cm/year was used in regulating the intensity of thinning and time intervals. As a result of the silvicultural characteristics of *B. huillensis*, especially in regard to crown form and its susceptibility to developing multi-stemmed trees and to suffer from wind-blow, short thinning intervals of low intensity were initially adopted. Since older individuals slow down in general development, response to thinning would also be slow and thinning cycles become longer as mean tree size increases. The final thinning is fixed at about a mean stem size of 55 cm dbh. Before and slightly above this size, not much growth is going on and it is therefore justified to recommend felling the crop any time after this mean size depending on the economics of the market.

B. huillensis is a shade tolerant species and its success and management as a plantation tree may present some problems. It is suggested that future plantation woodlots should be in mixture with suitable nursing trees like *Croton megalocarpus*, *Vitex keniensis*, *Ocotea usambarensis* or

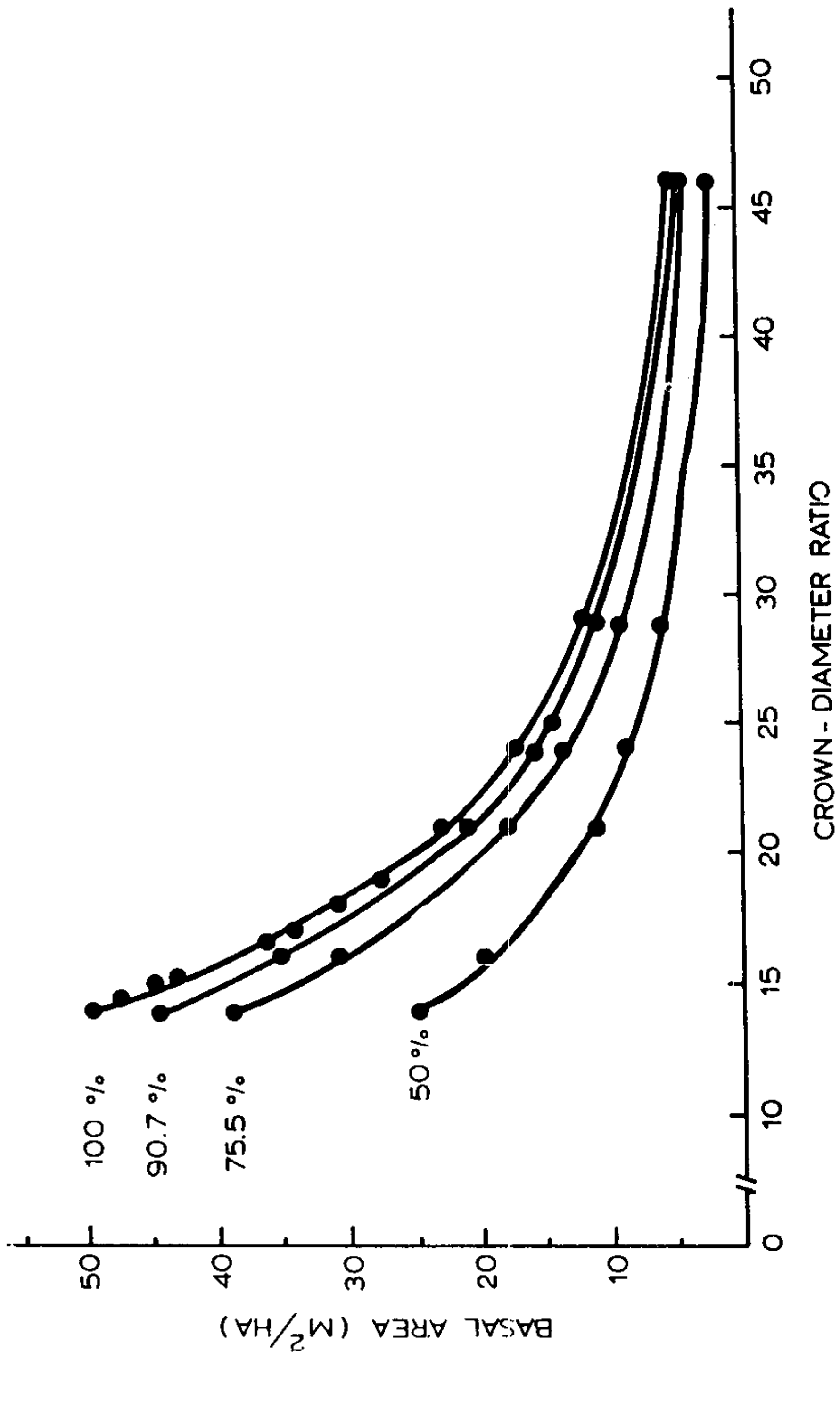

Fig. 1: Relationship between basal area density, crown diameter ratio and percentage canopy closure in *Brachylaena Huillensis.*

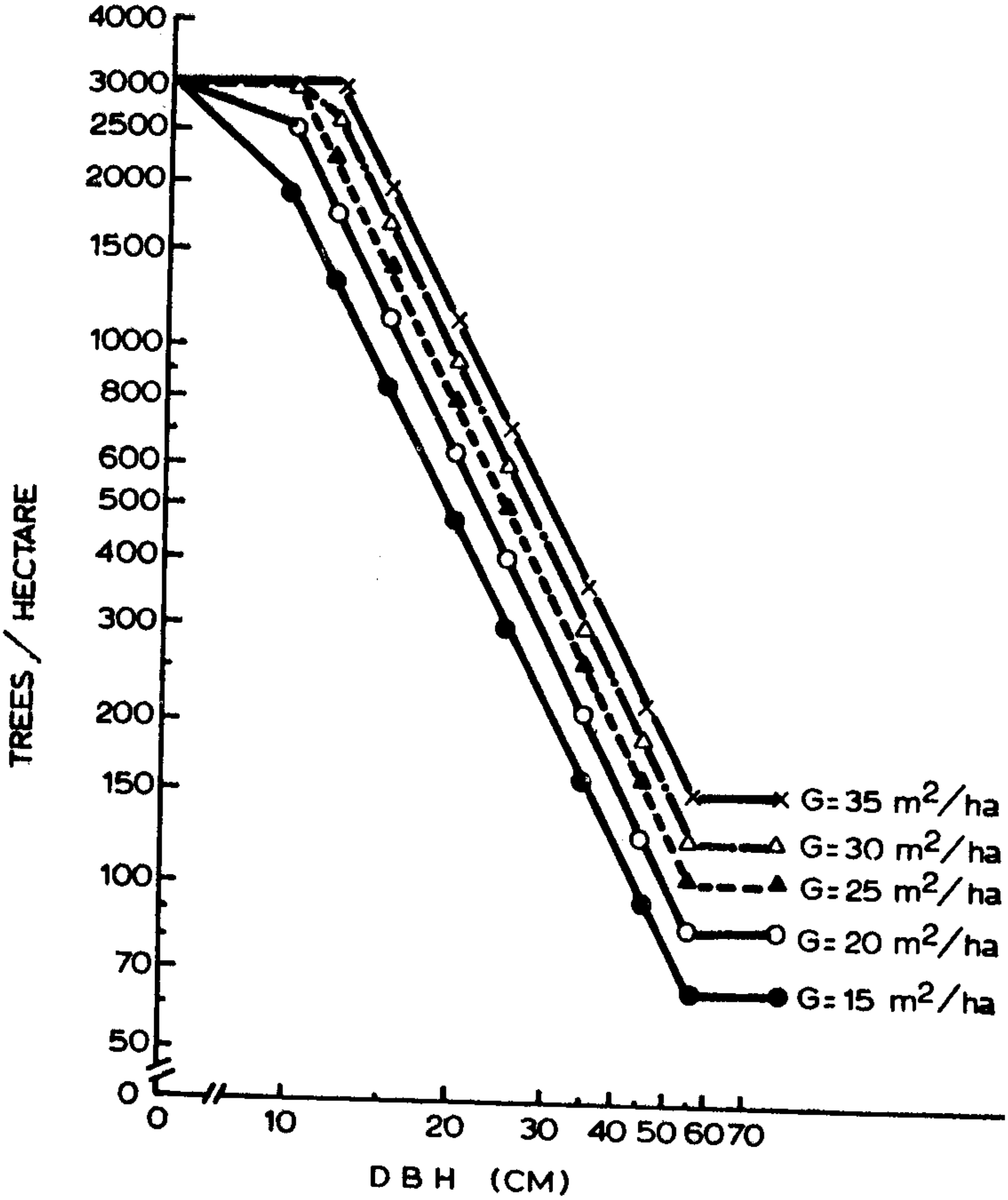

Fig. 2: Proposed experimental thinning schedules of *Brachylaena huillensis*. *G* **= Basal area (m²/ha) after thinning.**

other local suitable species slightly faster in growth than *B. huillensis*. In such crops, *B. huillensis* will be the main crop and the tree that will require more attention in terms of space and shade made available in the course of its development and growth.

While a tentative density control regime has been proposed, it would be necessary, meanwhile, to carry out more sensitive thinning experiments using the growing crops to clarify this schedule. In planning the experiment, it would be more informative to include the mean limiting basal area of the crop (about 30 m^2/ha) established by the present study. An upper basal area (35 m^2/ha), minimum basal area left after thinning to allow optimum increment for a more silvicultural based thinning interval (20–25 m^2/ha) should be included (Fig. 2). A no-thinning treatment as a control should also be included in the experiment. Results from such an experiment would greatly help in pointing out deviations from the results of the present study.

SUMMARY

Investigations on relations between crown and bole diameters revealed a positive relationship: $Y = 0.98 + 0.151x$; $r^2 = 0.76$, where Y is the crown diameter (m) and x is the bole diameter (cm). The relationship was found to be useful in the determination of crowding and was applied to develop an interim crop density control regime with possibilities for developing other regimes depending on the desired degree of canopy closure. Experimental density control regimes were proposed, also on the basis of results of the crown bole diameter relationship.

The suggested thinning regime will be useful for controlling density of the few existing plantations of the species. It is proposed that future plantings of *B. huillensis* should be in mixtures aimed at giving the best opportunity for the tree to reduce development of multi-stemmed forms and produce better formed and longer stems and therefore higher quality wood.

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REFERENCES

[1] Dawkins, H. C. (1963). Crown diameters; their relation to bole diameters in tropical forest trees. *Comm. For Rev.* 42, 318–33.

[2] Kwan, Y. W. (1966). Crown diameter/bole diameter relationship of *Dyera constulata* and its planting distance and crop density. *Malayan Forester 29(3)*, 163–169.

[3] Larson, P. R. (1963). Stem form development of forest trees. *For. Sci. Monogr.* 5. Soc. Amer. Foresters, 42 p.

Mugasha, A. G. (1980). The relationship between crown diameter and dbh for *Ocotea usambarensis* Engl. as a guide to feasible stocking in second regeneration stands. *Tanz. Siv. Res. Note* No: 38, 15 p.

[5] Suri, S. K. (1975). Correlation studies between bole diameters and crown projection area as an aid to thinning. *Indian Forester 101*, 539–554.