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INFLUENCE OF SHADE ON THE GROWTH OF SEEDLINGS OF *BRACHYLAENA HUILLENSIS* IN FOREST AND NURSERY CONDITIONS

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Once seedlings have germinated, success in establishment depends on the prevailing environmental conditions. Among these is the amount of light available at the time of germination and thereafter. Trees vary widely in their light requirements as demonstrated by Richards (1952), Knight (1975), and Whitmore (1984). Few studies, however, document the light requirements of the seedling stages of tropical species (see, for example Nicholson, 1960; Lebron, 1979; Sasaki and Mori, 1981 and Augspurger, 1984).

Richards (1952) and Whitmore (1984) have attempted to show the general role of light in influencing the regeneration of tolerant, mid-tolerant and intolerant trees. Seedlings of some species like *Khaya grandifoliola* in West Africa (Jackson, 1973) were observed to grow only when light was made available by opening up the canopy. Some trees maintain 'seedling banks' that persist under a dense canopy for long periods without making significant growth in height, until light is available. Wardle (1970), for example, found seedlings of *Nothofagus solandri* in New Zealand that were 20 years old but only 20 cm in height.

In dry forest conditions, shade tolerant seedlings may not respond immediately to canopy opening as happens in some secondary and mid-tolerant species. In some cases, opening the canopy may cause retardation in growth. *Vepris glandulosa*, a shade tolerant tree in semi-deciduous dry forest of central Kenya will always persist and grow slowly under canopy. Seedlings growing in gaps become stunted and almost always are scorched by the sun if exposed (Kigomo, 1985). Information on light requirements of a species during its growth could help in "tailoring" its regeneration under a manangement system. A study was therefore undertaken to establish the light requirement of *Brachylaena huillensis*.

In growing plants, the rate of increase is proportional to the plant size and growth has been shown to increase exponentially with time (Blackman, 1919). On the basis of this information, it is possible to relate general growth characteristics and dry matter production to light levels and time. The effects of different shading treatments on the growth of the seedlings of *B. huillensis* in a nursery were also investigated.

EXPERIMENTAL SITES AND METHODS

Experimental Sites

Brachylaena huillensis grows in residual forest stands within the lowland dry forests in the coastal belt of Kenya, extending into northern Tanzania, and the semi-deciduous forests of the central highlands of Kenya.

This study was carried out in Karura and Ngong forests which lie around Nairobi City and Muguga which lies some 15 km to the north of Ngong forest in Kenya. The forests are at altitudes of 1750 m (Karura), 1850 m (Ngong), and 2090 m (Muguga) above mean sea level. The mean annual rainfall for the three forests averages about 1000 mm.

Methods

Seedlings established in groups in Ngong and Karura forests were identified and five plots of 1 m square marked out in each forest. Seedlings within each quadrat were numbered using plastic labels. A plan was produced showing the approximate position of each seedling. For each, height and number of leaves and branches were assessed every month for a period of 12 months.

The quadrats were classified into three groups according to the rate at which photosynthetically active radiation (PAR) was received at the seedling level. Light intensity was measured using integrated Steady State Light meters. Concurrent measurements of light levels in the open were made and light climates of the experimental plots were expressed as a percentage of full sunlight reaching the seedlings.

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Results and Discussion

Table I summarizes the data on assessment of seedlings of *B. huillensis* established naturally in the forest. Table II gives a summary of results of growth and vegetative habits of these seedlings made over a period of one year.

Seedlings established naturally were within light levels of betwen 2 and 14 % of full sunlight. The majority of plots were around two parent trees and distances did not exceed 10 metres from each other. The initial mean heights of seedlings ranged from 8.9 to 18.9 cm. This suggests that they were either of different ages, or that growth is slower in deeper shade. The more rapid growth rate in less shaded areas (0.69 cm/month, compared with 0.47 cm/month in deeper shade) suggests that the latter explanation is more likely.

Seedlings in less shaded areas produced more branches and therefore higher mean numbers of leaves throughout the year. Concomitant increases in leaf numbers per plant, and growth in height as seedlings approached higher lights levels, especially in the openings, may be an adaptive feature to a certain range of light intensities. Fewer seedlings occurred in more open areas, and in completely open areas, there were hardly any. Where these occurred, they appeared to have established in a shaded area which was later opened up. This was evident from the presence of stumps in the openings. In such seedlings heavy branching and remarkably reduced growth in height, characterized by very closely spaced branches, was a common feature.

Throughout the year no losses were experienced in the three shade categories. Apparently once a seedling has developed deep roots, mortality is much reduced compared with the earlier stages of establishment where mortality is usually extremely high.

Seedling growth was better in moderate light than in very low intensities, though even here the seedlings survive and grow. Long term monitoring of seedlings in the field would be necessary to draw more definite conclusions.

The importance of shade in the raising of seedlings of Brachylaena in the nursery

The Objectives of this experiment was to determine:

(i) the growth of seedlings of *B. huillensis* in the nursery under different shading regimes with the aim of producing suitable seedlings for planting after one year or more;

(ii) the advantages, if any, of shifting seedlings through shading regimes (hardening or de-hardening) with the aim of producing seedlings suitable for planting in the field, and

(iii) the effects of various degrees of removal or replacement of overhead shade (simulated canopy changes) from growing seedlings with the aim of seeking possible explanations as to what would happen in terms of seedling growth and productivity when various interventions interfere with the optimum requirement of overhead shading in the course of seedling growth.

Materials and Methods

A shade house, constructed to provide three sections of shade intensities through slits of different sizes was used in the experiment. The highest shading regime was 95% and another shade structure within a 50% shading section was constructed to provide 5% light transmission. A perforated light-orange muslin material was used to create the required light climate. Light environments thus used for the experiment provided 5%, 40-50%, and 100% (in the open) of full sunlight.

Experimental Layout

Matched seedlings of approximately equal sizes were planted in polythylene containers and in one of 4 conditions:

Treatment

A	5% of full light	–60 seedlings
B	45% of full light	–60 seedlings
C	100% full light	–60 seedlings
D	100% full light	–120 seedlings planted in nursery bed

Each set of seedlings remained in its shade environment for a period of one year.

Another set of four groups, each of 60 matched seedlings in polythylene containers, was pre

TABLE I—SUMMARY DATA OF GROWTH AND SURVIVAL OF SEEDLINGS OF BRACHYLAENA IN NGONG FOREST

Plot	Date of assessment	No. of Seedlings	No. of leaves	Ht. Increment (cm)	No. of branches
	26–11–87	16	22.0	18.9	
	11–12–87	16	23.1	19.3	0.8
	13– 1–88	16	22.5	19.7	0.8
	12– 2–88	16	20.1	19.7	1.1
	10– 3–88	16	17.3	20.3	–
I	15– 4–88	16	21.8	21.3	–
	19– 7–88	16	32.2	25.3	–
	18– 8–88	16	30.3	25.3	–
	23– 9–88	16	30.1	25.8	2.0
	24–10–88	16	30.4	26.0	2.0
	23–11–88	16	30.2	26.2	2.3
	26–11–87	17	13.2	11.5	–
	11–12–87	17	14.6	11.6	–
	13– 1–88	17	13.8	11.5	–
	12– 1–88	17	12.9	11.6	0.8
	10– 3–88	17	12.6	12.5	–
II	15– 4–88	17	14.1	12.8	0.9
	19– 7–88	17	18.1	13.8	–
	18– 8–88	17	16.8	16.0	–
	13– 9–88	17	17.7	16.3	1.1
	24–10–88	17	17.5	16.9	
	23–11–88	17	18.4	17.1	1.1
	26–11–87	20	9.7	9.4	–
	11–12–87	20	9.9	9.5	
	13– 1–88	20	9.0	9.4	–
	12– 2–88	20	9.1	9.9	0.3
	10– 3–88	20	8.1	10.6	–
III	15– 4–88	20	9.9	11.9	0
	19– 7–88	20	13.3	12.4	
	18– 8–88	20	13.3	13.2	
	23– 9–88	20	13.4	13.6	0.6
	24–10–88	20	13.3	13.9	0.7
	23–11–88	20	13.8	14.1	0.8

TABLE II—GROWTH CHARACTERISTICS OF YOUNG SEEDLINGS OF BRACHYLAENA IN THE NGONG FOREST

Plot No.	% full light	Init. seedling ht (cm)	Ht. increment (cm/month)	Mean No. of Branch	Mean No. of leaves/ sd1.	Survival %
I	10.1	18.9	0.69	1.29	42.4	100
II	4.2	11.2	0.51	0.92	14.9	100
III	3.0	8.9	0.47	0.42	10.6	100

pared for a growth experiment under shifting management through the A,B,C, shading regimes. Shifting interventions were:

Monthly Sampling and Assessment

Pricked out seedlings in the polyethylene bags were initially kept in the most shaded section of the structure for 3 weeks. This was to minimize variability and to stabilize the seedlings and make it possible to match them by size so that sample seedlings started off approximately equally in terms of size and biomass in their actual experimental environments.

At the time of setting up the seedlings in their respective treatments, seedling height, number of leaves, number of branches and leaf lengths of 20 randomly selected seedlings from the size-matched lot were measured, and the means of these parameters derived. In addition, shoot and root lengths and dry weights were assessed. In the subsequent bi-monthly measurements of dry-weights, 10 randomly selected seedlings were sampled for each treatment instead of 20.

To take measurements of shoot and root lengths, careful extraction of individual seedlings from the soil was necessary. Water was gently ran into the polyethylene container avoiding disturbance of the seedlings or loss of hair-roots. After whole seedlings were isolated, they were placed in a newspaper overnight. Shoot and root lengths were then measured. Shoots and roots were seperated and fresh weights determined. They were then dried at 70°C to a constant weight over a period of 48 hours. The shoot and root dry-weights were taken using an electronic balance.

In all the treatments, seedlings were assessed monthly for these parameters except for the shoot/root lengths and their corresponding dry-weights which were taken at intervals of 60 days. Equal rates and intensities of watering were applied to each of the seedling groups.

From the raw data, monthly changes in shoot/root length and dry-weight ratio as well as total plant dry-weights were determined. Monthly growth in leaf area per plant was derived from leaf lengths. Leaf areas were estimated from a regression relationship (Steel and Torrie, 1980) of leaf length and area estimated from 106 leaves accurately traced and determined on graph paper (Fig. 1). Leaf area per seedling was estimated by multiplying leaf area (derived from mean length; Fig. 1) by mean number of leaves per treatment sample of seedlings. Changes in growth and biomass were calculated from several intervals (each of 60 days) and for the different treatments using the overall growth parameters, mean dry weights and leaf areas derived or measured in each environment.

Results and discussion

Figure 2 illustrates the growth in height of the seedlings in and through the various environmental shading regimes. The lowest rate of growth in height was observed with seedlings growing in the lowest in light through the year (Fig. 2 (I)A). Seedlings growing in the higher light levels grew faster although the rate for seedlings in 45% and 100% light followed very similar trends of growth (Fig. 2 (I)B,C). Seedlings growing in full light in the nursery bed had a comparable rate of growth in height with B and C in the first 5 months but the rate dropped after this period (Fig. 2 (I)D). Seedlings planted in the nursery bed grew at higher densities than those growing individually in polyethylene containers.

	(Dates and period of assessment in months)										
	Dec 3		Feb 3		April 3		Jun 3		Aug 3		Oct 3
Treatments	0	1	2	3	4	5	6	7	8	9	10
E	5%	.	I>	100%	I	.	I		I	.	
F	5%	.	I>	45%	I>	100%	I		I	.	
G	100%	.	I>	5%	I		I		I	.	
H	100%.		I>	45%	I>	5%	I		I	.	

. = Assessment (no harvesting or shifting)

I = Assessment and harvesting but no shifting

I> = Assessment, harvesting and shifting of seedlings to the indicated shading regime.

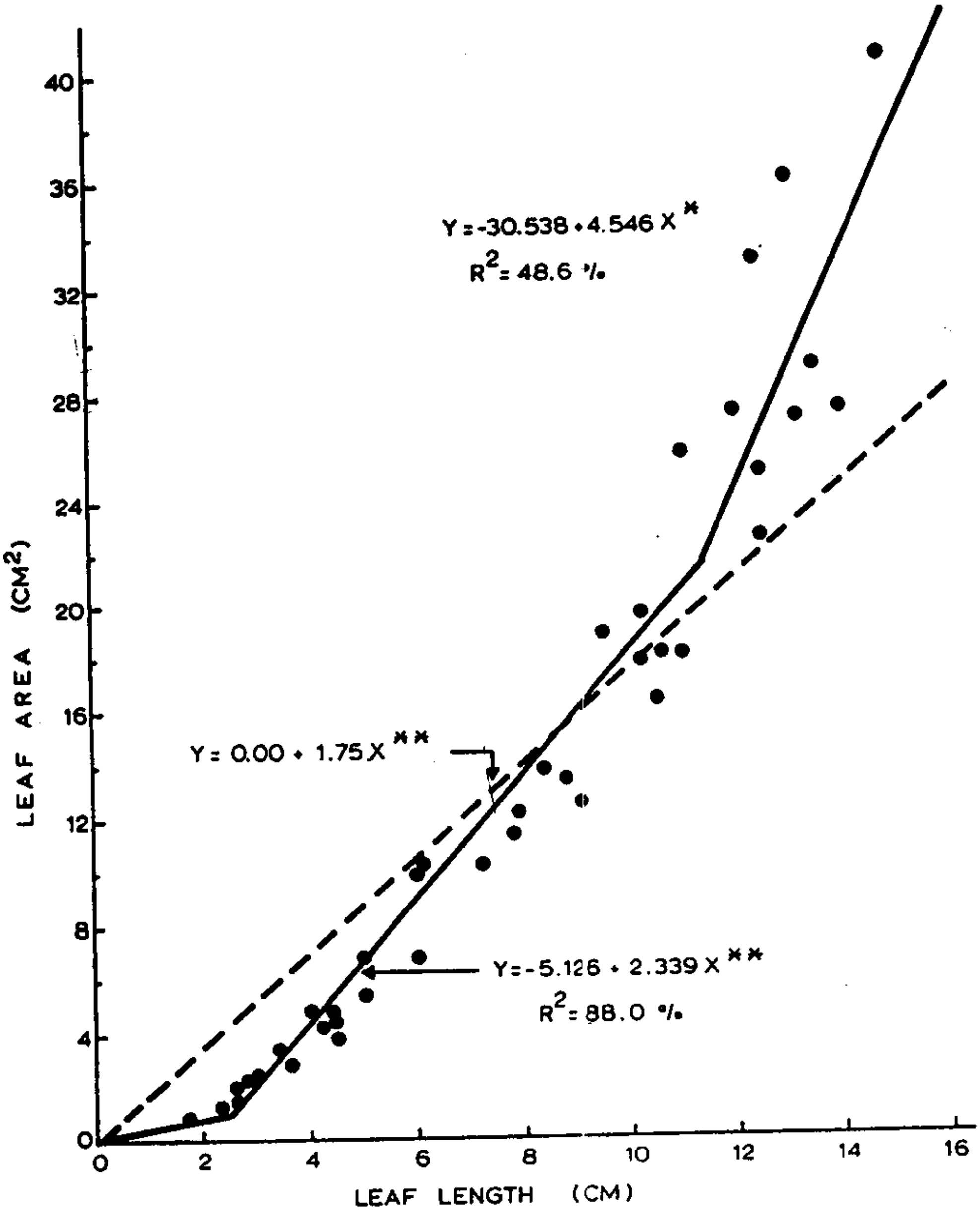

Fig. 1: Relation between leaf length and leaf area in seedlings of *B. huillensis*

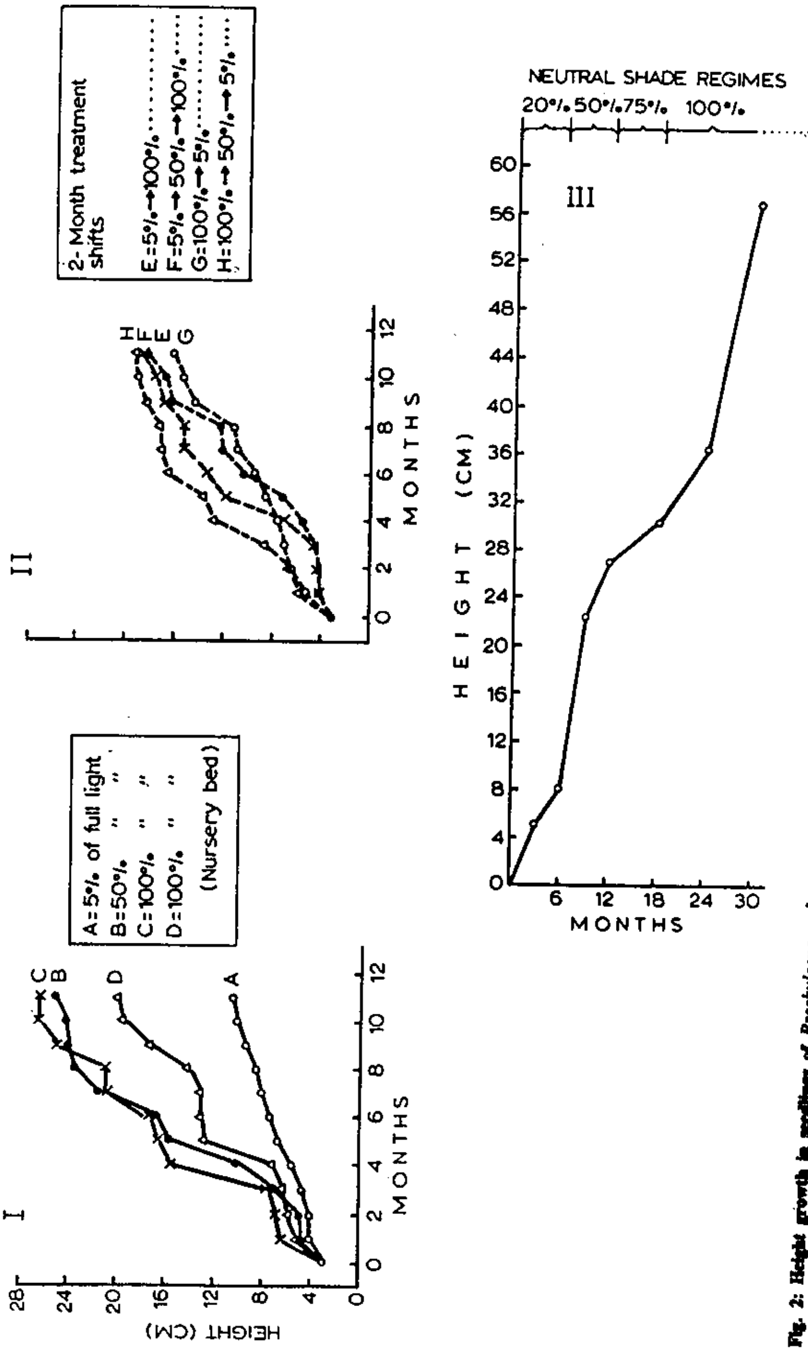

Fig. 2: Height growth in seedlings of *Brachylaena* under constant (I) and shifting (II and III) neutral shade regimes.

when seedlings growing in 5% light, were shifted to 100% full light there was a drop in the rate of growth and serious scorching of the leaves was observed. The scorch observed when heavily shaded seedings were abruptly exposed to direct radiation from the sun probably resulted from the high heat load, increasing leaf temperatures and respiration and perhaps resulting in an inability of seedlings to take up enough water to match transpiration.

Seedlings growing under 40-50% of full light after being transferred from 5% or 100% and then transferred to 100% or to 5% respectively (Fig.2 (II) F,H) had the highest rate of growth during the 40-50% full light period. After the 45% shade environment, rates of growth were less steady. Early superiority in seedling growth initially in full light was reversed immediately the seedlings were shifted to an environment of 5% light (Fig.2 (II),G). Determinaton of suitability of size of seedlings for planting in the field is based on height. Seedlings are suitable for planting on cleared sites when they are 25 to 30 cm in height. For enrichment and ceremonial or commemorative planting, bigger seedlings are preferred. Seedlings were therefore grown through the shade structure to determine the period required to raise large sizes of seedlings for the latter planting purposes.

Figure 2 (III) shows growth in height of seedlings growing progressively through 10-20 % full light for 6 months, in 40-45% full light for 6 months, 6 months in 75%, and 12 months in the open (100% full light) but later in a fresh soil mixture. The fastest rate of growth in height occurred during the 6 months when the seedlings were kept under the 40-45% shade regime. under the 75 and 100% full light, rates of increment were lower. After 6 months in the open, changing the seedling to larger containers with more fresh soils greatly improved the rate of growth. From the results shown in Fig. 2 (III), normal healthy seedling for planting on reasonably clear sites will be attainalbe from 9 to 12 months after pricking out. Production of larger seedlings will require more than 1 year and preferably beyond 2 year if seedlings 60 cm or taller are required.

Figure 3 shows rate of growth and changes in leaf-area (a_1,a_2), dry-weight (b_1,b_2), shoot/root ratio for length (c_1,c_2) and dry-weight (d_1,d_2) with time. The rate of growth in total leaf-area per plant followed a similar trend to that of height (Fig 2(I)). As also observed in the case of growth in height, transfer of seedlings to light levels above and below about 45% full light lowered the rate of leaf-area growth (Fig.3 (a_2) G,H). Similar observations were made for growth in dry-weight (Fig.3 (b_2) G,H). The highest rate of growth in dry-biomass was given by seedlings shifted systematically from the lowest to the highest light levels (Fig.3 (b_2) F); under a fixed shade environment, high light levels meant higher rate of growth in terms of dry-matter (Fig. 3, b_1).

The shoot-root ratio in length, both under fixed and changing light regimes remained almost constant at about 0.5 (Fig. 3 c_1, c_2). Trends in the rates of changes with time of dry-matter under both fixed and changing shade environments were influenced by the intensity of the light regimes. Initially, seedlings growing under the lowest light allocated more resources to shoot development but after 4 months more was allocated to root development. For seedlings growing under increasing light levels, allocation of resources to the development of root system became more important with time (Fig.3, d_1). The change of the shoot-root ratio with time was different from that indicated in the fixed shading regime suggesting that changes in levels of shading will influence productivity as the seedling grows (Fig. 3, d_2). Transferring seedlings to higher levels of light promoted root development and therefore dry matter. The reverse was true for seedlings shifted to lower light environments.

In general, the results indicated that increments in mean seedling height, leaf-area and weight were proportional to the light received. The smooth transfer of seedlings from 5 to 45% and then to 100% of full light resulted in greater yields than any other regime. Better yields were, however, further indicated when growth occurred under the 40-50% shade environment under fixed or shifting shade treatment.

Conclusion

The slow growth of seedlings of *B. huillensis* under heavy shade and the fast growth under higher light levels show that seedling growth in the nursery, and therefore possibly in nature, is limited to some extent by light. Adaptation to a low light compensation point indicates that the seedlings are well adapted to establishing and maintaining themselves under heavy shade, but growth rates are low. The results also indicate that seedlings will improve their rates of growth if

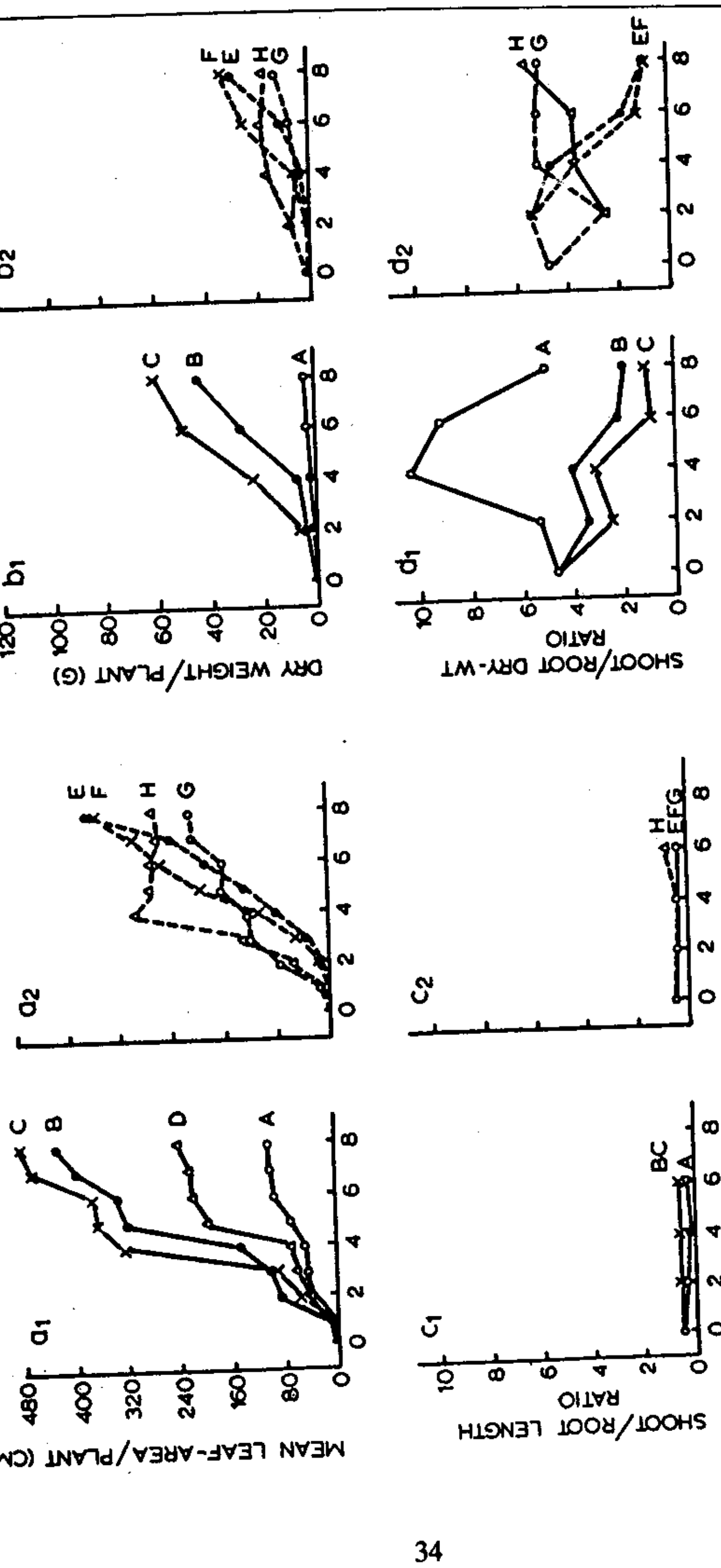

Fig. 3: Relations between mean leaf area (a_1,a_2), mean plant weight (b_1,b_2) and shoot root ratio (c_1,d_1 d_2) against time. Keys to shade treatments in the cases of a_1, b_1 c_1 and a_2, b_2, c_2 and d_2 are as indicatedin Fig. 2. I and II respectively.

given the benefit of higher light intensities but only up to a certain level.

Although the studies in the nursery were not designed to produce data suitable for comparison with growth in natural conditions, it may be possible to draw a tentative conclusion that seedlings of *B. huillensis* growing on the forest floor exist through sophisticated physiological adaptions for growth at low light levels. This makes it possible for the seedlings to undertake efficient utilization of a range of sunflecks. Higher rates of growth of seedlings in the nursery at light levels of 40-45% may mean that although shade is crucial for the establishment and healthy growth of the species, other factors in the field especially competition for other resources could also be important. It will therefore be necessary to carry out more work aimed at finding out particularly the role of moisture in determining the rate of seedling growth in the forest.

The results of changing shading for established seedlings support the view that opening up the canopy increased growth rates of newly established or older seedlings (Jackson,1973, Liew and Wong (1973). Since *B. huillensis* seedlings appear to establish better in shade, an alternation of shade and open condition may be the optimum for successive natural regeneration.

It will be necessary to raise seedlings in the nursery under intermediate shading. This will mean growing seedlings for 2 months at 20-25% light or slightly below this level. These should then be kept for a longer period in the intermediate shading regime with only 1 or 2 months in the least shading and in the open to harden before planting them in the field. This management system will produce more healthy and better formed seedlings than the weak or heavily branched short seedlings produced under heavy shade and in the open respectively.

To ensure good survival and seedling form in natural conditions, it will be necessary to leave seedlings to grow and develop through a changing system of light quantity and quality until these are able to withstand full light after penetrating the main over-shading canopy.

SUMMARY

Investigations on the role of shade in the establishment of seedlings of *Branchlaena huillensis* under natural conditions and under nursery management were carried out in Ngong, Karura, and Muguga forests and in the nursery.

Growth studies in the nursery, under three light regimes, and in natural forests indicated that seedlings remained healthy in 2 to 14% of full light but grew slowly in the forest. Under 45% of full light, seedlings were healthy and grew fast in the nursery. Unshaded seedlings in the nursery grew fast but had poor form. Exposure of shaded seedlings to full light resulted in the damage from scorching and reduced growth. It will be necessary to let seedlings grow and develop through a changing level of light quantity until these are able to withstand full light after penetrating the main over-head canopy. To ensure healthy and better formed seedlings for planting in the field, it will be necessary to raise them in the nursery under intermediate shading.

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