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THE GROWTH OF CAMPHOR (*OCOTEA USAMBARENSIS* ENGL.) IN PLANTATION IN THE EASTERN ABERDARE RANGE, KENYA

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Ocotea usambarensis Engl. (East African camphor). is an indigenous timber species in Kenya belonging to the family Lauraceae. The tree is one of the most important timber species remaining in Kenya and its exploitation in the natural forests has been heavy. Camphor grows naturally in the southern and eastern natural forests of Mt. Kenya. eastern slopes of Aberdare range and has also been reported to grow in Taita Hills (Wimbush. 1950. and Dale and Greenway, 1961). It occurs naturally in the highlands between altitudes 1,375 and 2.440 metres above mean sea level (a.s.l.). but is more prevalent between 1.830 and 2.150 metres a.s.l. At the optimum natural occurrence. the tree attains a dbh of 200 cm and maximum height of 45 m with a clear bole of 9–15 m.

Camphor produces very useful utility hardwood. The timber is not. however. durable in the ground (lasting 2–4 years), has a low resistance to termite attack but is resistant to fungus and highly resistant to acid (Wimbush. 1937. and 1950). The timber finds its main use in furniture. cabinets. and joinery. Demand for camphor is currently very high and though it is available on the market. it is a scarce timber by all standards due to its limited ecological distribution and past excessive exploitation which rendered it depleted in terms of size. quality. and population density in natural stands.

No useful cultivation of camphor has been undertaken partly because it has been available in natural conditions in the past and because seed is difficult to obtain. It is also difficult to raise planting materials through cuttings. The tree has been observed to produce useful seeds once in ten or so years and these have to be treated to give good germination. Seeds are also eaten by pigeons while on trees. In natural conditions seedlings and suckers are sometimes noted but these are heavily eaten up by wild animals. especially elephants. Regeneration is not. however, apparent and no investigations have been directed to the seed biology. seed masting and consequent regeneration problems (Abraham. 1958). The object of the present study was to look for information on the rate of growth in plantation situations where seedlings have been successively raised and planted out.

Materials and Methods

The camphor growth plot was planted in 1910 near Wanjerere Forest Station, eastern Aberdare Range. The plot was among other species trials planted on a ridge of average elevation 2,440 metres a.s.l. The station receives a mean annual rainfall of 1.780 mm. Rain falls mainly in April and May but a short fall occurs from mid-October to mid-December. July and August have cold misty weather while January to mid-March is usually a sunny, dry period.

Initial espacement was 1.5 × 1.5 m (4,300 seedlings per hectare) and the plot was first marked out for measurements of dbh and height in 1928 and then in 1931. 1935. 1936 and 1941. It was abandoned but relocated. redemarcated and measured in 1957 and 1963. Another period of neglect between 1963 and 1983 followed. Subsequent measurements of the above parameters and plot development records were undertaken up to age 75.

Thinnings were carried out at ages 18. 25. 26. 47. 53 and 75 years on the basis of appearance of crown in terms of closure. Measurement data on stocking and bole diameter and height growth were summarized and presented for discussion below.

Results and Discussion

Growth characteristics of camphor over 75 years are given in Table IA and B. At age 20 the crop achieved a top height of 10.4 m (roughly site index 10). Rate of height growth is therefore relatively low. At age 53 top height was 24.7 m and at 75 years was 29.4 m. Mean annual increment in plot tree height was low and steady but after age 47 started declining steadily. Height increment did not seem to be affected by density or thinning treatments and the observed low periodic decrease may be a result of other site factors. Height ranges at each time of measurement were unusually large and tended to increase with age. This observation may in part be attributed to differences in individual trees and groups of trees that seem to have been disturbed through group pole cuttings and later on stem damages by humans.

Dale and Greenway (1961) estimated that young camphor trees will grow at a rate of 1.8 m per year. Parry (1951) reported that it was possible to obtain a rate of growth in height of 0.9 m for the first 10–20 years especially with suckers on favourable sites in Tanzania highlands. These rates correspond to top heights of 36 and 18 m respectively at age 20. Parry (1951) further estimated that it would be possible to achieve a top height of 24.4 m at age 50 in the Kenyan highlands, which compares well with the present findings. Dale's estimated rate of increment in height is far much above the present results. While reasonable growth in height occurs in natural conditions within limits of altitude noted above, Wimbush (1950) noted that growth was lower particularly near the upper limit of the tree's altitude range. Wanjerere at 2,440 m a.s.l. is on the extreme limit of camphor growth and this may in part contribute to the low mean heights. No records of growth in height were made before 18 years but as noted by Dale *et al.* (1961) and Parry (1951), initial rate of growth in height, at least for the first 10–15 years may have been higher. This observation was also made by Wood (1963), who estimated mean annual increments of camphor plots growing within 1,680–1,860 m a.s.l. to be 1.08 m (age 7) and 1.08 m (age 8.75) but this declined to 0.66 m at age 17. The height growth rate of 0.51 m indicated in the present study plot at age 18 years. (Table I) and at 2,440 m a.s.l. may not therefore be that badly low.

TABLE IA—GROWTH CHARACTERISTICS OF CAMPHOR AT WANJERERE (EASTERN ABERDARE RANGE)

Year	Age (Years)	Stocking (Stems/ha)	DBH (cm)	Mean heights (m)	Diameter and height ranges		Basal Area (m²/ha) (After thinning)
					DBH (cm)	Heights (m)	
1910	0	4,300	—	—	—	—	—
1928	18	3,128	11·2	9·1	8·7–15·4 (16)*	7·6–10·4 (8)*	31·0
1931	21	3,128	12·2	9·8	9·5–17·0 (16)	8·5–11·3 (6)	37·2
1935	25	1,483	13·5	10·7	10·5–18·6	10·1–12·2	21·1
1936	26	1,151	13·8	10·7	(18)	(5)	20·2
1941	31	1,151	17·3	12·8	12·9–23·4 (20)	12·2–14·0 (4)	27·1
1957	47	548	26·2	20·9	18·5–34·3 (18)	18·6–23·5 (8)	30·1
1963	53	321	28·2	21·1	19·6–41·4 (19)	15·8–24·7 (9)	20·2
1983	73	316	32·5	22·7	18·0–50·2 (22)	15·2–28·6 (21)	26·2
1985	75	212	32·9	22·8	19·4–50·6 (21)	15·0–29·4 (22)	19·7

*(Coefficient of variation in per cent).

TABLE IB

Age (years)	Stocking (stems/ha)	Mean annual increments		Periodic mean annual increments	
		DBH (cm)	Heights (m)	DBH (cm)	Heights (m)
0	4,300?	—	—	—	—
18	3,128	0·62	0·51	11·20	9·10
21	3,128	0·58	0·47	0·33	0·23
25	1,483	0·54	0·43	0·33	0·30
26	1,151	0·53	0·41	0·30	0·00
31	1,151	0·56	0·41	0·70	0·42
47	548	0·56	0·44	0·56	0·51
53	321	0·53	0·40	0·33	0·03
73	316	0·44	0·31	0·22	0·08
75	212	0·44	0·30	0·20	0·05

At age 75, mean stem dbh was 32.9 cm. Mean annual increment in stem diameter was 0.62 cm at age 18 but fell gradually to 0.56 cm at age 47 before falling steadily to 0.44 cm at age 75. Observed trend in stem diameter and corresponding mean annual increments are well below estimated means for some other local indigenous commercial timber species, in particular Meru oak *(Vitex keniensis)* and Cedar *(Juniperus procera)* growing within a similar central highland zone of the Mt. Kenya and the Aberdare range (Kigomo, 1981 and 1985).

Parry (1951) and Wood (1963) estimated diameter increment rates that suggest that camphor grows fast in its early growth but this vigour declines rapidly after around ages 20–30 years. This trend of growth was also observed with height. The estimate may not, however, be fairly comparable due to large differences in stocking between the present study plot and the Tanzania plots. As in the case of growth in height, diameter ranges were unusually large and a similar explanation may apply in this case.

Effect of stocking on stand development

Initial espacement of 1.5 × 1.5 m (4,300 stems ha^{-1}) was possibly too high a stocking for camphor with the high initial rate of growth observed above. The crop is likely to start competing quite early in its development and this could be a contributing factor to the relatively lower stem diameters and rates of increments observed in the early growth. Thinning operations at ages 18 and 25 did not produce any notable advantageous effects on growth and periodic mean annual increments continued falling below mean annual increments. Stand density was possibly still too high to have benefited from the thinning intensities applied. It is at age 26 that the thinning operation improved diameter growth. Both annual and periodic mean annual increments improved for the next 20 years even without further thinning. At age 47 crop density was reduced by half but this resulted in only a brief period of 6 years of reasonable annual increments. After this period, periodic mean annual increments in both diameter and height continued falling steadily up to age 75 despite thinning operations at ages 47 and 53. Heavy thinning at age 53, particularly, gave no marked increase in girth over the next 20 years and only a flush of epicormic production followed this thinning and another one at age 75. Epicormic development and low girth increment suggest that the crop was incapable of further reasonable diameter increments and only very low increments in girth and height may be expected after this age.

It is apparent from this latter observation that if stocking is not kept to an optimum, allowing for further individual development, it would be unlikely to achieve growth dimensions estimated by Parry (1951) for a camphor crop. In the present study, mean diameter and top height of 41.4 cm and 24.7 m respectively at age 50 and 51 cm and 29.4 m respectively at age 75 were achieved only with dominant trees (Table I). Control of stocking should advantageously be undertaken early during the camphor stand development when the crop has the highest potential for growth and therefore better response to density release. Such undertaking should produce early taller and fatter camphor stems at corresponding ages than recorded in the present camphor stand.

With the rate of growth observed in the present camphor crop, it will be possible to achieve a rotational mean tree diameter of 48 cm at age 109 and 60 cm at age 136. Otherwise a better growing crop as observed with dominants would achieve 48 cm dbh at age 68 and 60 cm dbh at age 85. It is observed that even the faster growing individuals were slower than Parry's projected average growing camphor crop cited above.

Basal area development and stocking control

Basal area is an important management parameter in the control of stand development over time. Results in the present study indicate that when camphor crop was thinned down to 31 m^2 ha^{-1} basal area at age 18, periodic mean annual basal area increment was 2.07 m^2 ha^{-1} to age 21. A standing basal area after thinning of 20.2 m^2 ha^{-1} at age 26 resulted in an increment of 1.38 m^2 ha^{-1} at age 31 and 20.3 m^2 ha^{-1} at age 53 permitted a periodic annual basal area increment of 0.30 m^2 ha^{-1} up to the age of 73 years. These declining basal area increment values and the overall observation on declining trend in growth parameters support the suggestion made earlier that growth potential is high in the initial growth of a camphor crop but steadily declines slowly and then fast after about age 50 onwards. Basal area as a measure of stocking over time is more indicative and sensitive in terms of magnitude than indicated by decline in stem diameter growth. The parameter could therefore be a better stocking control tool. Basal increment changes given above show clearly that camphor will benefit from initial early thinning treatments in order to improve growth rates especially in stem girths. Later thinnings did not result in reasonable increment in basal areas.

Maximum attainable basal area is an important control point in assessing maximum or optimum density carrying capacity of a site in a developing stand. The camphor crop under study was subjectively thinned according to appearance of crown. It is observed in Table IA that the thinning trend kept the basal area after operations to an average of 26 ± 6.1 m^2 ha^{-1} over the growth period. This thinning trend is also shown in Fig. 1 against age

Dawkins (1963) working with several tropical hardwoods, estimated a range of maximum attainable or growth limiting basal area of 19–23 m^2 ha^{-1} for many of these species. Earlier work in Uganda natural stands and a wider review cover (Dawkins, 1958) estimated that it would be unlikely for a tropical hardwood species to grow further without serious crown deterioration if standing at a basal area exceeding 32 m^2 ha^{-1} and suggested that this would possibly be the highest limiting basal area. For most species in East African tropical high forests (T.H.F.) limiting basal areas fell between 18 and 28 m^2 ha^{-1} depending on species and site. Later estimates made on some East African and even Asian hardwood species were in fair agreement with these estimates. Mugasha (1980) reported 18 and 21 m^2 ha^{-1} as the limiting basal area in a stand of *Ocotea usambarensis* at two different sites. Kigomo (1980 and 1981) obtained estimates of 18.5 and 25 ± 3 m^2 ha^{-1} for *Juniperus procera* and *Vitex keniensis* respectively. It is apparent from these results that basal area left after thinning a crop should be below the limiting maximum so as to allow enough space for further growth.

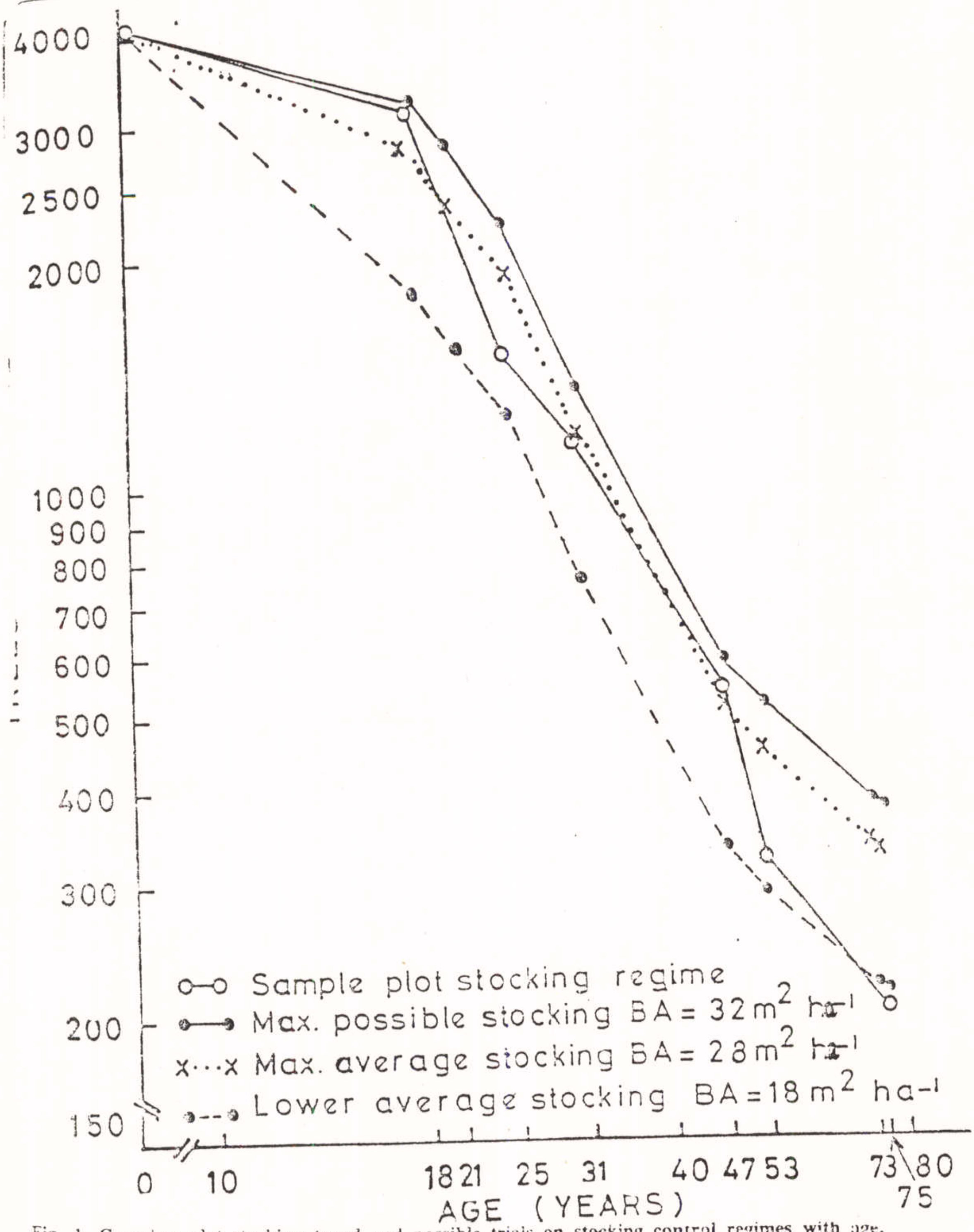

Fig. 1. Camphor plot stocking trend and possible trials on stocking control regimes with age.

The two extremes of limiting basal area are shown in Fig. 1. The average maximum of 28 m^2 ha^{-1} is also plotted. It is observed in the figure that the subjective thinning trend fell within the two extrêmes and followed closely the 28 m^2 ha^{-1} basal area limit. Since most of the local studies on basal area limit as a stocking control parameter agree fairly well with the limits estimated above, it would be only fair to direct future studies on stand density control on camphor to around these limits. Suitable experimental thinning regimes should therefore include five treatments of four basal area control steps ranging from 16, 20, 24, 28, to 32 m^2 ha^{-1}.

Conclusions

Growth results from the present camphor study demonstrate that the tree growth is limited by extreme upper altitudes possibly due to low temperatures and associated site factors.

Growth rate is initially fast but declines steadily and thinning control should take advantage of this early high growth potential. Growth responses in later thinning operations are low and their intensities should also be low to avoid profuse epicormic growth associated with more open stands in older crops.

While the present findings are quite essential to the management of camphor, especially since they have been derived from long-term measurements of the sample plot, the same should also be treated as tentative due to the inadequate number of plots to give wider and therefore more reliable figures. Investigations relating to the questions on seed biology and germination should be urgently carried out. Initial espacement, tree special requirements with age, and thinning schedule where the stocking control regimes arrived at above are tested should be carried out also and in replications. Results from these investigations would greatly help in improved management of camphor and in pointing out any deviations from the findings demonstrated by the present study.

Summary

A plot of *Ocotea usambarensis* Engl. (East African camphor) was marked out in 1928 in a small plantation established in 1910 at Wanjerere, central eastern Aberdare range. Growth trend and development under a stocking control based subjectively on appearance of crown was followed up to age 75 years.

Growth of camphor at Wanjerere, upper limit in altitude for the growth of the tree was relatively slow. At age 18, mean dbh. was 11.2 cm, at age 53 was 28.2 cm, and at age 75 was 32.9 cm. Stem diameter ranges were unusually large with corresponding stem diameters at the above ages of 15.4 cm, 41.4 cm and 50.6 cm respectively. Corresponding dominant heights were 10.4 m, 24.7 m and 29.4 m respectively.

At the lower rates of growth, it would be possible to attain a rotational mean diameter crop of 48 cm and 60 cm at ages 109 and 136 years respectively. The dominants attained these dimensions at ages 68 and 85 years respectively. Corresponding rotational top heights would be at about 32 m and 39 m respectively.

Results from this study raised some management questions and lines of future investigations relating to seed biology, initial espacements and stand density control in camphor stands are suggested.

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