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GROWTH CHARACTARISTICS OF NATURAL REGENE-RATES OF AFRICAN PENCIL CEDAR (JUNIPERUS PROCERA)

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Juniperus procera Hochst ex Endl., commonly known as the "African pencil cedar" is a tropical conifer and widely distributed tree of the drier highland forests of East African. A prominent feature of the African cedar wood is the characteristic extreme resistance of its heartwood to termite attack and is generally a very durable wood in the ground. The sapwood is perishable in the ground and rapidly destroyed by termites. Timber produced from african cedar is of economic importance in both construction and lining purposes. Cedar is the largest Juniper in the world but unfortunately older trees are often piped due to the heart rot fungus, *Fomes Juniperinus* Fr. (Dale *et al.* 1961). It is therefore important to know its rate of growth and its probable cutting cycle sizes through selection system especially in natural forests in order to avoid loss in timber produce through internal decay. Such determination should take into account the management of african pencil cedar trees of class 4 or 5 as regards heartwood (redwood-the durable content of the wood). Determination of average age or size at onset of internal decay would be of economic importance.

Kigomo (1985) took measurements of girth diameters of boles and their corresponding redwood of twenty felled stems of cedar at North Kinangop and Uplands natural forest in an attempt to find out the relation between volume of redwood to the total volume underbark. From this results it can be reduced that at breast height diameter of 60 cm, the volume of redwood is 40 per cent and the equivalent of redwood content vould be 45 cm.

The objective of this study was to determine the rate of growth of natural regenerates of African cedar. The growth data is anticipated to provide information on general growth, the effect of tree diameter upon annual diameter increment, the probable cutting ages under the prevailing environmental conditions and african cedar's reduced utility to redwood proportion only.

Study Site and Methods

The study plot was established in a natural forest with scattered patches of african pencil cedar regenerates at Timboroa (0° 7′N, 35° 40′ E). Most of these patches were young regenerates of 15 years old that were the result of a 1931 fire. The cedar natural regeneration plot is situated on a wooded escarpment north of a small river. On the upper ridge the ground is more or less level but soon falls away quickly to the south and east. The forest stand was vegetatively characterized by a fair and good neat layer of African cedar from where 50 trees were included in the study plot. *Olea chrysophylla* Lam., poor stems of *Podocarpus gracilior* Pilger, *Rapanea rhododendroides* (Gilg) Mez and scattered clumbs of *Arundinaria alpina* K. Schum. are some of the associated species. In the open parts species of *Robus, Myrsine, Clutia, Scutia* and grasses dominate. The area is at an elevation of 2,700 metres above sea level and experiences a mean annual temperature of 13.6°C and mean annual rainfall of 1300 mm. Rainfall is mainly distributed from March to September but maximum rainfall occurs in May and August. Soils are dark red friable clays with deep humus to soil derived from volcanic and basement complex rocks.

A quarter of a hectare plot was demarcated by African cedar corner posts on a cleared line in 1946. To streamline the age and sizes of the study trees, ringbarking of interfering large trees and pruning to 7 metres was carried out. Fifty trees were left in the plot. Measure trees were numbered with aluminium tapes and plotted on a chart and the point of measurement at 1.3 metres marked with a red and white paint.

After the 1946 measurements of diameter at breast height and heights, further remeasurements were carried out in 1958, 1963, 1971, 1976 and in 1981. Difference between individual tree measurements at different periods were used to determine periodic mean annual increments (P.M.A.I) and overall mean annual increment in diameter and height growth.

To determine the effect of initial diameter (diameter at start of a growth period) upon increment in D.B.H. (O.B.), regression model analysis of mean annual increment of individual trees upon their corresponding initial diameters were carried out by the methods of Bailey (1959) and Draper *et. al.* (1967).

Age-diameter curves and therefore probable cutting ages of african cedar natural regenerates are estimated by the method of Osmaston 1956) and as briefly discussed below.

Results

The general growth data at different ages in terms of stocking, basal area, mean diameter and height and their corresponding mean annual increments are shown in Table I. Stocking remained almost constant except at age 40 years when five more trees were added to the experimental trees. Basal area increment between age 15 and 50 years was approximately 6 per cent per annum rising from 10.0m² to 30.7m² per hectare in thirty five years. Mean (D.B.H.) and height are impressive for african cedar. Results show an initial fast growth in diameter and height with a tendency to slow down with age. Initial prunning and ringbarking of large diameter trees in the experimental plot may have created conditions approaching free growth of the remaining trees. Under the current development status it is most probable that the standing basal area at age 50 years may check the rate of increment in diameter and further increments may be expected to be lower. A release from root and light competition may then be necessary to avoid much lower rate of increments.

Table I—Basic Stand Data for Growth of *Juniperus Procera* (cedar) Natural Regenerates at Timboroa

Age (years)	Stocking (Stems/Ha)	Basal area (m/Ha)	Mean DBH (cm)	Mean height (m)	MAI DBH (cm/yr)	MAI height (m/yr)
15	247	10·00	22·7	14·7	1·51	0·98
27	242	15·54	28·5	17·1	1·06	0·63
32	242	18·73	31·4	18·1	0·98	0·57
40	266	26·33	25·3	20·0	0·88	0·50
45	262	26·38	35·8	22·2	0·79	0·49
50	262	30·65	38·6	23·5	0·77	0·47

Relationship between initial diameters of individual trees and their corresponding periodic mean annual diameter increments over several growth periods are shown in Table II and figure 1 (*a*) and 1 (*b*). Most of the attempted regression models did not yield any significant relationship and only second and third order polynomial regression results (R^2) are shown in the table. Except for the 1963-76 growth period where the two equations explains 60% variation of the initial diameter upon diameter increment relationship, the rest of the growth periods yielded no statistical significance. In 75% of the growth periods considered in the analysis, explained variation fell below 35% and therefore no significant correlation between initial diameter of individual trees and their corresponding diameter increments may be attributed to these results.

Diameter-annual increment scatter graph was produced and by carefully drawing a smooth curve through the points a diameter—annual increment curve is futher produced and read off as presented in Table III. The time it took the indicated rates of growth to pass through a diameter class is also shown in Table III. From the time of passage, approximation of an age-diameter relationship is established and diameter sizes corresponding to various ages of the crop can be read from the curve in Figure 2. It is observed from the latter curve that a crop of natural regenerates of an african pencil cedar crop may be expected to attain 60 cm. D.B.H. (O.B.) (equivalent of 45 cm D.B.H. of heartwood proportion) in 100 years. An optimistic final cutting height of about 35 metres may also be expected.

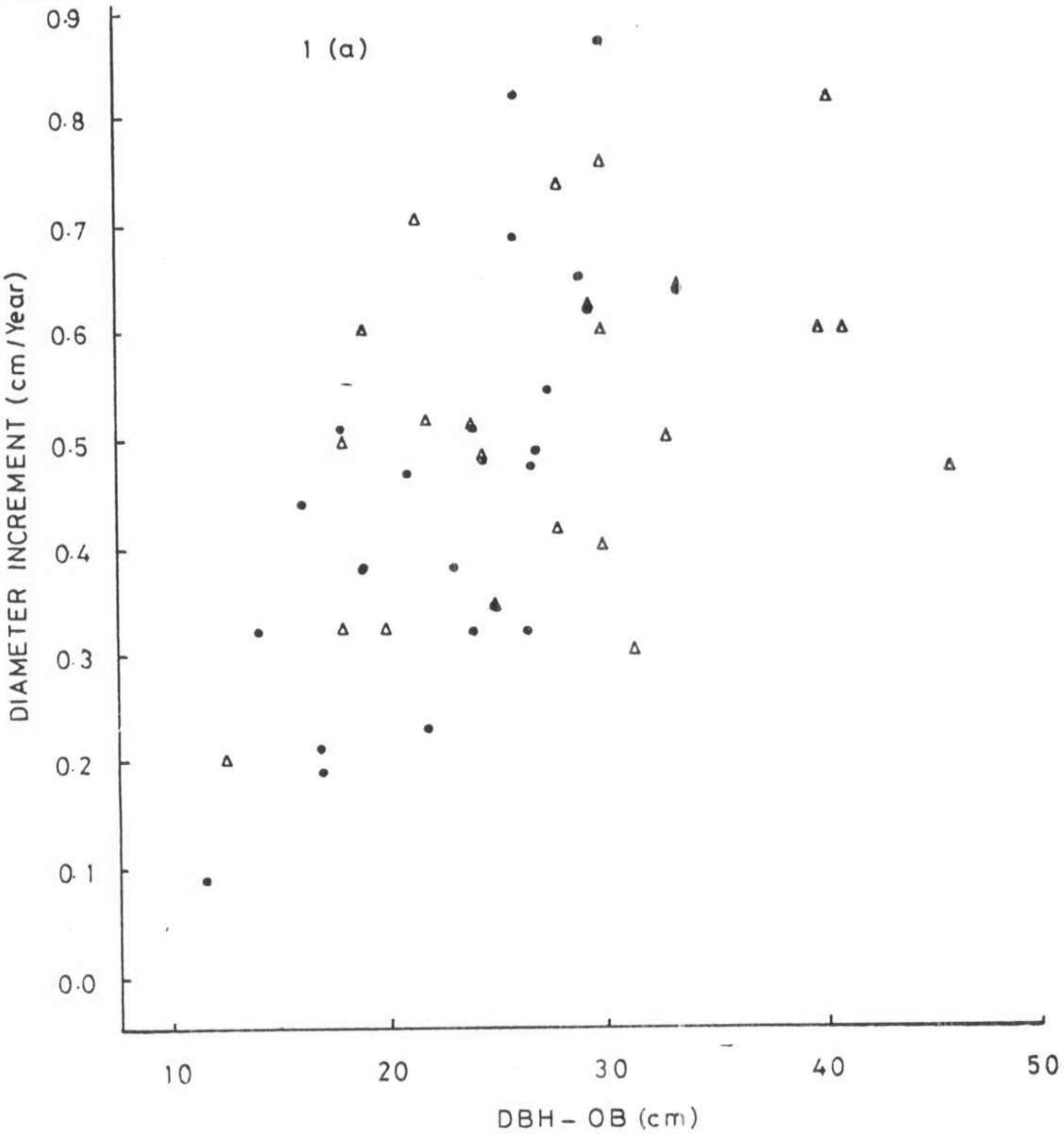

Fig. 1 (a)—The Relationship between diameter increment and initial tree diameter of natural Afrcan cedar regenerates at different ages—15 (• • •) and 27 (△△△))years.

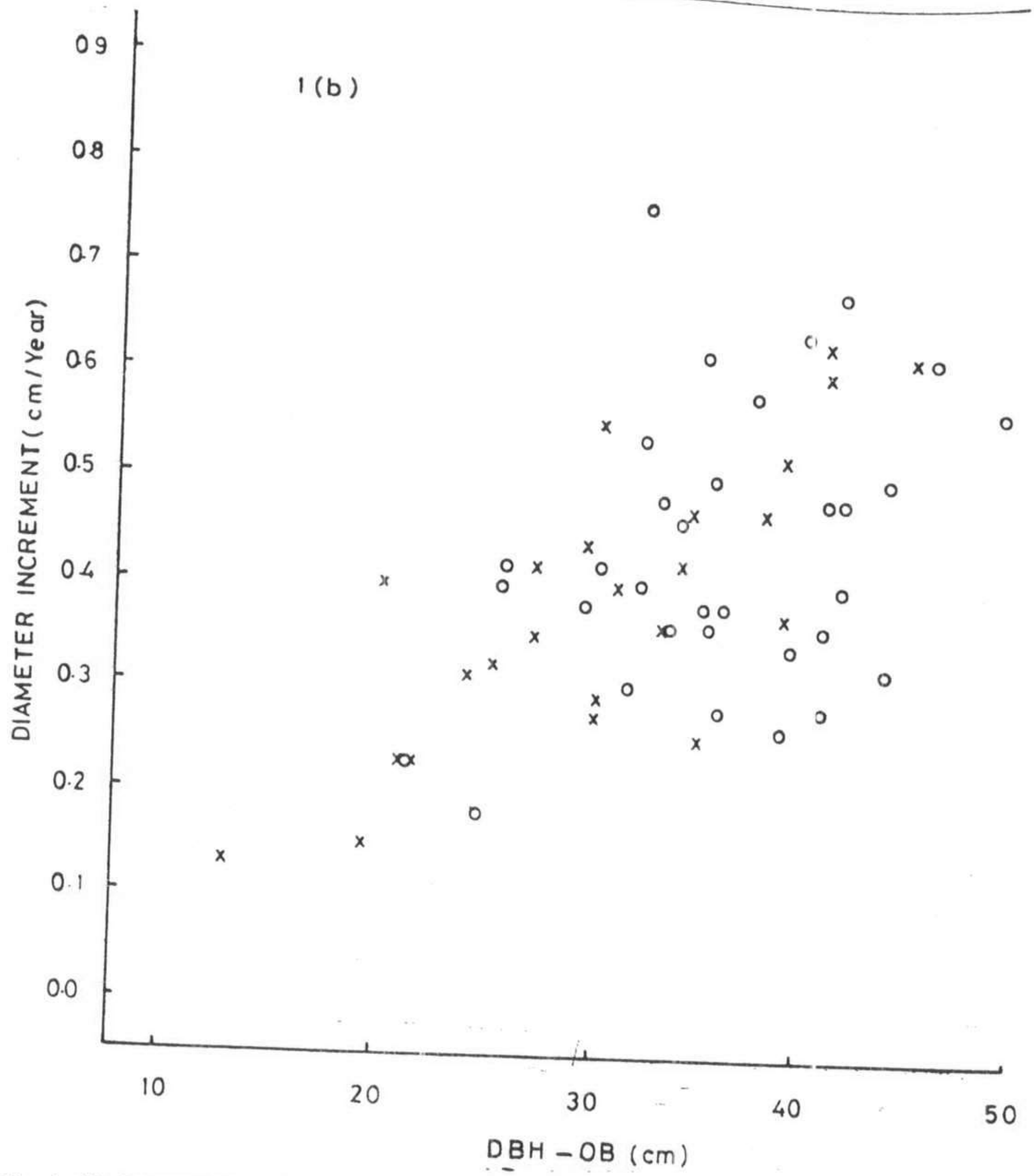

Fig. 1 (b) Relationship between diameter increment and initial diameter of African cadar regenerates at different ages 32—(x x x) and 40 (○○○) years.

TABLE II—RELATIONSHIP CHARACTERISTICS OF INITIAL DIAMETER UPON PERIODIC MEAN ANNUAL DIAMETER INCREMENT OF *Juniperus procera*

Periodic growth	Age (yrs) at initial diameter	Mean initial diameter (cm)	Mean periodic annual increment (cm/yr)	Coefficient of multiple determination (R^2)
1946—1958 ..	15	23·06	0·47	0·335 quadratic. 0·341 cubic.
1958—1971 ..	27	26·29	0·54	0·255 quadratic. 0·256 cubic.
1963—1976 ..	32	30·57	0·38	0·618 quadratic. 0·645 cubic.
1976—1981 ..	40	37·05	0·44	0·0531 quadratic. 0·0720 cubic.

TABLE III—DIAMETER—ANNUAL INCREMENT CURVE OF *Juniperus Procera* REGENERATES AT TIMBOROA

Diameter class (cm)	0–25	26–35	36–45	46–55	56–65
Class interval	25	10	10	10	10
PMAI (graph)	1·49	0·45	0·49	0·53	0·56
Time of passage (years) ..	17	22	20	19	18

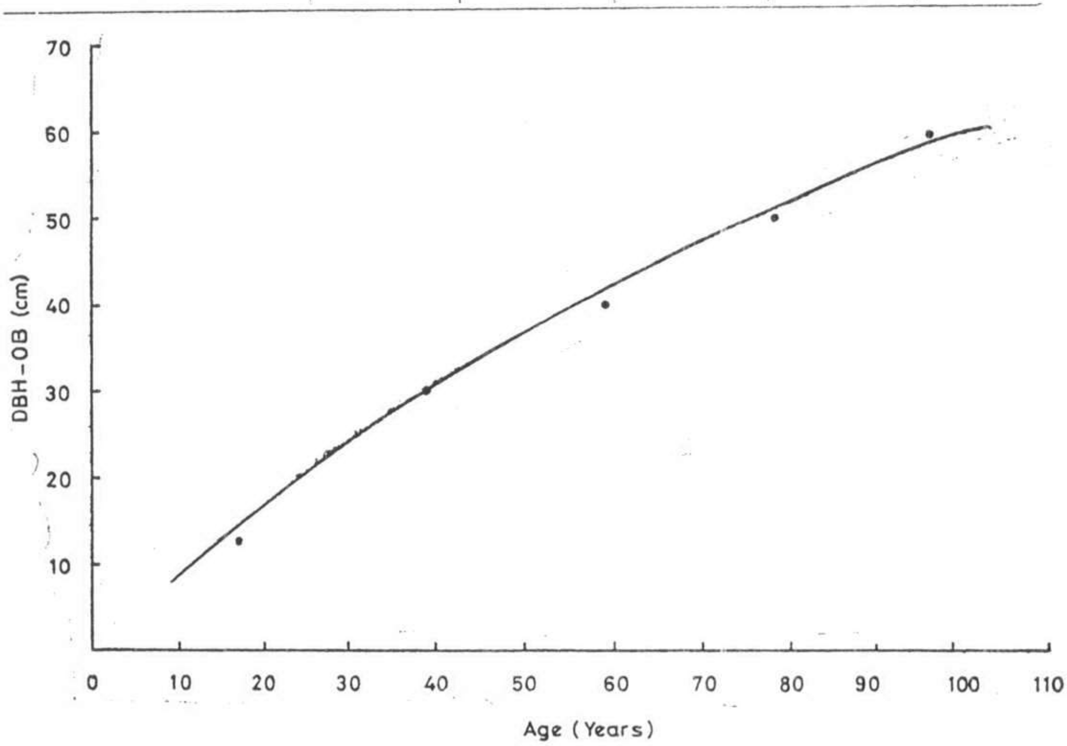

Fig. 2—Age-diameter curve of African pencil cedar (*Juniperus procera*).

Discussion and Conclussions

Juniperus procera grows over a wide altitudinal range and tolerate both high and low rainfalls (Pudden 1955). An earlier fast growth is observed with the young regenerates in the present study. At a lower, elevation of 2, 100m and mean annual rainfall of 990mm at Muguga a trial plot of an african cedar shows a mean annual increment in diameter and height of 0.92 cm and 0.53 m. respectively in the first 20 years (Thogo et al., 1974). Wimbush (1938) assessing rate of growth of cedar at Londiani recorded 0.81 cm diameter increment per annum in a young crop of thirteen and half years. The higher elevation and cooler temperatures coupled with slightly heavier rainfall at Timboroa and similar sites seem to be of advantage to the growth of african cedar which show annual increment in diameter and height of 1.06 cm and 0.63 m respectively in the first 27 years. The trend of rate of growth suggest that there was initially enough space for growth but as the crop approaches age 50 the lowering rate of diameter increment may suggest that the crop has started competing for space. As basal area increases, thinning in such a crop may be required to improve freedom of growth in the remaining stems. Under the present stand conditions and with a rate of diameter increment at age 50 years of 0.70 cm, at age 60 the crop will be expected to have attained an average DBH of 45 cm and thinning the plot from 262 to 160 stems per hectare (Kigomo 1985) may help in reducing root and light competition.

Results of the present study indicate that large diameter trees in a stand may not necessarily have a competitive advantage in growth. Uniform growth over several growth periods however suggest that fast trend of growth may continue for sometime in the course of stand development until a check is exerted by high basal area. It should be noted that the crop under study was a sub-climax stand of almost pure african cedar regenerates in a free growing state that was the result of a fire. It is therefore most likely that competition in growth was mainly between trees of african cedar crop, and the situation may be different in an early development of a more mixed species stand. Results here agree with an analysis involving several tropical trees in mixed-species natural forest stands which failed to show relationship between diameters and their corresponding annual increments (Beaton, 1960).

This study further shows that such an almost pure stand of natural regenerate of african cedar can naturally be managed to harvestable diameters of 60 cm at a final cutting age of about 100 years as indicated in the present study. Much delay in felling of large diameter trees may result in the crop losing more timber by rot than they would be putting on by growth.

One major problem in managing an African cedar natural forest in perpetuity is lack of natural regeneration under its own canopy in high forests (Kerfoot, 1963; Pudden, 1955; Wimbush, 1937). Troup in Pudden (1955) suggest that profuse natural regeneration may occur under a combination of favourable factors such as sufficient rainfall and good and timely regeneration following on a severe fire. It is doubtful that such managerial conditions could be effected systematically with safety or success at a profitable cost. Wimbush pointed out that failure of natural regeneration could be the result of depths of humus which must be destroyed to give facility for seed to root in the soil. Most of the above reviews indicate that regeneration of seedlings in high forest of african cedar should be preceded by ground manipulation in an attempt to get the seed in contact with the soil.

The present climax African cedar natural forests on Mt. Aberdares are the result of past accidental fires that have converted the mountain natural forest stands into sub-climax of pure african pencil cedar or with mixture of few broadleaved trees mainly the brown olive and then to true climax stands (Wimbush 1937). Possibly a controlled small scale surface fire treatment or manual cleaning of top ground litter may improve natural regeneration of African pencil cedar. The effect of these treatments and their intensities should however be assessed to avoid any possible detrimental effects to the sites.

Phenological observations especially in the flowering of cedar canopy and a follow up of what happens to the seed after falling may help in explaining factors limiting natural regeneration.

Summary

A stand of natural regeneration of African pencil cedar (*Juniperus procera*) which was the result of an earlier fire, was selected for the assessment of incremental growth in diameter and height. Early growth data of cedar at Timboroa is tabulated. Mean annual increment in diameter and height of 1.06 cm and 0.63 m respectively are recorded in the first 27 years. Growth in later years decline slowly with increase in basal area but remain reasonably high at 0.77 cm and 0.47 m per year at age 50 years. The observed growth is impressive when compared to rate of increament at Londiani and Muguga of even younger African cedar trial plots. Large diameter trees do not necessarily outgrow smaller diameter trees possibly due to competitive utilization of available initial free growth conditions for all individual trees. Under the present conditions of growth at Timboroa and similar sites, *Juniperus procera* crop may be expected to attain 60 cm D.B.H. (O.B.) and about 35 m in height in 100 years. Difficulties in sustaining timber production in perpertuity in African cedar natural forests due to lack of natural regeneration is mentioned and a follow up investigation of the fate of seed after falling is suggested.

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