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GROWTH RATES OF IMPORTANT EAST AFRICAN MONTANE FOREST TREES, WITH PARTICULAR REFERENCE TO THOSE OF MOUNT KENYA

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ABSTRACT

The length increments of seedlings and branches, and the extension growth of specimens of different age classes of 12 forest tree species were measured on Mt Kenya between May 1992 and July 1995.

Of all examined species, the camphor tree, *Ocotea usambarensis* showed the lowest growth rates. The growth rates of other species of the primary forests, namely *Zanthoxyllum gillettii* and *Vitex keniensis* were between 30 and 200 % higher. The seedlings of *Vitex* outgrew even pioneer species such as *Macaranga kilimandscharica* Pax and *Neoboutonia macrocalyx*. These trees showed growth rates at least twice as high as those of the primary species.

Juniperus procera was found to be the fastest growing species in the cedar forest, underlining its success in forming dense stands after a fire. Only young *Podocarpus latifolius* showed a similar fast growth. *Olea europaea* ssp. *cuspidata*, *Olea capensis* ssp. *hochstetteri* and *Cassipourea malosana* had nearly equal growth rates, however, considerably lower than those of *Juniperus procera* and *Podocarpus latifolius*.

Hagenia abyssinica fell within the range of the fast growing species, illustrating the ability of this species to regenerate very fast under suitable conditions.

INTRODUCTION

Today, only about 2 % of Kenya's land area are still covered with indigenous forests (Doute *et al.*, 1981). Mt Kenya's forests comprise nearly 2,000 km^2, or 20 % of the total forested area (Beentje 1990), and is thus the most extended and coherent natural forest block in the country. In addition to producing timber and firewood, the forests of Mt Kenya represent Kenya's largest water catchment system, supplying water for about 50 % of the Kenyan population. In addition, the National Park of Mt Kenya attracts up to 20,000 visitors every year, providing considerable financial revenue for the National Park. Both the forest belt and alpine zone harbour an enormous variety of different conspicuous vegetation types with a unique flora and fauna, including several endangered species, *e.g.* the eastern bongo (*Tragelaphus euryceros*), black rhinoceros (*Diceros bicornis*), elephant (*Loxodonta africana*), black fronted duiker (*Cephalophus nigrifrons*) and giant forest hog (*Hylochoerus meinertzhageni*) (Milner *et al.*, 1993). For all those reasons Mt Kenya has been included in the UNESCO MAB 6 Program.

Unfortunately, the natural forests of Mt Kenya have been subjected to heavy tree felling for decades. Moreover, due to selective logging, they also have undergone significant changes of their species composition.

For the total area of Kenya, Myers (1979) estimated a former natural forest cover of 15 %, which is equivalent to about 80,000 km^2. Today, even including plantations of exotic species, only a quarter of this area still merits the term forest. Although private tree planting of exotic species has reduced the fuelwood deficit considerably, the destruction of the natural forests has increased drastically in the last decades. Currently, Kenya has an annual deforestation rate of 1.5 %, which is in part driven by a human population growth rate of 3.8 %. If current rates of forest clearing continue, no natural forest will remain by the year 2040 (Barnes 1990).

Publications on the growth of tropical forest trees are still very rare. Some growth rates have been measured in cultivated species (*e.g.* Crow & Weaver, 1977; Schmidt & Weaver, 1981) or have been reported from field observations (Breitsprecher & Bethel, 1990; Chapman & Chapman 1990, Lieberman 1885; Lieberman *et al.*, 1985a,b; Lieberman & Lieberman, 1987). Despite the enormous ecological and economical importance of the montane forests and the increasing demand for land and fuelwood of a rapidly increasing population, only very few studies have been carried out on the growth rates of the most valuable indigenous timber species (Kigomo, 1980; 1985a,b, 1987), and these were mainly obtained from plantations. Therefore, information on the natural growth performance of these indigenous tree species is badly needed for the planning of sustainable forestry. The present study is a first step in filling this gap.

MATERIAL AND METHODS

The growth of 12 tree species characteristic of the major types of primary and secondary forests of Mt Kenya were determined between 1992 and 1995. All measurements were made under natural conditions. Seeds of each species were germinated directly in the field in undisturbed stands of the mother trees. The growth (elongation) of 50 seedlings of each species was measured 90 days after germination.

For the measurement of secondary growth, 40 individuals of each species in three age classes (under five years, 20–50 years, over 50 years) were selected in the field and marked. To limit the influence of site differences, these individuals were selected always only in one representative, undisturbed stand per tree species. In all 3 age classes, trees of similar girth widths at breast height (dbh) were selected, to avoid growth differences due to different tree age (Struhsaker, 1997). The dbh of these 40 marked specimens of each tree species were measured every 3 months. Of 10 of these individuals of each species in the 3 age classes, additional samples were taken using a Mattson stem drill. These samples were examined microscopically. As growth of the investigated species takes place mainly during and shortly after the wet seasons, resulting in two distinct growth rings every year, which were used as marks. Similar growth rings were observed in the Neotropics for periodically flooded forests or dry seasons (Worbes, 1989). The 50 values so obtained from the two methods were added up to calculate the mean growth.

Slices were cut from available timber samples of other individuals of the species and examined in the same way to allow estimating the approximate age of specimens of a certain dbh. However, as these samples often could be only obtained from other sites, these data were not used in the final growth analysis to avoid errors due to site differences.

To measure the elongation of branches, 10 branches of 5 specimens of the marked individuals of each species were marked. Every month, the last-unfolded pair of leaves at the tip of the branches was labelled. At the end of the observation period the branches were collected, and the growth calculated from the distance between the labels.

RESULTS

Growth of seedlings (Figure 1, table 1)
Ocotea usambarensis, by far the most important and endangered timber species of Kenya showed the lowest growth rates of all investigated species. Seedlings of this species only reached an average height of 4.6 cm 3 months after germination, which is less than other primary forest species, as *Zanthoxyllum gillettii* (5.3 cm), *Podocarpus falcatus* (6.9 cm) or *Olea capensis* and *Olea europaea* (8.8 and 7.5 cm). However, there was another group of primary species characterised by a very fast growth of the seedlings, *e.g. Vitex keniensis* (reaching 13.7 cm in the same time span), *Podocarpus latifolius* (10.1 cm), and *Hagenia abyssinica* (11.2 cm). Seedlings of secondary forest species as *Macaranga kilimandscharica* (12.22 cm) and *Neoboutonia macrocalyx* (9.55 cm) elongated only a little faster than those of the named primary forest species. This suggests that the influence of the early growth of the seedlings is of minor importance for the dynamics of the forest vegetation.

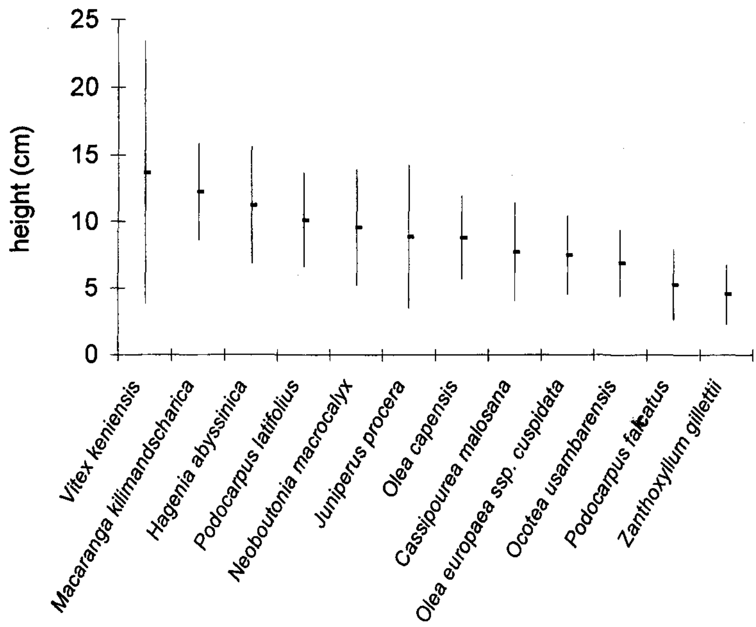


Fig. 1. Mean height of seedlings after 90 days growth.

Table 1. Mean annual growth increments of East African montane forest trees 1992-1995. (dbh in cm; x, S.D., Range, cv).

	Height of seedlings after 90 days growth				Annual length increment of branches				Annual diameter increase of trees 1-5 years				Annual diameter increase of trees 20-50 years				Annual diameter increase of trees > 50 years			
N=	50				50				40				40				40			
Increment (cm) Family/species	x	S.D.	Range	cv (%)	x	S.D.	Range	cv (%)	x	S.D.	Range	cv (%)	x	S.D.	Range	cv (%)	x	SD.	Range	cv (%)
RHIZOPHORACEAE																				
Cassipourea malosana	7.72	3.71	2.73–12.86	48	15.6	7.33	6.88–29.51	47	0.73	0.11	0.42–0.96	15	0.47	0.09	0.29–0.61	19	0.41	0.07	0.31–0.53	17
ROSACEAE																				
Hagenia abyssinica	11.23	4.38	5.21–17.23	39	19.4	8.15	10.95–31.44	42	1.46	0.2	0.68–1.71	14	0.93	0.17	0.71–1.25	18	0.72	0.13	0.49–0.95	18
CUPRESSACEAE																				
Juniperus procera	8.86	5.4	2.54–16.88	61	16.3	7.66	8.29–26.81	47	1.54	0.23	1.11–2.03	15	0.87	0.15	0.66–1.09	17	0.63	0.12	0.44–1.01	19
EUPHORBIACEAE																				
Macaranga kilimandscharica	12.22	3.67	6.89–19.57	30	35.2	9.15	19.38–49.26	26	2.59	0.83	1.35–3.22	32	1.86	0.45	1.28–2.57	24	1.36	0.29	1.03–1.87	21
Neoboutonia macrocalyx	9.55	4.39	3.33–15.98	46	39.1	8.21	26.91–52.37	21	2.87	0.95	1.44–4.67	33	1.92	0.52	0.97–2.66	27	1.48	0.31	0.98–2.05	21
LAURACEAE																				
Ocotea usambarensis	4.57	2.24	1.89–8.67	49	18.3	4.21	12.16–26.55	23	0.86	0.07	0.38–1.27	8	0.52	0.11	0.29–0.83	21	0.25	0.05	0.1–0.45	20
OLEACEAE																				
Olea capensis	8.79	3.19	3.29–15.66	36	24.2	4.11	14.92–32.25	17	0.77	0.19	0.25–1.13	25	0.53	0.12	0.24–0.92	23	0.45	0.09	0.31–0.62	20
Olea europaea ssp. cuspidata	7.47	2.99	2.84–13.22	40	20.6	6.18	10.66–33.93	30	0.48	0.24	0.21–0.92	50	0.36	0.15	0.11–0.59	42	0.32	0.11	0.20–0.55	34
PODOCARPACEAE																				
Podocarpus falcatus	6.88	2.55	4.12–13.29	37	18.7	5.42	9.32–27.11	29	0.85	0.11	0.37–1.29	13	0.32	0.09	0.16–0.52	28	0.28	0.08	0.15–0.41	29
Podocarpus latifolius	10.13	3.55	5.91–16.77	35	22.4	8.29	11.88–38.39	37	1.27	0.17	0.99–1.83	13	0.69	0.14	0.32–0.88	20	0.43	0.14	0.19–0.63	33
VERBENACEAE																				
Vitex keniensis	13.65	9.81	2.99–21.24	72	not measured				1.87	0.22	1.26–2.94	12	0.72	0.19	0.57–1.03	26	0.59	0.14	0.31–0.74	24
RUTACEAE																				
Zanthoxyllum gillettii	5.26	2.68	1.79–9.33	51	not measured				1.39	0.21	0.77–2.05	15	1.02	0.16	0.78–1.67	16	0.73	0.12	0.58–0.97	21

Growth of branches

Macaranga and *Neoboutonia* outgrew all other investigated tree species (figure 2). Their annual length increments of the branches (35.2 and 39.1 cm respectively) was on average approximately about 75 % higher than the growth rate of the primary species, which elongated by about 20 cm/year on average.

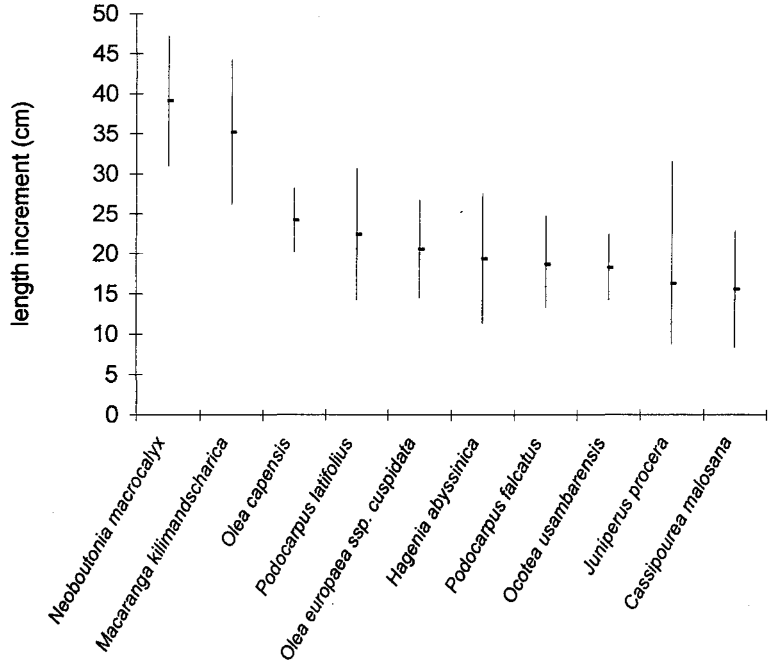


Fig. 2. Mean annual length increment of branches 1992–1995.

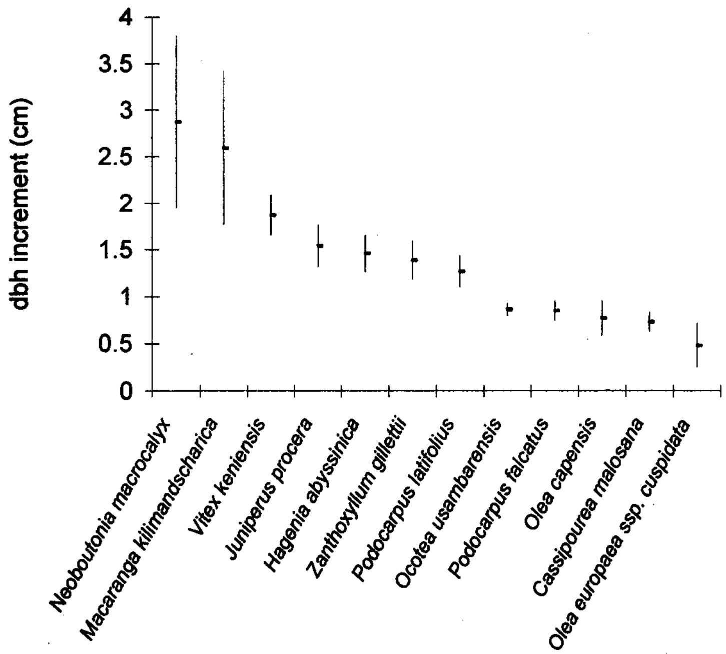
Diameter increment by secondary growth (figures 3A, B, C)

One-to-five-year old trees of all investigated species showed the highest rates of secondary growth. Older trees reached only 25-60 % of this rate.

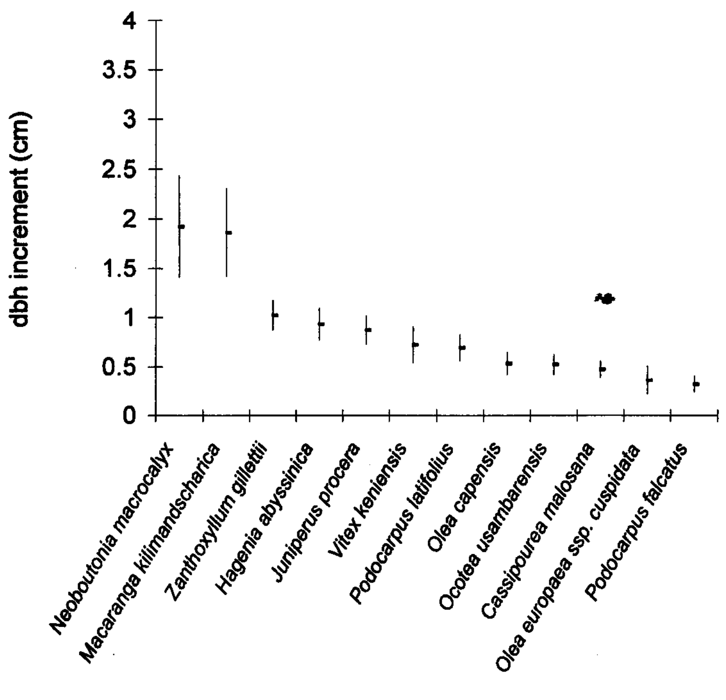
According to their rates of secondary growth the young trees could be grouped in three classes. *Ocotea usambarensis, Podocarpus falcatus,* both *Olea* species and *Cassipourea malosana* were the slowest growing species, attaining an annual diameter increment of between 0.5 and 0.9 cm. All other primary forest species (*Zanthoxyllum gillettii, Vitex keniensis, Podocarpus latifolius, Juniperus procera* and *Hagenia abyssinica)* grew about twice as fast (1.4–1.9 cm/year). The third group consisted of the two Euphorbiaceae (*Macaranga kilimandscharica* and *Neoboutonia macrocalyx*, which are typical for secondary forests), reaching 2.6 and 2.9 cm/year.

The difference between primary and secondary forest species became even more evident when comparing the secondary growth rates of trees older than 20 years. Here the growth rates of all species decreased by approximately 30-50 %, however, the observed decrease was lowest for the secondary species.

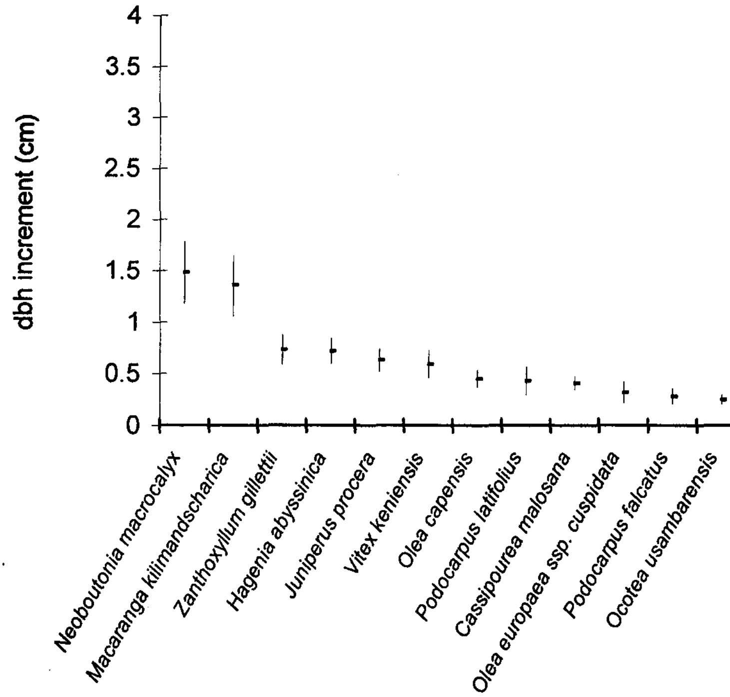
In individuals older than 20 years, the percentage decrease in diameter increment was comparable for all species. The two pioneer species of the secondary forests, however, still grew about 4 times as fast as all primary species.


4
3.5
3
2.5
2
1.5
1
0.5
0
dbh increment (cm)
Neoboutonia macrocalyx
Macaranga kilimandscharica
Vitex keniensis
Juniperus procera
Hagenia abyssinica
Zanthoxyllum gillettii
Podocarpus latifolius
Ocotea usambarensis
Podocarpus falcatus
Olea capensis
Cassipourea malosana
Olea europaea ssp. cuspidata

3A.


4
3.5
3
2.5
2
1.5
1
0.5
0
dbh increment (cm)
Neoboutonia macrocalyx
Macaranga kilimandscharica
Zanthoxyllum gillettii
Hagenia abyssinica
Juniperus procera
Vitex keniensis
Podocarpus latifolius
Olea capensis
Ocotea usambarensis
Cassipourea malosana
Olea europaea ssp. cuspidata
Podocarpus falcatus

3B.



3C.

Figure 3 Mean annual dbh increment of A. young trees (1–5 years) 1992–1995. B. 20–50 year old trees 1992–1995. C. mature trees (>50 years) 1992–1995.

DISCUSSION

The median dbh increments found are very well comparable to the ranges given for mean annual growth rates for African forest species (0.5–4.8 mm, Struhsaker, 1997) and neotropical rainforest species (*e.g.* 2.6–7.8 mm, Chapman & Chapman, 1990; 2.5–8.1 mm, Crow & Weaver, 1977; 0.8–11.5 mm, Lang & Knight, 1983; 0.4–13.4 mm, Lieberman *et al.,* 1985a; 1.1–6.5 mm, Schmidt & Weaver, 1981). This is especially interesting, as particularly in contrast to the neotropical sites, the study area shows very distinct wet and dry seasons. In contrast to Connell *et al.* (1984) and Alder (1992), the annual dbh increment generally decreased with size and age of the measured individuals, reaching the lowest rates for mature trees, which is also reported by Struhsaker (1997) for Kibale forest, whereas Swaine *et al.*, (1987a) found larger trees having higher growth rates. In close correspondence to the results of Felfili (1995) however, light requiring canopy and pioneer species showed the highest increment rates.

The dbh growth rates for *Ocotea, Vitex, Podocarpus,* and *Juniperus* measured in the natural forests were similar to those obtained by Kigomo (1981, 1985a,b, 1987) for trees of routinely thinned plantations.

The growth rates of the species measured showed high differences between species, but also between individuals of the same species. This corresponds closely to the observations of

Korning & Balslev (1994). In contrast, the growth of individual trees during the study period showed much less variation. This phenomenon is also mentioned by Swaine (1989). The coefficient of variation (cvs) values calculated never reached more than 61 %. This is a very clear contrast to the high individual growth variability found for species in other tropical forest regions. Especially in tropical lowland forests, cvs rates of often much more than 100 % were reported (Felfili, 1995; Gentry & Terborgh, 1990; Pires & Prance, 1977; Swaine *et al.*, 1987b).

CONCLUSIONS

The results of the present study give valuable information for the management of natural forests, especially with respect to replanting. After clearcutting or for fast reforestation of agronomically used areas, indigenous pioneer species as *Macaranga kilimandscharica* and *Neoboutonia macrocalyx* could be extremely useful. Due to their fast growth these species would be valuable to limit the influence of erosion. In their shade, more valuable, slow growing primary species, *e.g. Ocotea usambarensis,* can be raised (Bussmann & Beck, 1995). For the fast establishment of plantations or agroforestry, several valuable and fast growing indigenous species as *Juniperus procera* and *Vitex keniensis* could easily be used to replace the presently-favoured exotic softwoods.

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