ECOTROPICA 1: 79 – 84, 1995

REGENERATION AND SUCCESSION PROCESSES IN THE CEDAR FORESTS (JUNIPERION PROCERAE) OF MOUNT KENYA.

Rainer Willi Bussmann & Erwin Beck*

Universität Bayreuth, Lehrstuhl für Pflanzenphysiologie, D-95440 Bayreuth, Germany

Abstract. Approximately 2000 km^2 of the submontane and montane zone of Mount Kenya are covered with natural forests or woodland vegetation. The western and northern parts of that belt, at an altitudinal range of 2500-2950 m carry several types of evergreen xeromorphic forest which are characterized by the East African Pencil Cedar (*Juniperus procera* Hochst. *ex* Endl.). Due to the great physiognomic and floristic variety, the syntaxonomical rank of an alliance, namely the Juniperion procerae, was allotted to these forests. Typically, they occupy the drier parts of the montane zone, where deep humic Acrisols dominate. The regeneration and succession processes of these forests were studied. Fire seems to play an important role in regeneration, entailing rapid germination of the seeds of *Juniperus procera*. The young trees outgrow all other species and frequently monotonous forests arise within a short time. This regeneration cycle is typical of the forests of the higher altitudes. In lower areas, and if fire is absent for longer time periods, mainly broad-leaved species contribute to the climax forests after breakdown of the over-aged cedars. Over-exploitation by logging and clear-cutting for plantations of exotic softwood species as well as for agricultural use have already destroyed large parts of the cedar forests, and the regeneration of the remaining stands seems to be impaired by the high population density of wildlife, especially elephant and buffalo. *Accepted 11 October 1995.*

Key words: Mount Kenya, tropical montane forests, regeneration, succession, ecology.

INTRODUCTION

Mount Kenya, a solitary mountain of volcanic origin with a base diameter of about 120 km and an altitude of 5198 m, is located on the eastern side of the Great Rift Valley, directly on the Equator, about 180 km north of Nairobi (Fig. 1). The deeply incised, often in the upper parts U-shaped, valleys indicate former glaciation. Most parts of the broad cone-shaped mountain, up to approximately 3400 m in the south and 3000 m in the dry north, are still covered with indigenous forests, which are, however, frequently disturbed by human activities. Cultivated land now extends up to 1800 m on the southern, 2400 m on the eastern and western, and up to nearly 2900 m on the northern slopes. The forests of Mt. Kenya today cover about 2000 km^2, and represent nearly 20 % of the total remaining natural forests of Kenya (Beentje 1990).

As important area of water catchment, the mountain feeds the Ewaso Nyiro and Tana River systems, and thus is essential for the water supply to a large part of Kenya (Berger 1989, Decurtins 1985, 1992, Leibundgut 1986).

The various types of evergreen xeromorphic montane forests on the moderately humid to dry western and northern slopes of the mountain are dominated by the large East African Pencil Cedar *Juniperus procera* Hochst. ex Endl. This conspicuous tree typically grows in the drier submontane, montane and rarely subalpine areas of many East African mountains (Kerfoot 1961). Temperature as well as annual rainfall below 700 mm apparently limit its spreading (Winiger 1979, 1981; Rheker 1992; Young 1990).

Despite the importance of these forests only a few studies (e.g., Wimbush 1937) have been carried out on their regeneration patterns, and even less on the rejuvenation, i.e., germination capacity and growth, of *Juniperus procera* itself.

The cedar forests of Mount Kenya, growing on humic Acrisols (Speck 1982) with rainfall between 700 and 1500 mm, represent the typical vegetation of the altitudinal range between 2500 and 2950 m. Phytosociologically they form the alliance Juniperion procerae in the order Juniperetalia procerae and the class Juniperetea procerae (Bussmann & Beck 1995a). In these open single or double-storeyed forests *Juniperus procera* grows to about 50 m under favourable conditions. Other important tree species, mainly of the lower canopy, are the African Olive (*Olea europaea* ssp. *africana*) and *Podocarpus latifolius*. An occasionally dense grass layer with *Stipa dregeana* and *Brachypodium fle-*

* corresponding author

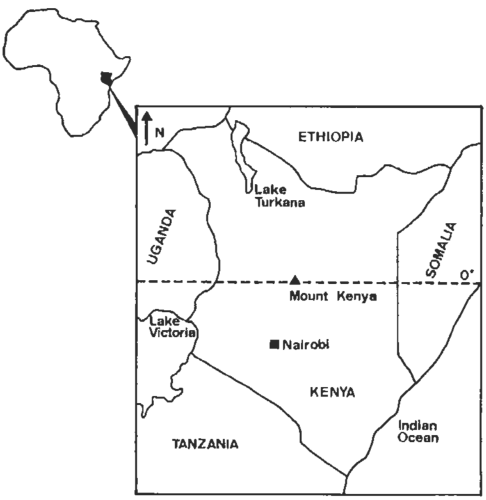

FIG. 1. Location of Mount Kenya.

xum, interspersed with herbs such as *Sanicula elata, Isoglossa gregorii* and *Achyranthes aspera,* and low shrubs like *Berberis holstii,* is also characteristic of these open cedar forests.

METHODS OF INVESTIGATION AND RESULTS

Flowering, germination and growth of Juniperus procera

A phytosociological study of the forests of Mount Kenya was carried out between February 1992 and June 1994. More than 600 relevés were established, each being considered to represent a floristically homogenous and typical area. After having consulted aerial photographs, the locations of the relevés were chosen direcrly in the field. The quantitative analysis of the vegetation plors was performed using the method of Braun-Blanquet (Braun-Blanquet 1964) as described in detail by Mueller-Dombois & Ellenberg (1974) and slightly modified by Hammen *et al.* (1989). Minimum areas were from 32 to 256 m^2. In addition 33 stand-profile diagrams were established, following Hammen *et al.* (1989). Transects of 60 m length and 20 m width were mapped, stem and crown diameter and height of all woody plants were measured and plotted as exactly as possible.

On Mt. Kenya the main season of flowering and fruiting of *Juniperus procera* (as well as most other forest species) coincides with the long rains, i.e., the period between early March and late April. A second flowering may take place after the short rains have set in by mid-October.

In germination tests, 100 seeds of *Juniperus* were germinated in the greenhouse (polythene bags with natural soil) and laboratory (in standard petri dishes, on filter paper) of the Botany Department of the University of Nairobi and in the greenhouse of the Botany Department of the Universität Tübingen (in standard germination containers, using a commercially available soil mixture). The seeds were maintained under illumination, as well as in the dark. Illumination was found to be a requirementand germination was quantitatively successful only under bright light. In the dark, only a few seeds germinated (Fig. 2). These results suggest that the African Pencil Cedar may successfully regenerate from seeds only in forest gaps. In addition, in our experiments germination was dependent on complete removal of the oily fruit flesh. If the fruits had been crushed, but the flesh was not fully removed, or if crushed fruits were mixed with flesh-free seeds, germination of the latter was completely inhibited. This suggests the presence of a strongly inhibitory constituent in the fruit flesh, an idea which is corroborated by observations in the field, where plenty of fruits may be found rotting under the mother trees without any indication of germination. This, in turn, might provide an explanation for the fast germination of *Juniperus* seeds after fire, assuming destruction of possible allelopathic compounds on the one hand and concomitant killing of competitors on the other.

Once established, *Juniperus procera* belongs to the fastest growing species of the cedar forests and thus, outgrowing competitors, can form dense stands after fire.

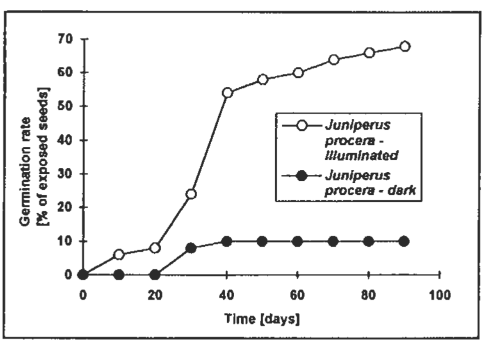

FIG. 2. Germination of *Juniperus procera.*

Regenerative cycles in African Pencil Cedar forests

Fire apparently plays an important role in the regeneration cycle of the Juniperion procerae. In a study of the cedar forests of the Aberdare Range, Wimbush (1937) suggested that without impact by fire the *Juniperus* forest is only a seral stage in the successional development resulting in a broad-leaved forest. He summarized his observations in the following regeneration cycle (Fig. 3): After fire, herbaceous pioneer species and scattered *Juniperus procera* seedlings establish in gaps (1), leading to a regenerating forest (2) which is gradually invaded by broad-leaved tree species like the olives, *Olea capensis* ssp. *hochstetteri, Olea europaea* ssp. *cuspidata* and *Olinia rochetiana.* After 2 decades, the *Juniperus* trees may have attained a height of about 9 m. In dense stands, the cedar trees start to outgrow the other species, reaching about 30 m after 80-90 years. In this way, a pure cedar forest (3) results by suppression of other trees. Two hundred year old *Juniperus* trees are usually at their maximum height of about 40-46 m. Although normally infected by the fungus *Fomes juniperinus* which thins the crowns, the *Juniperus* trees may live for another 300-700 years. If a burnt area is invaded mainly by broad-leaved species, these will form the canopy from which only scattered *Juniperus* specimens emerge (4). As the cedar seems not to regenerate very well without fire, natural gaps in these forests are filled with broad-leaved species and pure broad-leaved forests build the climax community (5+6). This cycle was confirmed for the Aberdare Range by Schmitt (1991).

The present study, however, can only partly lend support to such a regeneration scheme. Some of the plant communties of the 'pure Juniperion procerae' on Mount Kenya appear to follow the Wimbush cycle, in particular in deep gorges or on steep ridges, where *Juniperus procera* shows poor regeneration even after fires, and thus a climax of broad-leaved forest can establish itself. However, most cedar forests examined on Mt. Kenya appear to be stable while corresponding to stage 4 of the succession cycle. In addition, the submontane Cassipourion malosanae-forests (Bussmann & Beck 1995a) with only scattered *Juniperus* trees, which could be interpreted as stage 6 of the Wimbush cycle, show regeneration of cedar in gaps even without fire. According to our recent compilation, fires are very frequent on Mt. Kenya in general, but very rare in this humid forest type.

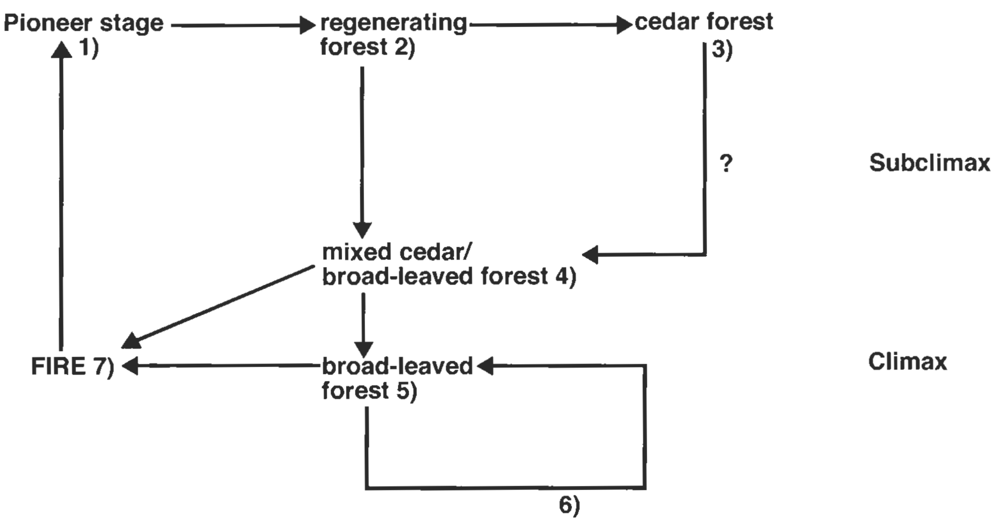

FIG. 3. Regeneration cycle of the Juniperion procerae. For explanation see text.

In heavily-logged areas, more or less pure stands of broad-leaved trees were encountered, with few *Juniperus* trees left.

Forests dominated by *Juniperus procera* alone were seen only at higher altitudes, forming the upper borderline of the Juniperion procerae, and were described as the phytosociological association Myrsino africanae - Juniperetum procerae. On Mt. Kenya, several large

FIG. 4. Regeneration cycle of the Myrsino africanae - Juniperetum procerae. For explanation see text.

patches were found in these forests, which indicate various regeneration stages after fire. The following regeneration processes were deduced from the analysis of these plant communities (Fig. 4): After fire, a pioneer vegetation with a very high cover of *Myrsine africana* and juvenile *Juniperus* (1) develops, which was syntaxonomically categorized as Myrsino africanae - Juniperetum procerae typicum. Broad-leaved trees migrate into this plant community, and due to different ecological conditions and different seed intake may produce different kinds of climax forests (2). *Juniperus procera*, however, is the consistently dominating canopy species. Those mentioned climax stages which were phytosociologically allotted to as subassociations are open forests with scattered shrubs, allowing regeneration of all tree species. Seedlings and young trees of *Juniperus* were frequently found in these forests, even when fire had been absent for a longer time-period (3). This indicates that at higher altitudes broad-leaved forests in sensu Wimbush (1937) cannot replace the *Juniperus* forests, even if burning has not occurred for a long time. After a fire (4), the same regeneration cycle starrs again.

Forest destruction

The submontane and montane cedar forests have been and still are suffering considerably from human activities. In many areas of former *Juniperus* forests, plantations of fast-growing softwoods (before 1945 mainly *Cupressus lusitanica*, more recently *Pinus radiata* and *P. patula*, FAO 1981) have been established, and heavy logging has devastated large parts of the area (Fig. 5). Such forest areas have been and still are used for livestock grazing, leaving no natural herbal vegetation.

In late 1993, some plantations of *Cupressus lusitanica* and *Pinus radiata* in the Naro Moru and Sirimon regions were opened after clear-cutting to temporary farming by presidential decree. As a consequence, shambas now extend almost to the Naro Moru Gate of Mount Kenya National Park (Fig. 6) and the remaining natural forests are again subjected to extreme pressure by the squatters who continue felling trees for timber and firewood.

On the drier northern slopes of the mountain a so-called gap in the forest belt has been mentioned by several authors (e.g., Hutchins 1909, White 1950). Whether this gap is natural or man-made has been a matter of debate. In the late 1970s, some areas of the Mt. Kenya Forest Reserve, especially on the norrhern slopes of the mountain, were excised by the Kenyan government for farmland, and long-term residents of the area stated that the gap has been widened by clearing the forest for farming purposes. In many shambas in the gap area solitary forest trees or remnants of such trees are still present, suggesting a former extension of the forest belt even into the gap. Climatic conditions are less likely to be responsible for the gap since in an even drier area 10 km further north Mount Kenya the Ngare Ndare forest, with extensive stands of *Juniperus procera* is growing very well. Thus, we do not assume the forest gap to be of natural origin. Rather a formerly closed forest belt must be concluded.

Nevertheless, since the gap was already reported at the turn of the 20th century it must have been generated some time ago. Prior to the establishment of the "White Highlands" the area in question was inhabited by the Illaikipiak Maasai (Ole Sankan 1971) who were pastoralists and may have cleared the forest for livestock grazing. Burning shortly before the long rains improves the growth of grass, a method still used in pastoralist communites. The remaining forests of the Juniperetea procerae are heavily affected by legal and illegal logging for timber, especially for fence poles, since the durable cedar wood is termite-resistent. Even the forests along the Sirimon route, which are now part of the Mount Kenya National Park, have suffered severely from such activities. After the region became part of the Park illegal cutting was continued, especially so in the easily accessible areas.

In wide parts of the Juniperion procerae, few seedlings and juveniles of the originally dominant tree species were be encountered. Therefore, fundamental changes in the composition and physiognomy of these forests must be envisaged in the long run. In contrast to the situation in the camphor forests of the humid submontane E and SE slopes of Mt. Kenya (Bussmann & Beck 1995b), the ample game population, especially buffalo, contributes much to the destruction of the cedar forests by eating the seedlings and young trees. Substantial damage by browsing was frequently observed and especially in the dry season the forest floor is partly bare of vegetation as every herb or bush is eaten and trampled by game. Nevertheless, mainly human activities are responsible for the poor regeneration of the Cedar forest, in particular the frequent fires caused by arsonists and honey hunters that mostly destroy all seedlings before they reach maturity.

AKNOWLEDGEMENTS

We gratefully acknowledge the financial support of this work by the Deutsche Forschungsgemeinschaft (DFG) and the Gesellschaft für technische Zusammenarbeit (GTZ). The authors would also like to thank their Kenyan colleagues, Prof. J.O. Kokwaro, Nairobi and Dr. J.C. Onyango, Maseno, for their untiring assistance and especially Mr. S.G. Mathenge, Nairobi University Herbarium, for identifying many difficult species in the field and the herbarium. Finally, thanks are due to the National Research Council of Kenya for

FIG. 5: *Juniperus* forest devastated by logging (Photo April 4,1993).

FIG. 6. Clearfelled plantation opened to temporary farming (Photo July 7,1994).

granting permission for research on Mount Kenya, and to Mr. Bongo Woodley, the Warden of Mount Kenya National Park and his staff for their logistic support.

REFERENCES

Beentje, H. J. 1990. The forests of Kenya (Proceedings of the twelfth plenary meeting of aetfat, symposium II). Mitt. Inst. Allg. Bot. Hamburg, 23a (Proceedings of the twelfth plenary meeting of aetfat, symposium II). Pp. 265-286.

Berger, P. 1989. Rainfall and Agroclimatology of the Laikipia Plateau, Kenya. Geographica Bernensia, African Studies Series A7: 1-102.

Braun-Blanquet, J. 1964. Pflanzensoziologie (3rd edition). Wien.

Bussmann, R.W., E. Beck. 1995a. The forests of Mount Kenya (Kenya), a phytosociological synopsis. Phytocoenologia 25: 467-560

Bussmann, R.W., E. Beck. 1995b. Regeneration and succession processes in the Ocotea-forests (*Ocotetea usambarensis*) of Mount Kenya. Verhandlungen der Gesellschaft für Ökologie 24: 35-39.

Decurtins, S. 1985. Hydrogeographical investigations on Mt. Kenya and its w and nw slopes. Laikipia Reports 5: 1-14.

Decurtins, S. 1992. Hydrographical investigations in the Mount Kenya subcatchment of the Ewaso Ngiro River. Geographica Bernensia, African Studies Series A10: 1-151.

F.A.O. 1981. Tropical forest resource assessment plan. Forest resources of tropical Africa, Technical Report 2. Rome.

Hammen, T. v. d., Mueller-Dombois, D., M.A. Little. 1989. Manual of methods for mountain transect studies. Paris.

Hutchins, D. E. 1909. Report on the forests of British East Africa. London.

Kerfoot, O. 1961. *Juniperus procera* Endl. (The African Pencil Cedar) in Africa and Arabia - I. Taxonomic affinities and geographical distribution. E. Afr. Agr. For. J. 26: 170-177.

Leibundgut, C. 1986. The runoff regimes in the Mount Kenya Areal. Geographica Bernensia, African Studies Series A1: 73-86.

Mueller-Dombois, D., & H. Ellenberg. 1974. Aims and methods of vegetation ecology. New York.

Ole Sankan, S. S. 1971. The Maasai. Nairobi: Kenya Literature Bureau.

Rheker, J. R. 1992. Forest Management and Timber Industry at Mount Kenya (Laikipia-Mount Kenya Reports 16). Bern.

Schmitt, K. 1991. The vegetation of the Aberdare National Park, Kenya. Hochgebirgsforschung 7: 1-250.

Speck, H. 1982. Soils of the Mount Kenya area - their formation, ecological and agricultural significance. Mountain Research and Development 2: 201-221.

White, F. 1950. The forests of Mount Kenya. Forest Society Journal Oxford ser. 3, 5: 32-38.

Wimbush, S. H. 1937. Natural succession in the Pencil Cedar forests of Kenya Colony. Emp. For. J. 16: 49-53.

Winiger, M. 1979. Bodentemperaturen und Niederschlag als Indikatoren einer klimatisch-ökologischen Gliederung tropischer Gebirgsräume. Geomethodica 4: 121-150.

Winiger, M. 1981. Zur thermisch-hygrischen Gliederung des Mt. Kenya. Erdkunde 35: 248-263.

Young, T. P. 1990. Mount Kenya forest - an ecological frontier. Pp. 197-201 *in* Winiger, M., Wiesmann, U., & J.R. Rheker (eds.). Mount Kenya area - differentiation and Dynamics of a Tropical Mountain Ecosystem Bern.