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Liverworts and Hornworts of Rwanda

Eberhard Fischer

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Liverworts and Hornworts of Rwanda

by

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Front cover. *Asterella khasyana* (Griff.) Pandé, K.P.Srivast. & Sultan Khan, Cyamudongo Forest.

Half-title page. *Herbertus dicranus* (Tayl. ex Gottsche *et al*.) Trevis., Mt. Sabinyo.

Abstract

The book contains the first part of a bryophyte flora of Rwanda covering 262 liverworts and hornworts. General information on flora and vegetation of Rwanda, the history of bryological exploration, and the phytogeography of liverworts and hornworts are provided. Keys for all genera and species recorded from Rwanda are presented. An introduction to the morphology of liverworts and hornworts is given, and collecting techniques are described. The main part of the book deals with the foliose and thallose liverworts and the hornworts. Each species is represented by habit photographs and microscopic details.

Keywords – liverworts, Marchantiophyta, hornworts, Anthocerotophyta, Rwanda, Albertine Rift, endemics

Dedicated to Tamás Pócs on the occasion of his 80th birthday

Table of contents

1. Purpose of this book

While most areas of the world are covered by a local flora of ferns and flowering plants, the situation is different for bryophytes. Many regions of the world do not yet have a bryophyte flora, including large parts of Africa. Most of the work on bryophytes in Africa has been done by non-Africans, usually Europeans (see chapter 3), many of whom travelled little or not at all in Africa but received collections made by explorers, or botanists specializing in vascular plants. The literature on these collections is copious but extremely scattered and usually not available to African students of bryophytes. The need for bryophyte floras covering tropical Africa is apparent and had already been stressed by O'Shea (2005). The lack of available literature, including floras and identification keys, means that local botanists are often unable to identify bryophyte specimens, and therefore bryophytes have usually been omitted from biodiversity studies. They have also been considered a 'difficult' group, which has been another obstacle to their study (O'Shea, 2005). However, bryophytes can be important in studies of biodiversity, as many species are sensitive bioindicators that respond quickly to environmental change. They are pioneer organisms growing, for example, on almost bare rock where they prepare the habitat for the colonization of flowering plants. They also contribute enormously to the water management and equilibrium of the forest because of their often large biomass. They intercept rain, swell up with the rainwater and accumulate water many times their weight (Pócs, 1980). Last, but not least, bryophytes are beautiful plants that enhance the aesthetic value of landscapes and habitats, notably when in dense masses in moss-draped forests or on rock-faces.

The publication of the present identification guide to liverworts and hornworts, as well as a guide to mosses (in prep.), is intended to greatly facilitate further bryological studies in Rwanda and adjacent countries. The guide is based on the author's observations and collections from Rwanda during 75 field trips since 1984. However, the identification of specimens would not have been possible without the numerous taxonomic papers available on African liverworts and cited in the Key section, especially the monumental series "African Hepatics" by E.W. Jones. These references have also been consulted for the compilation of species descriptions and identification keys (e.g. Jones, 1990). For writing the general chapters on morphology, anatomy and collecting, the publications of Schuster (1984), Gradstein & Pinheiro da Costa (2003) and Wigginton (2004) have been extensively used. Nomenclature and species concepts mainly follow Wigginton (2009) except for *Aphanolejeunea*, now included in *Cololejeunea* (Pócs & Bernecker, 2009), and *Leucolejeunea*, now included in *Cheilolejeunea* (Malombe, 2009). Where possible, fresh material from Rwanda has been illustrated, but for several taxa which were not available in the fresh state, herbarium material has been used.

2. Introduction

The Bryophytes of Tropical Africa are among the better studied groups, compared with those of Tropical America or Asia. Especially for Liverworts and Hornworts, numerous valuable taxonomic revisions, a modern catalogue (Wigginton & Grolle, 1996; Wigginton, 2009) and a modern flora for Western Tropical Africa (Wigginton, 2004) are available. The Liverworts of Katanga in South-Eastern D.R. Congo were studied by Vanden Berghen (1972a, 1978b). For mosses of Tropical Africa, only the today mostly outdated treatments for the Central African Republic (Potier de la Varde, 1928) and Gabon (Potier de la Varde, 1936) are available. For Southern Africa, a moss flora has been published (Magill, 1981, 1987; Magill & van Rooy, 1998), albeit not yet completed. The liverworts of Southern Africa are treated by a flora (Arnell, 1963) and a modern revision of the thallose hepatics (Perold, 1999). For the liverworts, E.W. Jones's "African Hepatics" series (Jones, 1952-1990) is an important source for identification. Numerous papers on African liverworts have been published by Vanden Berghen, and Pócs. All these papers, albeit very valuable, do not represent a Flora which can be used by the interested student to identify African bryophytes. The publication of Jones's Liverwort and Hornwort Flora of West Africa, edited by Wigginton (2004) and covering the countries from Senegal to Cameroon was a real milestone. For the mosses, De Sloover published a series of revisions on an African scale (e.g. De Sloover, 1973), the illustrations for which were later published in a separate volume (De Sloover, 2003). However, no complete bryophyte flora of a tropical African country including both liverworts and mosses yet exists. The attempt of the British Bryological Society to compile the "Bryophytes of Uganda" as a book, based on collections gathered during several expeditions of the British Bryological Society to this country finally resulted in publication of 13 families as separate papers (Váňa & Watling, 2004a,b,c; Hedenäs, 2005; Hedenäs & Watling, 2005; Bruggeman-Nannenga, 2006a,b; Ellis, 2007; Wilbraham, 2008; Frahm, 2012). The remaining 76 families are still to be treated which, with an output of 13 families in 9 years, may not be realised for some time. An identification guide to the bryophytes of Kenya was published by Chuah- Petiot (2003), but is not comprehensive, and covers mainly the most conspicuous taxa.

The present study is an attempt to provide a complete bryophyte flora for Rwanda, a small country situated near the Equator in the heart of Africa (Fig. 1). Since 1984, the author has visited the country more than 70 times with a special attention given to bryophytes. In 1991, the BRYOTROP-Expedition provided numerous additions to the flora. The genocide in 1994 interrupted all scientific activity, yet in 1996, cooperation could be resumed, and teaching started again at the National University in Butare. Due to an increased interest in ecology, the lack of a flora to assist in the determination of bryophytes became apparent. The idea of producing an identification guide had already arisen in 1988, but work on a guide was postponed for several reasons. However, some taxonomic papers were published subsequently (e.g. Fischer, 1995; Buchbender & Fischer, 2004; Fischer, 2007). With the rapid development of digital photography, it became much easier to publish

coloured illustrations, and it was decided to provide both habit photographs and also photographs of microscopic details in order to facilitate identifications. In the present volume, the liverworts and hornworts of Rwanda are fully covered, and a similar volume for the mosses is currently underway. However, the guides can be useful far beyond the borders of Rwanda, including for montane areas in tropical East Africa as a whole.

Fig. 1. Map of Rwanda.

3. History of bryological exploration

Until 1907, the flora and fauna of Rwanda was almost unknown. During the expedition of Graf von Götzen (1895) apparently no bryophytes were collected. Richard Kandt (see Bindseil, 2008) who lived in Rwanda as private naturalist from 1898-1902, 1905-1907 and later as the Imperial Resident for Rwanda until 1913 made some botanical collections, unfortunately only flowering plants.

In 1907 Adolf-Friedrich Herzog zu Mecklenburg began an expedition, with the intention of exploring Rwanda and the eastern Belgian Congo. He was accompanied by the geologist Egon Kirschstein, botanist Johannes Mildbraed, zoologist Hermann Schubotz, anthropologist Jan Czekanowski, Lieutenant and cartographer Max Weiss, physician and bacteriologist W. von Raven, as well as Lieutenant Walter von Wiese und Kaiserwaldau, Friedrich Weidemann, Sergeant Czeczatka and 25 Askari (Mecklenburg, 1909). They travelled by train to Lake Victoria, and marched to northeast Rwanda, where they collected at the Lake Mohasi (see Bamps, 1975). After having visited the court of King Yuhi V. Musinga, Mildbraed and Schubotz left the expedition for about two weeks in order to collect plants and animals in the Nyungwe forest (= Rugege Wald). Until March 1908, Mildbraed visited Lake Kivu and the Virunga Volcanoes, and afterwards the eastern Congo (Ituri, Aruwimi) and the Ruwenzori mountains. In May 1908 the expedition travelled down the river Congo by steam boat until they reached the western coast of Africa. They arrived in Hamburg on the 30th June 1908. The scientific results were published by 1925. The botanical volume, edited by Mildbraed in 1914 covered 718 pages. The hepatics were studied by Stephani (1914), who recognized 57 species collected during the expedition, among them 45 new species of liverworts and one new hornwort. He recorded 19 species for Rwanda, 17 of them described as new (Tab. 1). In addition, 28 species were recorded from Butagu valley on the Congolese side of the Ruwenzori, 23 of them described as new taxa. Many of these species from Ruwenzori were later also found in Rwanda. The genus *Sphagnum* was studied by Warnstorf (1914), covering 5 species of which 3 were described as new. The mosses finally were identified by Brotherus (1914), who described 57 new species from the 137 species recognized.

Their treatments would remain a classic work and the only bryological account for Rwanda and D.R. Congo (former Zaïre) for more than 30 years. It also was the basis for Demaret's checklists for Central Africa (see below). Stephani (1914) stated that "wie aus dem Vorstehenden ersichtlich ist, haben wir hier eine Sammlung von Lebermoosen vor uns, welche zu den interessantesten gehört, die jemals nach Europa gelangt sind; wenn diese Pflanzen sich auch an bekannte Gattungen anschließen, so zeigen doch die meisten der gesammelten Arten so überraschende Abweichungen, daß eine weitere Erforschung der ostafrikanischen Gebirge ein naheliegender Wunsch ist." (Stephani, 1914: 134) ("*As it can be seen from the previous treatment, we have here a collection of liverworts which is among the most interesting ones that ever reached Europe; even if these plants can be*

assigned to known genera, most of them show such surprising differences that a further exploration of the East African mountains is highly desirable").

Stephani (1914)	Actual name	Locality
Anastrophyllum calcaratum Steph.	***Anastrophyllum auritum* (Lehm.) Steph.**	Karisimbi, Rand des Hans-Meyer-Kraters, 3400 m
***Anthoceros myriandroecius* Steph.**		Rugege-Wald: Waldmoor, 1800 m
***Fossombronia pulvinata* Steph.**		Rugege-Wald: Waldmoor, 1800 m
Isotachis renistipula Steph.	***Isotachis aubertii* (Schwaegr.) Mitt.**	Rugege-Wald: Waldmoor, 1800 m
Isotachis conistipula Steph.	***Isotachis aubertii* (Schwaegr.) Mitt.**	Karisimbi, 3400 m
Isotachis aspera Steph.	***Isotachis aubertii* (Schwaegr.) Mitt.**	Rugege-Wald: Waldmoor, 1800 m
Lepidozia pulvinata Steph.	***Lepidozia stuhlmannii* ssp. *pulvinata* (Steph.) Pócs**	Karisimbi, Rand des Hans-Meyer-Kraters, 3400 m
Lepidozia carnosa Steph.	***Lepidozia stuhlmannii* var. *carnosa* (Steph.) Pócs & Lye**	Karisimbi, Rand des Hans-Meyer-Kraters, 3400 m
Metzgeria limbato-setosa Steph.	***Metzgeria madagassa* Steph.**	Rugege-Wald, 1900 m
Plagiochila expallescens Steph.	***Plagiochila kiaerii* Gottsche**	Bugoier Bambus-Mischwald, 2000 m
Plagiochila breviramea Steph.	***Plagiochila squamulosa* Mitt.**	Bugoier Wald, an Hagenia, ~2300 m
Plagiochila lurida Steph.	***Plagiochila squamulosa* Mitt.**	Bugoier Bambus-Mischwald, trockene Waldwiese bei Kahama
Radula stipatiflora Steph.	***Radula voluta* Taylor ex Gottsche, Lindenb. & Nees**	Rugege-Wald, 1800 m
Jungermannia mildbraedii Steph.	***Solenostoma mildbraedii* (Steph.) R.M.Schust.**	Rugege-Wald, 1900 m
Symphyogyna rigida Steph.	***Symphyogyna podophylla* (Thunb.) Mont. & Nees**	Rugege-Wald, feuchter Hohlweg, ~1900 m
Arachniopsis coactilis Spruce	***Telaranea coactilis* (Spruce) J.J.Engel & G.L.S.Merr.**	Rugege-Wald: Waldmoor, 1900 m
Lepidozia redacta Steph.	***Telaranea redacta* (Steph.) J.J.Engel & G.L.S.Merr.**	Rugege-Wald: Waldmoor, 1900 m
Lepidozia trifida Steph.	***Telaranea trifida* (Steph.) R.M.Schust.**	Rugege-Wald: Waldmoor, 1800 m
Chandonanthus quadrifidus Steph.	***Tetralophozia cavallii* (Gola) Vana**	Karisimbi, Rand des Hans-Meyer-Kraters, 3400 m

Table 1: Liverworts and Hornworts collected by J. Mildbraed in Rwanda 1907 (Stephani, 1914).

From 1926 to 1927, D.H. Linder of the Harvard Institute of Tropical Biology collected on the Virunga Volcanoes, the bryophytes being published by Theriot (1930). The French botanist Humbert was the first to collect on Mt. Kahuzi and Mt. Biéga in 1929, and also visited the Virunga volcanoes. His name is commemorated in the genus *Bryohumbertia* (Dicranaceae). From 1933 to 1935 the Belgian zoologist De Witte collected in the Albert National Parc (today Parc National Virunga in D.R. Congo and Parc National des Volcans in Rwanda), and so did the botanist Lebrun from 1937 to 1938. Based on these gatherings, a flora of the mosses of

Albert National Park was published by Demaret & Leroy (1944). Two years before, the first checklist of Central African mosses was published by Demaret (1940, supplément 1946), followed by a list of hepatics (Demaret, 1942). This first account of the bryophytes from Congo, Rwanda and Burundi presented a compilation of all data hitherto available. After the Second World War, botanical exploration was intensified. Demaret worked in the Ruwenzori from 1953 to 1957 and J.-J. Symoens collected in Rwanda and Congo from 1955 to 1958. He visited Nyungwe Forest as well as Tshibati and Lwiro, today part of the Kahuzi National Park. His hepaticological results were published by Vanden Berghen (1960, 1961, 1965).

After the independance of Rwanda and D.R. Congo (then Zaïre), only a few bryologists continued to work in this phytogeographically interesting region. In 1971 and 1974, J.-L. De Sloover collected in the Nyungwe Forest and on Mt. Karisimbi in Rwanda. He also made extensive collections on Mt. Kahuzi, Mt. Biéga and around the station Irangi. The hepatics were published by Vanden Berghen (1977) and the mosses by De Sloover (1973, 1975a-d, 1976a,b, 1977a,b, 1979, 1982, 1983, 1986,1987) in the course of some revisions for the whole African continent. Some other botanists, who mainly collected phanerogams, made bryophyte gatherings as well (e.g. Bouxin, Lisowski, Malaisse, Petit). During botanical explorations for the “Flore du Rwanda, Spermatophytes”, Troupin also collected some bryophytes.

In 1991, the BRYOTROP-Expedition (e.g. Fischer, 1993a,b), organized by the author, investigated the bryophytes along an altitudinal gradient from 850 to 4500 m in the Kahuzi-Biéga National Park, the Nyungwe National Park and Mt. Karisimbi. From 1984 to 2012 the author studied the bryophytes of Rwanda and eastern D.R. Congo and was the first to collect in remote sites (Cyamudongo Forest, Busaga Forest, Kagitumba, Ibanda Makera etc.) and bryologically undercollected regions.

4. Vegetation of Rwanda and bryophyte habitats

4.1. Montane Forests

The Nyungwe forest, situated at the eastern crest of the Central African Graben supports a remarkable vegetation. Only an overview is presented here, but more detailed descriptions are provided by Fischer & Hinkel (1992) and Fischer & Killmann (2008). Nyungwe forms part of the montane forests on the Congo-Nile-watershed, and supports a vegetation mosaic quite different from that of the lowland rainforests in adjacent D.R. Congo. Today, most of these forests in Rwanda have disappeared, and only Gishwati Forest (nearly completely destroyed), Busaga Forest, and Mukura Forest are still extant, as well as Nyungwe and Cyamudongo which are now protected as National Parks.

There exist strong and easily observable floristic discontinuities between different parts of Nyungwe Forest. On the one hand there is a distinction between the western and the eastern part of the forest, primarily for climatic reasons (rainfall)

and secondarily for geological or soil reasons. The boundary between these two regions is roughly a meridian going through the eastern slopes of Mt. Bigugu (a little east of Pindura junction). There is also a distinct altitudinal stratification, first described by Fischer & Hinkel (1990). From a botanical point of view, a lower zone can be observed between 1500 and 2100 m above sea level ("lower level of montane forest"), a medium zone between 2100 and 2600 m ("medium level of montane forest") and an upper zone between 2600 and about 2900 m ("upper level of montane forest"). However, it should be noted that the exact level of these transitions can be 100 m (sometimes 200 m) above or below these ranges, depending on local topographic conditions. In the literature, the altitude range of Nyungwe National Park is often given as 1600 to 2950 m, but a sector of the forest in the extreme south west may extend as low as 1400 m, which could have some implications in terms of diversity. Unfortunately there has been no assessment of that rather inaccessible part of the forest up to now.

Fig. 2. Montane forest. **A.** Nyungwe National Park, Karamba. **B-C.** Gisakura, 1900 m.

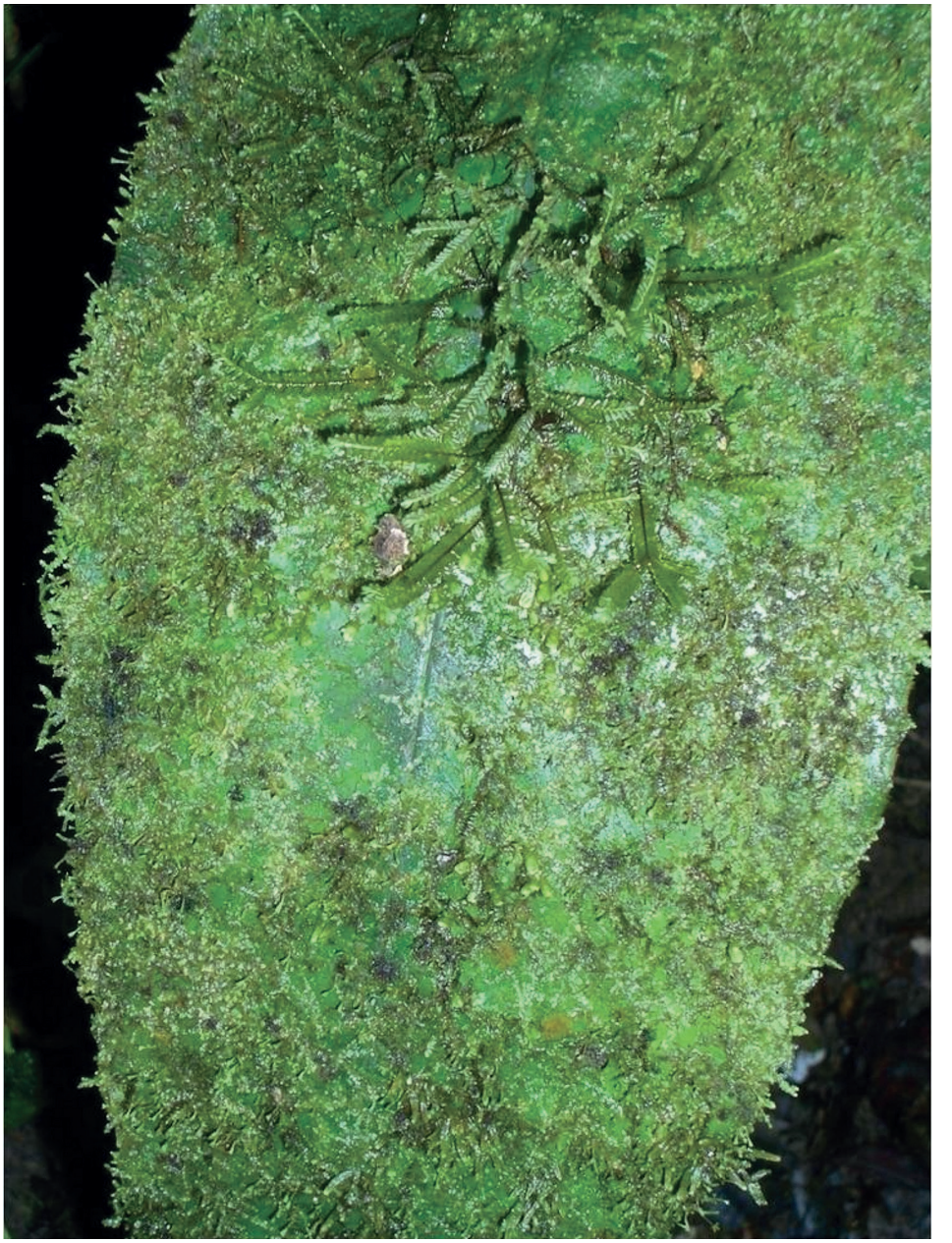

Fig. 3. Epiphyllous bryophytes. Nyungwe National Park, Kamiranzovu.

Montane forest at lower altitude

In the lower montane forest belt, we find mountain forest communities with dominating *Parinari excelsa* and *Carapa grandiflora* as well as *Newtonia buchanani*-forest with 2-3 distinguishable tree layers, and an upper tree layer of 35-40 m. The endemic tree *Pentadesma reyndersii* (Clusiaceae) occurs here. The lower montane forest is mostly restricted to the western part of Nyungwe and is well developed at Gisakura, Karamba and between Pindura and Bweyeye (Fig. 2). Epiphyllous bryophytes are abundant (Fig. 3). Around the Kamiranzovu, a typical swamp forest with *Syzygium guineense* ssp. *parvifolium*, *Carapa grandiflora*, *Anthocleista grandiflora* and *Podocarpus falcatus* is developed (Fig. 4). Secondary forests in the lower montane forest belt are characterized by *Musanga leo-errerae, Myrianthus holstii, Newtonia buchanani* and *Polyscias fulva*. Of special importance is the isolated Cyamudongo Forest, comprising only about 300 ha, which formerly almost certainly formed part of Nyungwe. It extends over five hills surrounding the valley of River Nyamabuye between c.1500 and 2140 m. Numerous species, e.g. *Cyathodium africanum, Notothylas flabellata, Cololejeunea cuneifolia* are currently known in Rwanda only from that forest. According to the local population, Cyamudongo has been isolated for at least 100 years.

Montane forest at medium altitudes

The middle montane forest belt is well developed near Uwinka. Here, forest communities with *Ocotea michelsoni, Syzygium guineense, Beilschmiedia rwandensis*, *Macaranga kilimandscharica* and *Melchiorea schliebenii* occur. In the eastern part of Nyungwe, forests with *Macaranga kilimandscharica* and *Neoboutonia macrocalyx* are dominant. Large areas of the south-eastern parts of the National Park near Nshili are occupied by bamboo-forests. Some of them are of anthropogenic origin, but are mainly outside the climatic bamboo zone. The bamboo *Sinarundinaria alpina*, which may reach a height of 25 m, forms either pure stands or grows intermixed with *Hagenia abyssinica* and *Polyscias fulva*. A herb layer is generally well developed (mainly herbs like *Panicum calvum* and various ferns).

Upper montane forest

The summit regions of the Bigugu massif, part of the upper montane forest belt up to 2800 m, are covered by a characteristic cloud forest of ± hard-leaved trees, which benefits from the high precipitation mainly as fog. Dominant trees are *Psychotria mahoni*, *Podocarpus latifolius* and *Syzygium guineense* ssp. *parvifolium*. An abundant shrub is *Mimulopsis solmsii*. The forest is characterized by the large number of epiphytes, especially bryophytes and lichens. The herb layer consists mainly of ferns.

Fig. 4. A-B. Montane forest. Nyungwe National Park, Kamiranzovu swamp, 2000 m.
C. Quartzitic rocks near Karamba, type locality of *Drepanolejeunea vandenberghenii*, 2000 m.

Fig. 5. A. Quartzitic rocks between Uwinka and Kamiranzovu, cushions of *Scopelophila ligulata*.
B. Quartzitic rocks at summit of Mt. Bigugu with *Campylopus* sp.

Fig. 6. A. Ericaceous shrub near summit of Mt. Bigugu, 2950 m. **B-C.** Ericaceous shrub at Rwasenkoko, 2400 m.

Ericaceous shrub

The upper montane forest belt otherwise consists mainly of ericaceous woodland. Below the summit of Bigugu, and in the western part of Rwasenkoko, a forest with *Erica bequaertii* and *Erica johnstoni* with a tree layer of 4-6 m height is developed (Fig. 6). It is characterized by large moss balls and a densely moss-covered soil (mainly *Breutelia* spp. and *Sphagnum* spp.). Between the bryophytes, *Deschampsia flexuosa* and *Lycopodium clavatum* are part of the herb layer. Among the epiphytes, large moss balls with *Plagiochila colorans, P. ericicola* and *Dicranum johnstoni* dominate. On small twigs of *Erica* spp. numerous Lejeuneaceae occur, e.g. *Colura saroltae* or *Colura berghenii*. The upper part of the canopy is mainly covered by *Usnea* species. The summit region of Mt. Bigugu is covered by a community dominated by *Erica bequaertii*. Other shrubs are *Vaccinium stanleyi, Struthiola thomsonii* and *Hedythyrsus thamnoideus*. The herb layer contains only a few vascular plants, e.g. *Hypoxis kilimandscharica,* or *Disa robusta* on open rocks (Fig. 5), and a dense bryophyte layer with dominant *Breutelia stuhlmannii*, *B. subgnaphalea, B. diffracta*, *Sphagnum strictum* ssp. *pappeanum* and *Leptodontium luteum*.

The open cliffs and the wet flush vegetation near Karamba, dominated by ericaceous shrubs are also remarkable and should be mentioned for their richness in bryophytes (e.g. *Sphagnum davidii*, *Breutelia stuhlmannii, Plicanthus hirtellus, Drepanolejeunea vandenberghenii* and *Anastrophyllum piligerum*). Due to the microclimate and the open quartzitic rocks, this type of vegetation occurs as low as 1900 m (Fig. 4, 5).

Swamps and moorland

The Rwasenkoko swamp, situated at 2400 m, is an example of a night-cold air lake. Here we find an inverse profile with *Syzygium-Podocarpus-Ocotea* forest on the summit of the hills, while the slopes bear *Andropogon shirensis*-grassland with scattered shrubs of *Hagenia abyssinica* and *Erica rugegensis*. In the valley, moorland and swamps can be observed. In the Rwasenkoko swamp, a nearly pure stand of *Erica rugegensis* with *Cyperus denudatus*, *Xyris valida*, *Osmunda regalis* and several *Sphagnum* species occurs. The small twigs of *Erica* spp. are covered by rare taxa, e.g. *Colura saroltae*, *Colura berghenii*, and *Lejeunea helenae*. Typical species in the more open parts of the swamp are *Alchemilla johnstonii*, *Lobelia mildbraedii*, *Cyperus denudatus* and C*yperus latifolius*. Shrubs like *Hypericum revolutum* have only a scattered occurrence. Comparable swamp vegetation on more eutrophic soil is found at Rugenge near Pindura. Here, *Haplomitrium blumei* is found associated with *Anthoceros myriandroecius* and *Aneura pinguis*.