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Front page photo: *Cussonia corbisieri* (*Guttiferae*) near Mpunde, December (photo A. Medwecka-Kornaś)

Dear Readers,
As part of the celebration of the centenary of the existence of the Polish Botanical Society, we are giving you a special issue of the yearly *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae* in the form of a supplement, containing a monographic study by Prof. Anna Medwecka-Kornaś, *Fire influence upon the savanna vegetation in Zambia and problems related with the role of this factor*.

This monograph deals with the very interesting topic of the flora, biology, and ecology of pyrophytic plants, which is now very popular all over the world. However, there are few such studies in the domestic bibliography. The field materials for this work were collected by the Author together with her husband, Prof. Jan Kornaś (botanist, phytogeographer, and florist) during their stay in Zambia. This study includes, among others, a floristic list of pyrophytes with their description, illustrated with the author's original drawings of plants. A great advantage of this study is the extensive review of the current bibliography in this field, included in the discussion.

It is also worth emphasizing that Prof. Anna Medwecka-Kornaś is a botanical authority recognised in Poland and abroad in the field of phytogeography, phytosociology, and plant ecology. Therefore, we hope that the current *AUPC Studia Naturae* supplement will be of interest to you and will encourage you to publish it in the next issues of the journal. At the same time, we invite you to visit the journal's website (https://aupcstudianaturae.up.krakow.pl/) and our Facebook profile.

Yours sincerely,
Editors of *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae*

Szanowni Czytelnicy,
W ramach obchodów Jubileuszu stulecia istnienia Polskiego Towarzystwa Botanicznego oddajemy w Państwa ręce zeszyt specjalny rocznika *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae* w postaci suplementu, zawierający opracowanie monograficzne autorstwa Pani Prof. Anny Medweckiej-Kornaś, pt. *Fire influence upon the savanna vegetation in Zambia and problems related with the role of this factor* (*Wpływ ognia na roślinność sawannową w Zambii i problemy związane z rolą tego czynnika*).

Monografia ta dotyczy bardzo intersującego tematu: flory, biologii i ekologii roślin pirofitycznych, który obecnie jest bardzo popularny na całym świecie. W krajowej bibliografii mało jest jednak tego rodzaju opracowań. Materiały terenowe do niniejszej pracy Autorka zebrała wspólnie z mężem Prof. Janem Kornasiem (botanikiem, fitogeografem i florystą) w trakcie ich pobytu w Zambii. Opracowanie to zawiera, m.in. wykaz florystyczny pirofitów wraz z ich opisem, ilustrowanym oryginalnymi, autorskimi rysunkami roślin. Dużym atutem tej pracy jest obszerny przegląd aktualnej bibliografii z tego zakresu, zawarty w dyskusji.

Warto również podkreślić fakt, że Pani Prof. Anna Medwecka-Kornaś jest uznanym w kraju i za granicą autorytetem botanicznym w zakresie fitogeografii, fitosocjologii i ekologii roślin. W związku z tym wyrażamy nadzieję, że bieżący suplement *AUPC Studia Naturae* spotka się z Państwa zainteresowaniem i zachęci do publikowania w następnych rocznikach czasopisma. Jednocześnie zapraszamy na stronę czasopisma (https://aupcstudianaturae.up.krakow.pl/) i nasz profil na Facebooku.

Z wyrazami szacunku,
Redakcja *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae*

Anna Medwecka-Kornaś

Fire influence upon the savanna vegetation in Zambia and problems related with the role of this factor

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Introduction – aim and circumstances of investigations

In some parts of the Earth, fire plays the role of a very important and not harmful ecological factor. This is particularly true of the Sudano-Zambezian Phytogeographical Region of Africa. In that area, the mutual relations between dry forest, savanna, shrubland, and grassland, as well as features of species and many plant formations depended to a high degree on conflagrations. The author had the opportunity to study those facts in some African countries, chiefly in Zambia, when her husband, Jan Kornaś, also a botanist, a professor at the university in the capital of the country – Lusaka. Together they made numerous car trips across the whole of Zambia (cfr. Medwecka-Kornaś, 1999) and collected a very rich herbarium material, more than 3500 herbarium specimens.

The aim of the present publication is to describe the results of the studies of savanna vegetation on selected, burned plots; some information from other localities is also included. Despite very rich literature about fire's impact on vegetation, such detailed data are rather scarce. Fieldwork was carried out from 1972 to 1973, but the features of plants remain not changed and the discussed ecological problems are still topical (cfr. Internet – fire in Africa) and can be even more important in the expected global warming and conflagrations. Here, the presented results of observations supplement some former papers of the author and of Jan Kornaś (see chapter below and the list of references).

Fire as an ecological factor – some opening remarks and data about former investigations

Common burning of vegetation occurs mainly in climates with a distinct dry period of 5–7 months (as it is in Zambia; cfr. page 8). Under such conditions in the tropics, the biomass (especially grass biomass) produced during the rainy season becomes a very good substratum for fire after drying. Conflagrations are initiated by natural phenomena, mainly solar radiation (e.g., Walter, 1968; 1973), or – what is more common – accidentally or deliberately by man. The present use of fire in the savanna zone of Africa is still in many aspects the same as practiced for thousands of years on this continent (e.g., Bourlière, 1983; Kozłowski, Ahlgren eds., 1974; Van Wilgen, 2009). In Zambia, where the savanna and savanna woodland, as well as some open grasslands, occupy large part of the territory, "bush fires" were and still are very widespread (Fig. 1).

As a consequence, there occurs a lot of fire-resistant plants, which are called "pyrophytes" according to the definition of Kuhnholz-Lordat and Scaett from 1938 (cfr.

Fig. 1. Fire on savanna near Lusaka. The end of the dry season in September

Schnell, 1971) as well as "pyrogenic plants" (e.g., Gagnon et al., 2010) – they are the subject of the author's research. In connection with the mentioned definitions the terms "pyrogenity" or "pyrogenicity" as an adaptation to fire, are also used.

The problem of fire's impact on the vegetation had called the attention of many authors since the end of the 19th century (cfr, chapter on page 54). Some general descriptions about it may be found e.g. in a handbook – in part – of the author (Kornaś, Medwecka-Kornaś, 2002) and in other books mentioned here further, mainly in the discussion. In Zambia, the experimental studies on the impact of fire on vegetation and the mutual relation of dry forest-miombo and savanna were undertaken more than 60 years ago (Trapnell, 1959). Some information concerning the fire in miombo was published later by Chidumayo (1988) and by Lawton (1978) from Zambia, as well as the description of vegetation in Rhodesia (now also Zambia) by Schnell (1971 l.c.). White's reports (1962, 1965) considering this area, with a description of some fire resistant plant formations and species are also important, as well as the chapter Weger, Coetze (1978), and the booklet Fanshawe (1971) with a general characteristics of Zambia vegetation, in which fire influence is taken into account. This problem is also considered in a monograph concerning Zambian pteridophytes (Kornaś, 1979), in the papers about fire resistance, life forms and ecology of particular fern species (Kornaś, 1978, 1985, 1993), about the fire-resistance of *Lycopodium carolinianum* (Kornaś, 1975), as well as some sedges (Medwecka-Kornaś, Kornaś, 1985). The former study of J. Kornaś (1958) concerning the influence of conflagrations upon the Mediterranean vegetation is also worthy of attention. The author of this manuscript discussed earlier the pyrophytic plants *Gardenia subacaulis* and *Hibiscus rhodanthus* from the region of Lusaka (Medwecka-Kornaś, 1980, 2013a), as well as *Calotropis procera* from Nigeria (in 2014) and published a general description of fire influence upon savanna vegetation (Medwecka-Kornaś, 1993, 2013b).

Noteworthy are documents concerning the nature in Zambia, which were created under the supervision of some ministerial offices, often on the base of agronomical Mount Maculu Research Station near Lusaka. Here belong e.g. publications of Fanshawe (1968, 1971) performed in various parts of Zambia, as well as the papers of Brockington (1960, 1961) concerning the practical use of grasslands. Worthy of notice is a contribution of Van Rensburg (1971) concerning the role of fire in Zambia. There are also other numerous descriptions of plant formations, chiefly forests, and grasslands, as well as lists of their plant species. They were prepared mostly for agronomic purposes and deal with various parts of the country, e.g. Barotse Province, determined also as "Western Province" situated near Lusaka (Verboom et al., 1970a, b; Verboom, 1972), and the large surface of Kafue Flats. Among numerous papers about this area, the issues of Ellenbroek (1987), Ellenbroek, Weger (1988), and Van Rensburg (1968a, b) may be found. The mentioned materials were published mainly in the mimeographed form in England and in part by the United Nations Development Program (FAO).

Geographical conditions, vegetation and fire occurrence in Lusaka region

Lusaka is situated in the central-southern part of Zambia (Fig. 2), on a relatively flat area being a part of the Central African Plateau, with the main altitude of 1000–1300 m. The natural conditions of the country are described e.g. by Kornaś (1979) and presented on the maps of Davies (1971 – with some texts), the map with explanations of Keay (1959), one of Wild, Fernandez (1967), the atlas of Philip and Son (1972) and the book of White (1983) – with the map.

Climate

The discussed region has a tropical continental climate with a prolonged drought in one part of the year, and fairly abundant rains in the other (type II – Walter, Lieth, 1960; Walter, 1973). The dry season extends from (April) May to October, with two clear sub-divisions of dry and cool (May-August) and dry and hot (August-October) weather. The rainy season, between November and March, is distinguished by the rains that are usually short-lasting, sometimes very violent, and even then the hours with sunshine are numerous. According to the data from the University of Zambia during

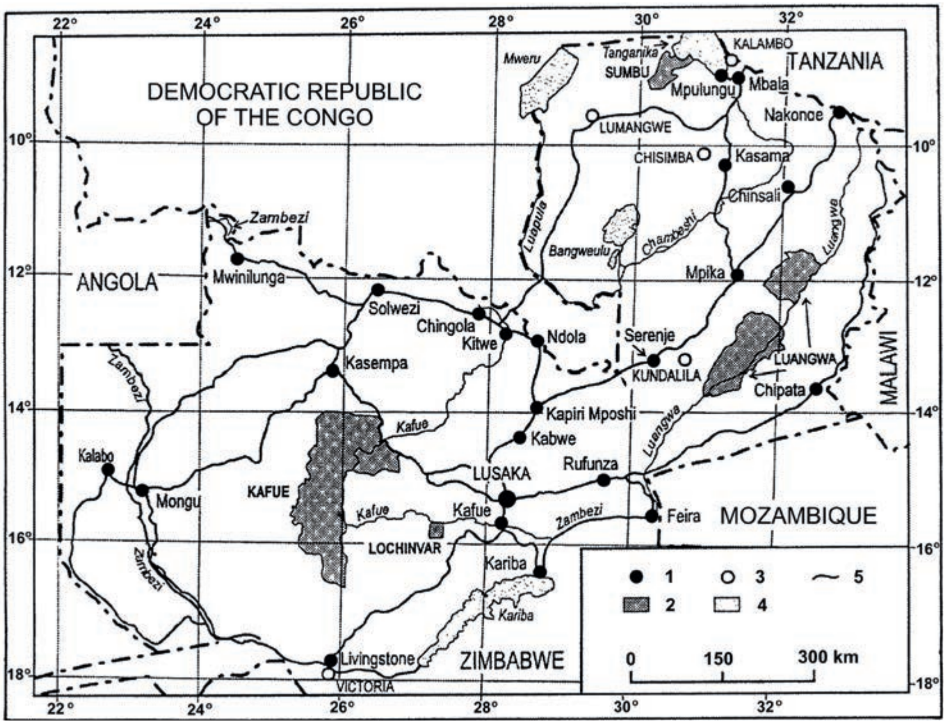

Fig. 2. Map of the Zambia Republic: 1 – main towns, 2 – mentioned in the text national parks, 3 – waterfalls, 4 – lakes, 5 – main roads

the years of the author's investigations, the sum of precipitations was relatively small and uneven lower in 1972 (482.0 mm) and higher in 1973 (793.2 mm). The rain measuring more than 50 mm per month occurred in 1972 not earlier than December and in 1973 as early as October. The changes between dry and wet, as well as wet and dry weather, can be determined by the author's observations: September 4, 1972 – evening storm and rain, first in the rainy season, October 5 – distinct rain in the evening, second in the rainy season, October 6/7 – week precipitation, October 24/25 – rain at night, then – in the morning downpour and drizzle throughout the day, November 30 – strong rain. Most distinct, powerful rains were noticed since December 1 as follows: January 27 – night storm after some days of rains, February 24, 1973 – cloudy and April 1 – a very cloudy and relatively dark day, May 25 – occurrence of dry conditions and June 12 – some clouds and cold weather.

The mean monthly air temperature in years of investigations had a value between 14.4°C (in June 1972 at 8 a.m.) up to 30.0°C (in October 1973 at 5 p.m.); a maximum of 37.2°C was noticed in October 1973 at 5 p.m. and minimum 10.0°C in May and June 1972 at 8 a.m. The difference between the morning and afternoon data exceeded usually 6°C. Sunshine, was relatively high in the dry season, measured then mostly from

9 to 10,5 hour per day. The average wind speed was between 8.4 and 16.9 km/h, the highest values attained usually about 20 km/h and in September 1973 up to 29.5 km/h.

Geological structure and character of the soils

The Lusaka region is formed of the Upper Pre-Cambrian sediments of the Katanga System (Archer D.R., in Davies ed., 1971). Those sediments consist of shales, sandstones, dolomites, limestones, as well of quartzites and are covered mostly by younger, loose deposits (Kornaś, 1979). The zonal soils on the plateau are qualified as fersialitic (Mäckel R. in Davies ed. l.c.), or as ferralitic (Werger ed., 1978). The first ones are concerned as connected with lower precipitations (500-800 mm per year), whereas the other ones – with precipitations of about 800 mm per year; however, some authors do not distinguish those two types. Ferralitic soils are defined also as ferralsols – according to FAO, or oxisols in the USDA (The United States Department of Agriculture) Soil Classification System (Montgomery, Askew, 1983), with textures ranging from loamy sands and sandy loams to clays. These types of soil were found on the first studied plot near Lusaka. The azonal types include e.g. the latosol, found on the second of here considered studied plots (see the description below). The large characteristic of tropical soil can be found e.g. in Sumner's book ed. (2000).

Plant cover and conflagrations

The extensive area of Zambia (including the region of Lusaka) is covered by open savannas, classified mostly as secondary vegetation, existing thanks to the influence of fire – an important part of traditional methods of land use in the described part of Africa.

The zonal type of vegetation, preserved in some places, includes the deciduous savanna woodlands "miombo" (Fig. 3). It is distinguished by its open canopy, composed mostly of trees of the genera *Brachystegia* and *Julbernardia*, there is a moderate grass cover in the herbaceous layer (Chidumayo, 1988; Stromgaard, 1992). In the dry season bush fires were (and certainly are until now) observed very often. After conflagrations, there are areas covered with ashes where the plant regeneration takes place relatively soon (Fig. 4).

Plots, time of observations and examined soil samples

The author's investigations were carried out on two selected plots of savanna, situated on a highland in the Central Province of Zambia (see descriptions below), and lasted about one year. Some additional observations were performed on similar, burned parts of vegetation on the University campus and – from the floristic point of view on several other sites (cfr. pages 48–52). Savannas, in the areas taken into consideration, were more widespread, than the zonal forests – miombo, and they exist mainly due to the influence

Fig. 3. The forest "miombo" by Chisamba near Lusaka in the dry season; September

Fig. 4. The forest "miombo" after fire – fragment between Kasisi and Constantia, about 25 km NEN of Lusaka, dry season; June

of fire (cfr. chapter on pages 56–58). In their vegetation apart from dominating grasses and other herbaceous plants, usually, some scattered trees grow – in the region taken into consideration, there were noticed e.g. a palm *Borassus aethiopum*, various species of *Acacia* and *Albizia*, as well as *Erythrina tomentosa* and *Strychnos* (e.g. *S. cocculoides*).

Both observation plots were located in a relatively flat area near Lusaka, one not far from the other. Each of them comprised 100 m² of open savanna, with a low share of shrubs and – in the second area – with not numerous, single trees. The ground layer of vegetation (in full development) was dominated by various species of tall grasses, and the whole plant formation remained under a strong influence of the yearly conflagrations.

Plot 1 (Fig. 5) with vegetation defined as savanna was situated 18 km to the east-northeast from the centre of Lusaka, between International Air Port and Kasisi (the village with Polish Catholic Mission), at altitude 1150 m, with coordinates 15° 20' S and 28° 25 E.

Plot 2 (Fig. 6) with vegetation defined as woody savanna was situated 22 km to the northeast of Lusaka, at the crossing of roads to Kasisi and Constantia, at altitude 1130 m, with coordinates 15° 16' S and 28° 25' E.

Seasons of the studies

The author's botanical observations covered nearly one year. They were initiated about two weeks after the occurrence of the fire on the first plot at the end of August and lasted until the end of July, whereas on the second plot they were carried out from the beginning of October until the end of July when the second fire appeared. Therefore the study period included the second half of the dry season, which is in Zambia the hottest part of the year, following the rainy season, and the relatively cool first half of the next dry season.

Soil conditions

Soil conditions on the studied plots were characterised by examination of two soil pits (profiles) and based on analyses of samples in the Laboratory of the School of Agricultural Sciences at Zambia University, performed with the interpretation by Prof. N.S. Miljkovic. The soil studies took place in October (at the beginning of the rainy season). One pit – 127 cm deep – was situated in the plot of vegetation no 1, and the second one – 66 cm deep in the plot no. 2 (Tab. 1).

The upper A horizons had a low content of organic matter and plate-like (profile 1) or granular (profile 2) structure. The deeper horizons in both soil pits were structureless, compact when dry or friable when moist. The boundary between A and B horizons was defined as abrupt. The described soils were leached and showed slightly acidic to acidic values of pH. Both profiles displayed an increase in clay fraction with depth. The B2 and B2/C horizons of soil pit 2 contained laterite gravels of the size of 5 mm. Available

Fig. 5. Savanna between Lusaka Air Port and Kasisi, Plot 1. of the author's investigations; green grasses, the middle of rainy season, January (a); The same savanna: yellow grasses in the dry season, June (b)

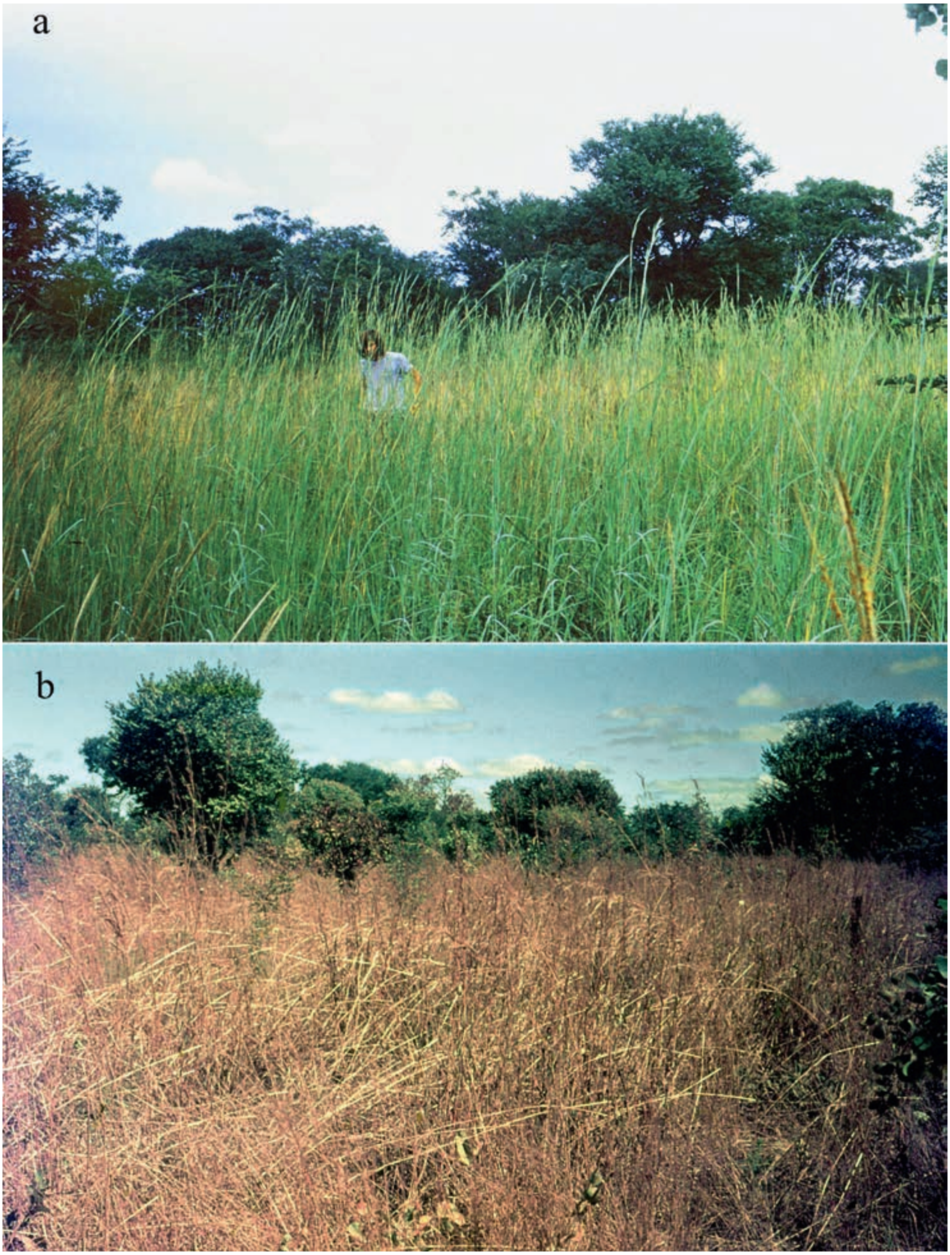

Fig. 6. Savanna at the road Kasisi-Constantia, Plot 2 of author's investigations, green grasses during the rainy season On the second plan the miombo forest, end of February (a); The same savanna: yellow grasses during the dry season. June (b)

Tab. 1. Some soil features on the studied plots

Horizon	Depth [cm]	Colour in the state		pH in water l: 2.5	Organic matter [%]	Texture class name	Available moisture [% weight]
		dry	moist				
Profile no 1: Oxisol – Choma soil series on schist and quartzite							
A	0–13	greyish yellow brown	brownish black	6.25	1.34	fine sandy loam	25.0
AB	13–20	dull yellowish brown	brown	5.80	0.46	fine sandy loam	17.4
B_1	20–38	dull brown	brown	5.75	1.03	sandy clay loam	20.6
B_2	38–51	bright brown	brown	5.85	–	sandy clay	30.3
	51–63	orange	brown	6.05	–	sandy clay	22.6
	63–89	bright brown	brown	5.90	–	sandy clay	21.5
B_3	89–94	orange	brown	5.95	–	sandy clay	18.3
	94–127	orange	brown	5.65	–	sandy clay	16.2
Profile no 2: Latosol – lateric soil on alluvial sandy deposits							
A	0–15	greyish yellow brown	brownish black	6.45	2.27	sandy clay	17.3
B_1	15–28	dull yellow brown	brown	5.40	0.93	sandy clay	17.8
B_2	28–40	yellow brown	brown	5.40	–	sandy loam	16.4
	40–53	bright brown	brown	5.50	–	sandy loam	15.7
B_2C	53–66	bright brown	brown	5.45	–	loam	14.7

moisture content varied from ca. 15% to ca. 30% by weight. According to USDA, the soil of the first plot was defined as oxisol – Choma soil series on schists and quartzite, and the soil in plot no. 2 as latosol – lateric soil on alluvial sandy deposits. The occurrence of latosol was connected with the location of the second plot at a lower altitude, nearer some tributary stream of the Chongwe River.

Soil temperature (not connected with fire) was measured in the Lusaka University Campus (by university workers) at the depth of 25 cm. The mean monthly value appeared to be from 18.1°C in May up to 26.2°C in November at 8 a.m. and slightly higher at 5 p.m. Maximum of 28.5°C was noticed in November and December afternoon, and a minimum of 14.0°C in June at the morning. In the absence of rainfall, the soil was very dry as well as hard and after several days of precipitations – moist and soft.

Methods of the performed vegetation studies

The particular plant species

The particular plant species, their ecological form, and phenology were observed. Disturbances by fire – traces on stems, leaves, on soil surface were particularly noticed. The underground plant parts were dug out of the ground. Drawings (by A. Medwecka-Kornaś), photographs (by A. Medwecka-Kornaś, with some contribution of Jan Kornaś), and measurement of water content in some plant tissues were accomplished. From an ecological point of view, the species were classified according to the C. Raunkiaer's (1905) system (cfr. e.g. Braun-Blanquet, 1932, 1964; Kornaś, Medwecka-Kornaś, 2002, and chapter on pages 59–60 in the present work). Special attention was paid to additionally distinguished plants with lignified underground axes and usually, herbaceous above-ground stems, called "geoxylic suffrutices" or simply "suffrutices" by White (1962, 1976) and other authors e.g. Burtt Davy (1972), or defined as "rhizomatous undershrubs" by Exel, Stace (1972).

The information concerning morphological and some ecological features of plant species are based – in principle – on the author's observations and connected in part with included further pictures. Some supplementary data for comparisons of plant features with data from other areas, are quoted mainly after the Flora Zambesiaca (Exel, Wild, 1960, and further volumes) or sporadically after some other positions of literature. The publications relevant to the problems under consideration include for instance the Flore d' Afrique Centrale, e.g. Bamps (ed. 1973, with some share of Polish author S. Lisowski), Flora of West Tropical Africa, Hutchinson, Dalzier (1954), and Flora of Tropical East Africa, e.g. Turrill, Milne-Redhead (ed. 1952). There were also taken into account the volumes of Lebrun, Stork (2003, 2015), containing maps of plant distribution in Africa, a guide to savanna plants (Ghazanfar, 1989), publications about Asteraceae (Lisowski, 1991), about grasses (Hood, 1967) and sedges (Haines, Lye, 1983).

The taxonomical identification of plant species was made in the great largely by Jan Kornaś and in selected cases checked (confirmed) by some other botanists, chiefly in the Royal Botanic Gardens, Kew. The collected specimens are deposited in the herbarium KRA (Kraków) and (duplicates) in some other herbaria, mostly in Lusaka University and in mentioned above Kew.

Plant communities

This part of the investigations was carried out according to the phytosociological method of Braun-Blanquet (e.g. mentioned above books: 1932, 1964), adopted by Pawłowski et al. in Szafer ed. (1966). The phytosociological records were repeated approximately monthly (cfr. tables 2 and 3 – Appendix 1). The degree of coverage of particular plant species was marked in the phytosociological tables. This degree was estimated according to the following scale: 5 = 75 up to 100 %, 4 = 50 up to 75 %, 3 = 25 up to 50%, 2 = less than 25% but more than 5% of soil cover, and 1 = the given species occurs with weak coverage, + the given species is sparse or very sparse. The second number on the tables expresses sociability – a grouping of plant individuals from 5 – the relatively large aggregations, through smaller and smaller up to 1 – single occurrence. The degrees of constancy (presence of species in the percentage of records: V = 81–100%, IV = 61–80%, III = 41–60%, II = 21–40%, I = 1–20%) are marked at the right margins of the phytosociological tables; plants from the last group are not included in the tables, but only mentioned in the text with species description.

Results

List of species observed, their short descriptions and Raunkiaer's classification

The plant species noticed in the studied plots and mentioned below are grouped according to their adherence to particular families, ordered alphabetically in the classes of Liliopsida and Magnoliopsida. The grasses (followed by sedges) are characterised at the beginning of this review regarding their important role in the studied vegetation. The nomenclature follows the Flora Zambesiaca (Exell, Wild eds., 1960 and further volumes) with some exceptions, concerning chiefly Cyperaceae. New names, introduced for some taxonomic units are mentioned in the first place, and former denominations, used in older literature are located afterward, as synonyms. For each species information about its position in the Raunkiaer's classification and a note about its registration on adequate phytosociological tables no 2 or 3 – Appendix 1 are quoted. In the relation to plants noticed with the first degree of constancy – in the text, a plot number and records of their occurrence are given.

The following designations and abbreviations are used further in the text: Fl. Zamb. = Flora Zambesiaca, Fl. Trop. E Afr. = Flora of Tropical East Africa, Fl. W Trop. Afr. = Flora of West Tropical Africa, Fl. Zimb. (electr.) = Flora of Zimbabwe (electronic version). Designations: Tab. 2 or 3 = phytosociological table no 2 or 3. Plot 1 or 2, and a number of record (rec.) = information about the occurrence of species noticed sporadically. The mark ‘ (apostrophe) means plot 2. The name of genera was checked in a dictionary by Willis (1973). When describing species: (...) – means the rest of the description of species in the source text.

Liliopsida (Monocotyledones)

Introductory remark: time of flowering and fructification of grasses and sedges is mentioned below jointly as a time of the development (existence) of spikelets.

Tab. 2. Grasses on the permanent plots in the optimum of development; species noticed with the first degree of constancy (in one record) are mentioned in the text with plant descriptions (pages 18–21)

Plot no.	1	1	1	1	2	2	Constancy degrees
No. of record	6	7	8	9	5’	6’	
Date – day/month/year	4 I 1973	27 I 1973	17 II 1973	21 III 1973	24 III 1973	1 IV 1973	
Species							
Hyparrhenia filipendula	1.2	2.2	3.2	3.2	4.3	4.3	V
Eragrostis racemosa	3.2	2.2	3.2	2.2	1.2	1.2	V
Setaria sphacelata	2.2	3.2	2.2	2.2	2.2	2.2	V
Digitaria milanjiana	+	1.2	1.2	1.2	2.2	1.2	V
Andropogon schirensis	+	+	3.2	3.2	3.2	3.2	V
Hyperthelia dissoluta	1.2	2.2	3.2	1.1	+	.	IV
Brachiaria dictyoneura	+	1.1	1.2	+	.	.	III
Brachiaria humidicola	.	1.2	1.2	.	1.2	.	III
Trachoypogon spicatus	.	.	1.1	1.1	1.2	.	III
Brachiaria brizantha	.	.	1.1	.	1.2	1.1	III
Digitaria gazensis	+	+	.	.	+	+	IV
Eragrostis superba	.	.	.	.	+	+	II
Sporobolus pyramidalis	.	.	.	.	+	+	II

1. Poacae (Gramineae)

Alloteropsis semialata (R. Br.) Hitchc. Tufted perennial, culms 60–85 cm. high, the basal parts with remains of the previous year’s leaves and shoots, often bulbously thickened, bulbs up to 1–1.5 cm in diameter; cluster of thin roots. Hemicryptophyte. Plot 1, rec. 7.; Fl. Zamb.: Culms 20–150 cm high.

Andropogon schirensis Hochst. Caespitose perennial, about 90 cm. high, growing in compact tufts 3–5 cm in diameter. Culms with tunics formed by fibrous remains of old leaf-sheaths at the base, spikelets from February to May, a cluster of thin roots.

Hemicryptophyte. Tab. 2; Fl. Zamb.: Densely caespitose perennial; culms up to 200 cm. high, erect, branched (…).

Brachiaria brizantha (A. Rich.) Stapf. Loosely tufted perennial, culms 60–80 cm high, sometimes geniculate ascending, with scarce tunics, spikelets from February to April (May), roots in upper parts slightly thickened. Hemicryptophyte. Tab. 2; Fl. Zamb.: Culms 30–200 cm high.

Brachiaria dictyoneura Stapf. Densely tufted perennial, culms ca 40 cm high, with swollen bases (small bulbs), spikelets noticed from February to April. Hemicryptophyte. Tab. 2; Fl. Zamb.: Culms 40–120 cm high, never rooting at the nodes (…).

Brachiaria humidicola (Rendle) Schweick. Stoloniferous perennial, culms 75 up to 120 cm high, stolons up to 85 cm long, with leaves, rooting and sprouting at the nodes. Spikelets were found in February and also in May (with some remnants until July). Clusters of thin roots. Hemicryptophyte. Tab. 2, Fig 7 – Appendix 2; Fl. Zamb.: Culms 40–150 cm. high, often geniculate (…).

Cymbopogon caesius (Hook. & et Arn.) Stapf. subsp. ***giganteus*** (Chiov.) Sales = *C. giganteus* Chiov. A tufted perennial, robust plant, culms up to 200 cm high. A cluster of not very thin roots. Hemicryptophyte. Plot 2, rec. 5'; Fl .Zamb.: Caespitose perennial, culms up to 200 (300) cm high.

Cynodon dactylon (L.) Pers. Stoloniferous slender perennial, culms 30–40 cm tall, in small tufts. Branched stolons rooting at the nodes, some underground rhizomes. Hemicryptophyte. Plot 2, rec. 5'; Fl. Zamb.: Stoloniferous sward-forming perennial (…) culms slender, up to 40 cm tall, erect, or ascending (…).

Dactyloctenium aegyptium (L.) Willd. Annual (sometimes perennial), culms 40–50 cm tall, forming small tufts. Occasionally branched running shoots, rooting at the nodes, with some upright stems. Mostly therophyte. Plot 2. rec. 5'; Fl. Zamb.: Slender to moderately robust spreading annual; culms up to 70 (100) cm tall (…) often shortly stoloniferous and mat-forming, less often erect (…).

Digitaria gazensis Rendle. Densely caespitose perennial. Culms about 55 cm tall with bases thickened into small bulbs 0.5 cm in diameter, covered by remains of old leaves. Spikelets from January till April. Short knotty rhizome shallowly in the soil, sometimes stolons. Roots above 5 cm long. Hemicryptophyte. Tab. 2, Fig. 8 – Appendix 2; Fl. Zamb.: Culms 40–120 cm, erect or creeping (…).

Digitaria milanjiana (Rendle) Stapf. Loosely tufted perennial, culms 40 to 120 cm high, slightly thickened at the bases, covered by leaf sheaths. Spikelets noticed in January and February (sporadically in May until July). Branched rhizomes and occasionally stolons, on the studied plots up to 90 cm long. Hemicryptophyte. Tab. 2; Fl. Zamb.: A rhizomatous perennial, occasionally forming stolons, rhizomes extensively branched (…). Culms 50–120 cm, ascending to erect (…).

Eragrostis racemosa (Thunb) Steud. Densely caespitose perennial, culms 40–60 cm tall in tufts 2.5–7 cm in diameter, with tunics composed of narrow, in part old leaves. Spikelets observed from January to March. Thin roots. Hemicryptophyte. Tab. 2; Fl. Zamb.: (Plant) without rhizomes or stolons; culms up to 90 cm tall, erect (…).

Eragrostis superba Peyr. Caespitose perennial, tufts small, up to 3 cm in diameter. Culms ca 50 cm high, relatively thick, up to 8 mm in diameter in a low part, with tunic. Spikelets observed from May until July and from November to February. Roots about 1 mm thick. Hemicryptophyte. Tab. 2; Fl. Zamb.: (Plant) without rhizomes or stolons; culms up to 120 (200) cm tall, erect (…).

Hemarthria altissima (Poir.) Stapf. et C.E. Hubb. Stoloniferous perennial, culms with swollen bases, prostrate, 80–100 cm long, forming small tufts; some creeping rhizomes. Hemicryptyophyte. Plot 2, rec. 5'; Fl. Zamb.: Culms up to 250 cm long (…) prostrate and rooting at the nodes below.

Hyparrhenia filipendula (Hochst.) Stapf. Caespitose perennial, culms 120–145 cm high, thickened at the base; with remains of old leaves, spikelets from October to April, some remnants observed still in May. Short scaly rhizomes, shallowly in the soil, roots about 5 cm long. Hemicryprophyte. Tab. 2, Fig. 9 – Appendix 2; Fl. Zamb.: Culms up to 200 cm high.

Hyparrhenia cfr. ***quarrei*** Robyns. Caespitose perennial, culms up to 200 cm high, their bases thickened with fibrous remains of old shoots and leaves. Hemicryptophyte. Plot 1, rec. 6; Fl. Zamb.: Culms up to 200 cm high (as noticed above).

Hyperthelia dissoluta (Nees ex Steud.) Clayton. Tufted perennial, culms 95–150 cm. high, thickened at the base, with scarce tunics, arising from a short rhizome. Spikelets from November to February. Hemicryptophyte. Tab. 2; Fl. Zamb.: Caespitose perennial; culms 100–300 cm high.

Microchloa kunthii Desv. Small perennial densely caespitose, tufts (of leaves) about 3 cm high, culms up to 35 cm high with tunics, a short rhizome. Hemicryptophyte. Plot 1, rec. 7; Fl Zamb.: Culms up to 60 cm tall, the leaves mostly crowded at the base.

Pogonarthria squarosa (Roem. et Schult.) Pilg. Perennial rigid plant, with dense but narrow tufts, culms 40–60 cm. high, roots slightly, equally, thickened. Hemicryptophyte. Plot 2, rec. 4'; Fl. Zamb.: Densely caespitose perennial, culms up to 100 (120) cm tall, stiffly erect (…).

Schizachyrium sanguineum (Retz.) Alst. Caespitose perennial, culms up to 160 cm high, thickened at the base, with old leaves tunic up to 0.5 cm in diameter, thin rhizomes. Hemicryptophyte. Plot 2, rec. 5'; Fl. Zamb.: Culms up to 160 cm high (as noticed above), erect (…).

Setaria sphacelata (Schumach.) Mos = *S. anceps* Stapf. Tufted perennial, culms 70–110 cm high, their basal parts thickened with tunic about 2 cm in diameter; spikelets in January and February, some their remnants found in April. Small rhizome? Hemicryptophyte.

Tab. 2; Fl. Zamb.: Tufted perennial, arising from a short rhizome, culms 20–300 cm high. Additional remark: a polymorphic species, varying greatly in overall size.

Sporobolus pyramidalis P. Beauv. Caespitose perennial, culms 60–100 cm high with persistent remains of basal leaves, cluster of roots. Hemicrypophyte. Tab. 2; Fl. Zamb.: (Plant) without rhizomes or stolons, culms up to 210 cm tall (…).

Trachypogon spicatus (L.f.) Kuntze. Tufted perennial, culms 70–130 cm high, thickened at the base, with tunics of old leaves. Spikelets in January and February, some their remnants till April. Sporadically some stolons or short rhizomes. Hemicryptophyte. Tab. 2; Fl. Zamb.: Culms 30–200 cm high. Additional remark: variation in the vegetative characters is considerable (…).

2. Cyperaceae

Introductory remarks: systematics and nomenclature in some groups of Cyperaceae became the subject of many changes. It concerns e.g. the genre *Bulbostylis*, designated now as *Abildgaardia*. The new approaches considered below are taken into account after R.W. Heines and K.A. Lye (1983). The relevant volume of Flora Zambesiaca has not yet been published until the present work. Regarding their scarce occurrence, Cyperaceae are not included in phytosociological tables, except for one publication about them in Zambia: Medwecka-Kornaś, Kornaś (1985).

Abildgaardia filamentosa (Vahl) K. Lye var. ***filamentosa*** = *Bulbostylis filamentosa* (Vahl.) C. B. Cl. Tufted perennial, tufts small up to 2 cm in diameter, stems 40–55 cm tall with tunic of old leaves and fire traces observed at the bases. Spikelets in February and March (or April). Thin roots up to 5–7 cm long. Hemicryptophyte/geophyte? Plot 1, rec. 3, 4., Plot 2, rec. 2'; Haines, Lye (1983): A fairly robust perennial with crowded culms from a short rhizome (rhizome not observed by the present author). Culms 20–70 cm long (…).

Abildgaardia hispidula (Vahl.) K. Lye subsp. ***brachyphylla*** (Cherm.) K. Lye. = *Bulbostylis hispidula* (Vahl.) R. Haines subsp. *brachyphylla* (Cherm.) R. Haines = *Fimbristylis hispidula* (Vahl.) Kunth subsp. *brachyphylla* (Cherm) Napper. Perennial tufted, tufts about 3 cm in diameter, stems up to 30 (40) cm tall with tunic of old leaves at the bases. Spikelets from November to January; clusters of roots up to ca 14 cm long. Hemicryptophyte. Plot 2. rec. 3', 4', Fig. 10a – Appendix 2; Haines, Lye (1983): A robust tussocky perennial (…). Culms 10–50 cm long (…).

Abildgaardia cfr. ***macra*** (Ridley) K. Lye. = *Bulbostylis* cfr. *macra* (Ridley) C.B. Cl. Perennial, caespitose – mostly old leaves clusters 1.5–2.5 cm broad, stems up to 30–35 cm high, thickened at the base into narrow bulbs about 0.5–1 cm in diameter. Burned lower parts of the leaves were observed. Spikelets noticed in January. Clumps of thin roots up to 4–8 cm long. Hemicryptophyte. Plot 1, rec. 6, plot 2, rec. 4', Fig. 10b – Appendix 2; Haines, Lye (1983): Culms 5–35 cm long (…).

Cyperus ciliato-pilosus Mattf and Kük. = *Kyllinga platyphylla* K. Schum. Perennial, relatively robust plant, stems up to 30–35 cm high, some occurring by ones, but mostly densely caespitose plants (tufts of fibrous coated stem bases up to 7 cm in diameter). Spikelets in December and January. Traces of fire were found near soil surface, dense system of roots was 4–5 cm long. Hemicryptophyte. Plot 2, rec. 4', Fig. 10c – Appendix 2; Haines, Lye (1983): A densely tufted perennial 15–50 cm tall (…) stolons absent.

Cyperus margaritaceous Vahl. var. ***nduru*** (Cherm.) Kük. Basionym = *C. nduru* Cherm. Perennial, culms 20–40 cm high, their bases covered by remnants of old leaves were found with traces of fire and swollen into small bulbs 0.5–1 cm large, grouped in series by 3–4 on small rhizomes. Dry specimens at the end of August, the young ones at the end of November, buds, flowers, beginning of fruits and later fruits from November to January. Roots up to 8 cm long. Hemicryptophyte or shallow geophyte? Tab. 3 – Appendix 1; Fl. W Trop. Afr.: Tufted plant with contiguous stem bases thickened by numerous leaf-sheaths (…); Haines, Lye (1983): A fairly robust perennial (…). In recently burnt grassland and open woodland (…).

Kyllingiella microcephala (Steudel) R. Haines and K. Lye. = *Scirpus microcephalus* (Steud.) Dandy. Perennial, small, mostly tufted plant, stems 5–14 cm high, their bases were covered by remnants of old leaves (partly burned off) and swollen into small bulbs up to 0.5 cm in diameter, bulbs by ones or in groups. Spikelets in November to January; thin roots 3–4 cm long. Hemicryptophyte. Plot 1, rec. 6, Fig. 10d – Appendix 2; Fl. W Trop. Afr.: A slender, tufted or shortly rhizomatous plant with swollen stem bases covered by brownish fibres (…); Haines, Lye (1983): stems 5–40 cm long.

Scleria bulbifera A. Rich. Perennial, culms relatively tall, up to 50–60 cm high, occurring in clusters, or in rows on creeping rhizomes, small bulbs 0,5–1 cm in diameter mostly in series, with short roots. Spikelets in December and January, some their remnants in February. Hemicryptophyte. Plot 1, rec. 6; Fl. W Trop. Afr.: Polymorphic rhizomatous perennial with swollen culm-bases (…); Haines, Lye (1983): A perennial with crowded stems on a creeping rhizome, or with somewhat distant stems arising from 1–5 cm long stolons. Stems 30–70 cm long (…).

3. Liliaceae

Gloriosa superba L. = *G. simplex* L. Perennial erect herb about 65 cm high, flowers observed in January. In the soil tubers about 1.5 cm in diameter with cluster of roots, creeping rhizomes at the depth of 7–11 cm. Geophyte. Tab. 3, Fig. 11a–c – Appendix 1, 2; Fl. Zamb.: Erect or scandent herb, with annual stems growing from elongated, often forked corm. Stems up to c. 3 m long in climbing plants, much shorter when erect.

Littonia littonioides (Welw. ex Bak.) K. Krause. Perennial herb, stems ca 25 cm high, young plants with flowers in November – December (January), fruits still in January.

Shallowly in the soil were found 2–3 small tubers with about 1 cm in diameter and slightly deeper – rhizomes, situated 7–8 cm below soil surface. Geophyte. Plot 1 rec 7, plot 2 rec. 3'; Fig. 12a, b – Appendix 2; Fl. Zamb.: Erect perennial herb to 60 cm tall, leafy almost to base (…).

4. Orchidaceae

Eulophia cfr. ***livingstoneana*** (Rchb. f.) Summerh. Perennial herb, stems 50 cm tall, development of leaves at flowering time, in September, or slightly later. Tuberous short rhizome with roots shallowly in the soil. Geophyte/hemicryptophyte. Plot 1, rec. 3; Fl. Zamb.: Terrestrial herb 50–100 cm tall. Perennating organs subterranean, tuberous, (…) irregularly cylindrical, horizontal, branching occasionally; rhizome short, up to 1 cm in diameter, roots scattered along tuber (…).

Eulophia parvula (Rendle) Summerh. Perennial, slender plant. Stems ca 25 cm tall, small flowers in September; subterranean tubers forming chains about 1 cm below soil surface. Hemicryptophyte/geophyte. Plot 1 rec. 3; Fl. Zamb.: Very slender terrestrial herb 20–60 cm tall. Perennating organs subterranean, tuberous, (…) irregularly conical, forming chains. (…) dambo or open grassland, usually after fire (…).

Eulophia cfr. ***pyrophila*** (Rchb. F.) Summerh. Perennial herb, stems 25–35 (45) cm tall, flowers noticed in August and September (November). Subterranean organs tuberous, tubers 1–2.5 cm in diameter and 1–3 cm long, forming short chains. Hemicryptophyte/geophyte. Tab. 3, Fig. 12c – Appendix 1, 2; Fl. Zamb.: Terrestrial herb 13–45 cm tall. Perennating organs subterranean, tuberous (…) forming chains (…). Short grassland and open deciduous woodland, often after fire (…).

Magnoliopsida (Dicotyledones)

5. Acanthaceae

Blepharis caloneura S. Moore. Annual plant about 35 cm tall, with creeping stems. Clusters of flowers at ground level were observed from August to October and also in April, and the leaves in the rainy season. Thin vertical root. Therophyte. Tab. 3 – Appendix 1; Fl. Zimb. (electr.): Erect or procumbent single stems unbranched annual herb, stems up to 40 cm long (…).

Dicliptera melleri K. Schum. Herbaceous perennial. Cluster of stems up to 45 cm high with knotty tillering base, and there traces of burning. Short lasting flowers soon after fire, from the end of August till October (than stems about 10 cm high), fruits in October up to November. Some flowers and fruits were found also in April. During the rainy season creeping stolons more than 30 cm long, with leaves and small roots. Tuber like tap root about 2.5 cm in diameter, with relatively long, thin side roots (excavated up to 18 cm). Hemicryptophyte. Tab. 3, Fig. 13a–b – Appendix 1, 2; Fl. Zamb. (electr.): Decumbent or procumbent pyrophytic perennial, producing few to numerous stems

5–30 (60) cm long from a woody base and rootstock (…). In burnt grassland and miombo woodland (…) periodically burnt.

Justicia elegantula S. Moore. Herbaceous perennial, tufted plant shoots below 10 or 10–20 cm high with tunic like leaves at lowest part, arising from the tillering base. Flowers from the beginning of September and in October, than leaves developed only in part, fruits in October – November (sporadically found also in April. Some stolons about 15 cm long, tap root tuber with cluster of thin roots, or only thin roots. Hemicryptophyte. Tab 3, Fig. 14 – Appendix 1, 2; Fl. Zamb. (electr.): Perennial herb with several erect or decumbent or creeping (and then sometimes rooting) unbranched or sparsely branched stems from a woody rootstock; stems to 50 cm long.

6. Anacardiaceae

Lannea edulis (Sond.) Engl. (and var. ***edulis***). Geoxylic suffrutex (White, 1962, 1976), stems few cm high, with wooden bases – there were found some fire traces. Inflorescence and fruits almost at ground level, coming up before the leaves or with the young leaves, soon after fire; from August to October (in part observed until November and December – at that time some old fruits can be still retained). The great leaves located (lying) on soil surface. Long wooden tap root (or trunk) up to 3.5 cm in diameter (excavated up to 30 cm and broken). Some plants were found with main root nearly horizontal, up to 1 cm in diameter. Chamaephyte or hemicryptophyte or geophyte? Tab. 3, Fig. 15a–b – Appendix 1, 2; Fl. Zamb.: Suffrutex with stems 3–30 cm high (…) arising from a large, nodose, rugose, woody trailing rootstock (…) in burnt ground (beyond other localities); White (1962): Usually a suffrutex about 0.3 m high sometimes up to 1 m high.

7. Annonaceae

Annona stenophylla Engl. et Diels, subsp. ***nana*** (Exell) N. Robson. Geoxylic suffrutex (White, 1976). Clusters of stems, mostly annual, in the rainy season up to 80 cm tall have old shoots burnt at the bottom. Flowers developed in two weeks after fire (on plot 1 at the end of August) and together with fruits, situated at the soil surface, can be found mainly in October and until January. Trailing rootstock located not deep in the soil, in part horizontally (was excavated up to 46 cm). Shallow geophyte. Hemicryptophyte or chamaephyte? Tab. 3, Fig. 16 – Appendix 1, 2; Lebrun, Stork (2003): Subshrub or shrub 0.5–1 m tall; White (1962): Rhizomatous suffrutex or dwarf shrub up to 0.5 m high.

8. Apiaceae (Umbelliferae)

Diplolophium zambesianum Hiern. Perennial herb, stems up to 1.20 m high. Flowers and beginning of fructification in August and September, dissemination in

October and November, then also the young leaves. In December ascertained the seedlings up to 7 cm tall. Flowers and fruits again in February and later (fruits were found until June). Tap root in the upper part thickened up to 1–1.5 cm in diameter. Hemicryptopyte/geophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Robust perennial herb 30–200 cm high; rootstock a hard woody rhizome.

Steganotaenia hockii (Norman) Norman. Perennial herb, stems 60–120 cm high, in clusters, regenerating after fire. Flowers in April and May, fruits noticed till September. Underground woody part with thickened vertical root up to 1.6 cm in diameter, numerous side roots Hemicryptophyte, Plot 1, rec. 1 and 3.; Fl. Zamb.: Perennial, glabrous suffrutex with a large underground woody caudex. Stems up to 60 cm long (…) especially in areas frequently burnt over, and perhaps adapted through its habit to this ecological situation.

9. Araliaceae

Cussonia corbisieri De Wild. Geoxylic suffrutex (White 1976), stems with flowers and fruits up to 40 cm high, later taller. Flowering and fructification in December and January, afterwards still some fruits. Leaves directly from underground woody root covered by bark (like a trunk), in the upper part until to about 4 cm in diameter, ramified (excavated up to 30 cm). In some specimens there were found oblique, or nearly horizontal roots, with diameter about 5 cm, situated shallowly below the soil surface. Hemicryptophyte. Tab. 3, Fig. 17 – Appendix 1, 2; Fl. Zamb.: A robust suffrutex arising from a woody subterranean rhizomatous rootstock, the whole plant less than 1 m tall (cfr. also White, 1962). Known only from Zambia and Zaire.

10. Asteraceae (Compositae)

Aspilia pluriseta Schweinf. subsp. ***pluriseta*** = *A. asperifolia* O. Hoffm. Herbaceous perennial, stems 20–35 cm high, in clusters, found with remnants of burning of vegetation. Flowers soon after fire, from August to February and fruits mainly from November to April. Shallowly in the soil bulbs up to 2–3 cm in diameter, roots located mostly horizontally. Hemicryptophyte/geophyte. Tab. 3, Fig. 18a – Appendix 1, 2; Fl. Zamb.: Rhizomatous perennial; branches c. 0.3–0.6 m long, prostrate or suberect; Lisowski (1991): herbe vivace (…) tiges (…) 30–60 cm long; note (in manuscript) of Jan Kornaś: Variable in habit, grows to a large size when unburnt.

Dicoma plantaginifolia O. Hoffm. = *D. pygmaea* Hutch. Dwarf herbaceous perennial to ca 5 cm high, leaves on the ground (rosette plant), flowers found soon after fire, in September (Plot 1) and October, usually before the leaves; sporadically till January and after the second fire noticed on Plot 2 in July; fruits (achenes with pappus) in the same months. Root slightly thickened in the upper part. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: A perennial herb, usually acaulescent, from a woody rootstock; roots numerous spreading thong-like. Stems sometimes developed but abbreviated, erect to c. 5 cm tall (…). A pyrophyte of miombo woodland and submontane grassland (…); Wild (1972): This species tends to flower precociously before the leaves if the grass cover is burnt over; Similar observations of Lisowski (1991): Herbe vivace, subacaule (…) flowers often after the passage of fire.

Elephantopus scaber L. Perennial herb with annual stems 45 cm tall and rosette of leaves at their base. Flowers in March, woody rootstock. Hemicryptophyte. Plot 1, rec. 9; Fl. Zamb.: An erect tough hirsute perennial herb to c. 130 cm tall with annual stems from a woody rootstock; roots numerous, thong-like.

Launaea nana (Bak.) Chiov. Small herbaceous perennial, shoots with flowers and fruits 5–14 cm high, developed soon after fire from August (on Plot 1) till October, leaves latter as first flowering, in rosette. Dissemination in September or October. Cylindrical tap root up to 2.5 cm in diameter, but narrow in the uppermost part, excavated up to 8 cm and brocken. In some plants roots situated not deep in the soil, nearly horizontally. Hemicryptophyte. Plot 1, rec. 1, 3, Plot. 2, rec. 2', Fig. 18b – Appendix 2; Fl. Zamb.: An acaulescent perennial herb with a terete semi-woody taproot. A pyrophyte of grassland and open miombo woodland.

Launaea rarifolia (Oliv. et Hiern.) L. Boulos. Perennial herb 25 cm high, leaves after the flowers, in rosette at soil surface (tillering plateau). Flowers and fruits in September and October. Vertical semi-woody taproot up to 1.5 cm in diameter (excavated up to 4.5 cm and breakable). Hemicryptophyte. Plot 2, rec. 2', Fig. 18c – Appendix 2; Fl. Zamb.: A scapose strict viry perennial herb up to 95 cm tall or sometimes (…) small herb 3–15 cm high. An infrequently collected pyrophyte of *Brachystegia* woodland and dambos.

Pleiotaxis eximia O. Hoffm. subsp. ***eximia*** = *P. amoena* R. E. Fr. Perennial herb (?), stems 14–20 cm high (in October), knotty tillering base. Flowers and new stems with leaves noticed in March and fruits in May. Tap root in the upper part up to 1 cm in diameter, with some lateral roots. Plant found individually in the rainy season Hemicryptophyte. Tab. 3 – Appendix 1; Fl . Zamb.: An erect robust silver-grey suffrutex, 15–80 cm tall, from a woody rootstock; Lisowski (1991): Geofrutex 25–130 cm high.

Vernonia filipendula Hiern. = *V. lancibracteata* S. Moore. Perennial herb tillering at the soil surface. Stems about 40 cm high, flowers and fruits in March and April. Roots thickened in the upper part. Plant found sporadically in the rainy season. Hemicryptophyte? Plot 1, rec. 9, 10; Fl. Zamb.: A stiffly erect perennial herb, 25–100 cm tall from a small woody rootstock (…) root tubers up to c. 4×1.4 cm, ± fusiform. Stems annual (…).

11. Boraginaceae

Trichodesma ambacense Welw. subsp. ***hockii*** (De Wild.) Brumitt. = *T. hockii* De Wild. Perennial herb, stems 25–50 cm high, in clusters which may be large, with remnants of old, burned off sprouts. Knotty tillering base. Flowers and fruits from August (Plot 1) to the end of October. Tap root soft, vertical or oblique, observed as cylindrical, thickened up to diameter of 3.5 cm, but narrow in the uppermost part and long (excavated up to 35 cm), side roots not numerous, near soil surface. Hemicryptophyte/geophyte. Fig. 19, Tab. 3, Fig. 20 – Appendix 1, 2; Fl. Zamb.: Perennial herb with 1-several erect stems up to 50 (70) cm from rootstock. In grassland and woodland subject to annual burning.

12. Chrysobalanaceae

Parinari capensis Harv. subsp. ***capensis***. Geoxylic suffrutex (White, 1976). Stems 10–30 cm high. On the soil surface it tillering with new shoots and charred remains of the old ones. Flowers before or simultaneously with leaves, relatively soon after fire in September and October, then also fruits noticed still in January. A long wooden trailing rootstock about 1 cm thick, horizontal or slightly oblique, situated 5–10 (20) cm deep in the soil, with not numerous small side roots. Hemicryptophyte – geophyte. Tab. 3, Fig. 21a–c – Appendix 1, 2; Fl. Zamb.: Extensively rhizomatous, geoxylic suffrutex; stems nearly always less than 30 cm tall, exceptionally (outside of Zambia) up to 1–2 m tall. In secondary grassland following the destruction of woodland by fire (…); White (1976): The most widespread Zambian geoxylic suffrutex.

Fig. 19. Boraginaceae: *Trichodesma ambacense* – plant noticed on studied plots and at the roadsides (see also page 50), September

13. Combretaceae

Combretum platypetalum Welw. ex. Laws. subsp. ***platypetalum***. Geoxylic suffrutex (White, 1976) or suffrutescent shrublet (West, 1972), on the studied plots 15–40 cm high. Flowers in September on new stems (offsets), before leaves. Thick woody rhizome. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Shrublet usually c. 15–30 cm high (…) with a thick woody rhizome, often leafless when flowering on annually produced shoots; White (1962): Suffrutex up to 0.3 m high, with stout woody rootstock; stems burned back to ground every year.

Terminalia sericea Burch. ex DC. Small deciduous tree with brown bark and petiolate leaves. Inflorescences in lateral spikes, fruits elliptic. Phanerophyte, found on the corner place inside. Plot 1, Tab. 3 – Appendix 1; Fl. Zamb.: Tree 3–12 (16) m high, or shrub.

14. Convolvulaceae

Astripomea malvacea (Klotzsch) Meeuse. Perennial herb, new stems (with buds, flowers and young fruits) in August and later, 20–30 cm long, afterwards up to 120 cm, mostly prostrate, in part also erect. The knotty tillering base up to 4 cm thick. In some plants, after fire, the remains of old sprouts, partly not burned, 50–70 cm long, with fragments of leaves. Flowers at the end of August (Plot 1) – then also the young leaves and fructification, and later through September until November, sporadically found also from January to April. The root-like trailing rootstock, with diameter of 1–1.5 cm in the upper part, situated not deep, 3–5 cm below soil surface (excavated up to 125 cm of longitude). Hemicryptophyte. Tab. 3, Fig. 22 – Appendix 1, 2; Fl. Zamb.: An extremely variable subshrub-like perennial herb. Stems up to 2 m long, several, erect or prostrate, arising (…) from a woody rootstock; White (1962): It may be shrubby and reach a height of 2 m.

Convolvulus sagittatus Thunb. Low, creeping plant, numerous stems 90–140 and more cm long, situated in part below the litter and below other species. On some sprouts fire traces visible in weeks after conflagration. The flowers, young fruits and new young sprouts in October. Single root. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: An extremely variable perennial. Stems prostrate or twinning, hairy, radiating for up to 0.6 m from a woody rootstock.

15. Euphorbiaceae

Euphorbia cfr. ***oatesii*** Rolfe. Perennial small herb, about 10 cm high in a stage with flowers, fruits and new leaves soon after fire, in September (Plot 1), through October – time of dissemination. Then also remains of old, burned off stems and appearance of new, young sprouts. Flowering noticed also in January. Stems in the rainy season elongated up to 30 cm and more. Cylindrical tap root about 2 cm in diameter, noticed as spongy; may be ramified and/or situated obliquely; some rhizomes were also observed. Hemicryptophyte. Tab. 3, Fig. 23a, b – Appendix 1, 2; Fl. Zamb.: Perennial herb, rootstock large tuberous, producing several woody subterranean stems up to 1.5 cm thick branching at ground-level; branches erect, up to c. 10 (20) cm high, or decumbent to 50 cm long, usually woody or sometimes herbaceous when produced after annual fires (some those features of plant were not observed on here described studied plots). Endemic of Zambia and Zimbabwe.

16. Fabaceae (Leguminosae, Papilionaceae)

Acacia cfr. ***pilispina*** P. Sermolli. Spinescent shrub, 1–1.25 m tall. About two weeks after the fire, in October (Plot 2) new stems arising from plant parts in the soil were observed and in January stems and leaves in full development appeared. Phanerophyte, or – when the aboveground parts are burned off – hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Shrub or tree 1–15 m high (…).

Albizia cfr. ***glaberrima*** (Schumach. et Thonn.) Benth. In the author's observations small tree 3 m tall. Soon after fire, in September (Plot 1) new, young leaves appeared and afterwards, in January – the plants were in full development. Phanerophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Tree 9–25 m high.

Alysicarpus zeyheri Harv. Herbaceous perennial plant , above 22 cm (up to 1 m) tall, with some creeping shoots and remnants of old stems burned off near soil surface. Flowers and fruits from September to November, dissemination up to December. Relatively thin, but hard (wooded) tap root. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Erect or somewhat spreading perennial herb 0.1–1.2 m tall, from a tough woody rootstock (…) often in recently burnt areas (…).

Crotalaria kapirensis De Wild. = *C. spinosa* subsp. *aculeata* sensu E.G. Baker. Annual plant stems 40 up to 100 cm high erect or spreading on soil surface. Flowers from January up to March, in the second part of this time – the fruits. Thin tap root. Therophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Similar to *C. aculeata* (which is erect spiny short – lived perennial) but up to 2 m tall and larger in all parts.

Crotalaria pallidicaulis Harms. Shrub 1 to 2 m high. Leaves in the rainy season, than in January February and March flowers and fruits. Phanerophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Shrub, 1–3 (4) m tall (…).

Crotalaria rhodesiae Baker. Perennial herb, stems prostrate or rising up to 60–160 cm long. On the first studied plot after conflagration, apart from the burned off remains of old stems, small sprouts with leaves and flowers were developed already in August. Some flowers occurred also later, together with fruits, namely from January up to March and April. The root seems to be woody and was excavated up to 12 cm of length. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Prostrate perennial, with many well branched puberulous radiating stems.

To three species of *Crotalaria* mentioned above the following remark may be referred: according to various observations, they adapted to survive on burned plots (Fl. Zamb. – description of the genus *Crotalaria*).

Desmodium velutinum (Willd) DC. Perennial woody herb, or shrub, up to 60 cm tall. After the fire, apart from burned off stems, new sprouts with young leaves were developed. Flowers and fruits occurred from December up to February and March, and in part until April. In this last two month the remnants of seeds were found. The dissemination was observed until June and July. Forced hemicryptophyte. Tab 3 – Appendix 1; Fl. Zamb.: Subshrub or woody herb, 0.5–3 m tall; White (1962): up to 1.8 m tall (...).

Dichrostachys cinerea (L) Wight et Arn. = *D. glomerata* Forsk. Shrub 0.5–1.5 m high, in October appeared some sprouts regenerating from plant parts on the soil surface. Flowers were observed in January. Phanerophyte (forced hemicryptophyte?). Tab. 3 – Appendix 1; Fl. Zamb.: Shrub or small tree 1–8 (12) m high, sometimes suckering and thicket-forming or even scandent, (…). A very variable and taxonomically complex species (…). According to some other observation in the absence of grass fires the described plant may form impenetrable, spiny thickets.

Erythrina abyssinica Lam ex DC. small tree, sheading leaves on the beginning of dry season (in April, May), afterwards flowers and fruits (May, June). Phanerophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Tree, rarely a shrub, 3–10 m tall; White (1962): It may be up to 15 m high and is fire resistant.

Indigofera hilaris Eckl. et Zeyh. Perennial herb, with several decumbent or weekly ascending stems mostly 30, but also up to 40–47 cm long, in clusters (on the studied plots they were in part burned off). Flowering usually soon after fire, from August (Plot 1) till October, fruits and dissemination in similar time, seeds were observed in part at the ant hill. A woody rootstock with some vertical root. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Trop. E. Afr.: Perennial, usually flowering after fire (…) stems up to 30 cm long. Upland or fire induced grassland (…). Fl. Zimb. (electr.): Stems, up to 40 cm tall (…). It is one of the most spectacular displays on the bare, blackened soil after a fire, when it blooms in large numbers before the leaves develop.

Indigofera vicioides Jaub. & Spach var. ***rogersii*** (R.E. Fries) Gillet. Perennial herb, about 30–40 cm tall with numerous ascending, and some elevated, stems, on observation plots in part burned off. Flowers before the leaves, in August until October – then also the fruits, leaves mainly in the rainy season. Thick wooden root up to ca 15 cm in diameter. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Trop. E. Afr.: Spreading annual or perennial herb (…) var. *rogersii* differs in being more often perennial (…). In Global plants on JSTOR: Herb up to 30 cm tall (…).

Tephrosia radicans Bak. Perennial herb, stems (30) 70–120 cm long, creeping on the soil surface, with raised up top parts. Leaves, flowers and fruits soon after fire, in

August (plot 1) and September, observed also later at the end of the rainy season, from February to April. Vertical, woody tap root. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Trop. E. Afr.: Perennial herb with a stout woody taproot; stems prostrate, often forming a mat; according CJB African plant database: Stem 0.8–1.6 m long.

Vigna antunesii Harms. = *V. nuda* N. E. Br. Perennial herb, stems with flowers ca 10–15 cm high, flowering before the leaves, and fructification in October, then still some remains of old, burned out sprouts. In the rainy season the long stems were developed. As the underground part of plants there was found a tap root fibraceous but soft, relatively thick, with branches near soil surface. Hemicryptophyte. Tab 3, Fig. 23c – Appendix 1, 2; Fl. Zamb.: Perennial herb from a thick, often extensive branched, frequently horizontal woody rootstock (…). Stem at first erect, later prostrate or less often climbing 6 cm to 1.8 m tall or long (…). Seasonally burnt grassland.

17. Guttiferae

Psorospermum baumii Engl. Shrub up to 90 cm tall. New sprouts with flowers 15 cm tall appeared in October after fire. In June the leaves become to be yellow. Phanerophyte or – may be – a forced hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Shrub or small tree 1–5 m high, much branched (…).

18. Lamiaceae (Labiatae)

Leucas cfr. ***nyassae*** Gürke. Herbaceous perennial plant, cluster of creeping shoots 70–80 cm long (at the end of rainy season). Flowers in April. In September drying of leaves, cylindrical tap root thickened in the upper part up to 1 cm of diameter, side roots thin, not numerous. On creeping shoots some adventitious roots. Hemicryptophyte. Tab. 3, Fig. 24a–b – Appendix 1, 2; Fl. Zamb.: Perennial herb up to 2 m high, stems erect or procumbent from a woody rootstock.

Scutellaria schweinfurthii Briq. subsp. ***paucifolia*** (Baker) A. J. Paton = *Scutellaria pauciflora* (Baker) A. J. Paton. Perennial herb, stems up to 40 (60) cm tall, in time of flowering 15 cm tall. Buds and flowers from August (Plot 1) to October, at the end of this month and in November – dissemination. Vertical tap root up to 1 cm in diameter with numerous thin side roots mostly horizontal. Hemicryptophyte? Tab. 3, Fig. 25a – Appendix 1, 2; Fl. Zamb.: Perennial herb 15–40 cm tall, with several slender, strict stems arising from a woody rootstock (…) scrub and grassland prone to burning (…).

19. Loganiaceae

Strychnos cfr. ***cocculoides*** Bak. Small tree as well as shrub about 1.20 m high. After fire new sprouts from old branches and – in part – from roots in the soil; they were in April up to 70–120 cm long. Flowers noticed in October; shedding of leaves in June. Phanerophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Deciduous shrub or small tree, (0.30) 1–6(8) m high, sometimes flowering on one-year shoots with small leaves on old fire-cut stumps.

20. Malvaceae

Hibiscus rhodanthus Gürke ex Schinz. Geoxylic suffrutex, during the flowering time erect stems 5-15 cm high, usually on some old parts of plant visible traces of conflagration. Flowers before, or simultaneously with young leaves, soon after fire, in August (Plot 1), and during September and November, in part also in January. The mentioned phases were found also thereafter, from April up to August. In rainy season the creeping stems, up to 20 (100) cm long, were developed. Seedlings appeared in October. Underground parts: woody, but not thick, long vertical root (c. 0.5–1.5 cm in diameter), usually with side roots; (cfr. Medwecka-Kornaś 2013a). Hemicryptophyte? Tab. 3, Fig. 25b – Appendix 1, 2; Fl. Zamb.: Perennial herb 5 cm – 1 m tall, producing annual shoots from a woody rootstock.

21. Myrtaceae

Syzygium guineense (Willd.) DC subsp. ***huillense*** (Hiern) F. White. A geoxylic suffrutex (White 1976). Fire traces observed on plants remnants 20 cm above the ground. Stems 75 cm high, leaves and flowers near the soil. Flowering noticed in September and in January. Chamaephyte, on the study area rather hemicryptophyte. Plot 1, rec. 1, 2; Fl. Zamb.: Rhizomatous geoxylic suffrutex up to 0.6 m tall, but often no more than 0.3 m, usually flowering on unbranched current year' shoots arising directly from the rootstock; West (1972): Suffrutescent shrublet or underground tree.

22. Ochnaceae

Ochna leptoclada Oliv. Geoxylic suffrutex (White 1976). Rhizomatous plant, on the study surfaces about 60 cm tall. Chamaephyte or phanerophyte. Tab. 3, Fig. 26a, b – Appendix 1, 2; Fl. Zamb.: Shrub or rhizomatous shrublet up to 1 (1.3) m high (or sometimes a small tree) (…); White (1962): Small shrub up to ca. 0.4 m high, with creeping ± caespitose, woody rootstock; West (1972): A suffrutescent shrublet.

23. Passifloraceae

Adenia goetzei Harms. Perennial herb up to 12 cm high (in the time of flowering). Flowers and young fruits in November. Ripe fruits observed still in January and also then dissemination and yellowing of the leaves. During seeds release stems were inclined to the soil surface. Plant tubers about 6 cm in diameter, situated 5–7 cm deep under soil surface. Geophyte. Tab. 3, Fig. 26c – Appendix 1, 2; Fl. Zamb.: Erect, simple or few-branched herb up to 30 cm high, arising from a subspherical tuber 5–10 (20) cm in diameter. Stems annual (…).

24. Pedaliaceae

Sesamum cfr. ***angustifolium*** (Oliver) Engl. Perennial herb, stems 60–65 cm high with flowers and later up to 90 cm high, single or in small bunch e.g. by four. Flowering from January till March and fruits still in April. Vertical tap root about 1.5 cm in diameter, with woody upper part at the base of stems, at least 30 cm long and with few, small side roots. Hemicryptophyte. Tab. 3, Fig 27a, b – Appendix 1, 2; Fl. Zamb.: Erect annual or perennial herb, stem simple or branched, 0.4–2.0 m high.

25. Periplocaceae

Ectadiopsis oblongifolia (Meisn.) Schltr. = *Cryptolepis oblongifolia* Schltr. Tufted suffrutex (White 1962) or low shrub; both forms about 50 cm tall, with sparsely branched stems. They can regenerate relatively soon after fire (e.g. in October on Plot 2). Flowers and fruits occurred in November, fruits were noticed also in January, February and even in April or later. Vertical woody tap root about 28 cm long or root located horizontally 5–7 cm under soil surface, of diameter up to 1.7 cm and with numerous side roots, more than 60 cm long. The plant was found also as a low shrub, 50 cm high, with vertical more narrow root about 60 cm long, with diameter up to 1.7 cm and some side roots, mostly horizontal. Forced hemicryptophyte (or phanerophyte in the lack of disturbance by fire). Tab. 3, Fig. 27c, d – Appendix 1, 2; Fl. Zimb. (electr.): Erect small shrub up to c. 1 m high; White (1962): Tufted suffrutex with wiry, sparsely branched stems up to 1 m high, but usually less, or a twinning shrub with slender woody stems up to 2 m height.

26. Polygalaceae

Polygala petitiana A. Rich. and var. ***calceolata*** Norlindh. Annual herb up to 90 cm tall, flowers during July, in elongated terminal racemes, leaves found from October to May. Therophyte. Plot 1 rec. 8, 7, Plot 2 rec. 5'; Fl. Zamb.: Annual herb up to 90 cm tall with slender, glabrous or nearly glabrous stems.

Securidaca longipedunculata Fresen. Shrub 40–125 cm high, some burned off stems and leaves were found at the end of August (Plot 1). At that time and in September there appeared the new sprouts, developed from above or below parts of old plants. They were already up to 70 cm long in October. Phanerophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Small tree up to about 6 m or shrub, sometimes spiny.

27. Ranunculaceae

Clematopsis scabiosifolia (DC.) Hutch. Herbaceous plant about 35 cm tall, leaves in the rainy season; in March and April – flowers and fruits. Hemicryptophyte. Tab 3 – Appendix 1; Fl. Zamb.: Perennial herb with erect stems (data for genus). Stems 0.7–1.5 m tall (…).

28. Rubiaceae

Fadogia cienkowskii Schwenf. var. ***cienkowskii*** Verdcourt = *F. katangensis* De Wild. Geoxylic suffrutex (White, 1976). Woody tillering plateau shallowly under the soil surface. Stems up to 60 cm tall, in clusters. After fire there were observed their not burned parts and some not burned fruits. Flowers and fructification in September, but mainly in October and afterwards, also in January and February. The seedlings 13 cm high were noticed in May (on Plot 2). Tap root woody, in the upper parts up to 5 (10) mm thick, in all probability going deep. Hemicryptophyte? Tab. 3 – Appendix 1; Fl. Zamb.: Suffrutex 0.3–1.2 m tall, stems simple, few to several (15) from the apical parts of a branching woody rhizome.

Gardenia subacaulis Stapf & Hutch. Geoxylic syffrutex (White, 1976). Plant of nearly aculescent erect parts of stems up to 6–10 cm high. Sprouting and blossom soon after conflagration. Flowers as well as fruits in September (Plot 1) and afterwards till January (February), later mainly fruits. They are relatively large, fire resistant and can lay on the soil surface one year (and – may be – for a longer time). Leaves after flowers, in clusters. Perennial woody underground axes up to 1.3 cm thick and long, situated nearly horizontally, about 10 cm below the soil surface (excavated up to 30 cm and broken). Hemicryptophyte or geophyte (cfr. Medwecka-Kornaś, 1980 – there slightly different phenological observations from the other sites). Tab. 3 – Appendix 1, Fig. 28a, b, Fig. 29a – Appendix 2; Fl. Zamb.: Small shrub or subshrub 15–60 (100) cm tall with decumbent or erect divaricate shoots from a long many-headed rhizome; White (1962): Rhizomatous suffrutex, up to 15 cm high.

Psychotria cfr. ***spithamea*** S. Moore. Geoxylic suffrutex (White, 1976), shoots 20 cm high, found with some remnants of old, burned off parts. Leaves in the rainy season, flowers then in December and January, fruits noticed until March. Long creeping rhizomes about 0.4 cm in diameter, thickened in some parts (excavated up to 26 cm), wooden roots not deep in the soil. Phanerophyte or hemicryptophyte. Tab 3, Fig. 29b – Appendix 1, 2, Fig. 30; Fl. Zamb.: Subshrub with several stems 10–50 cm tall from a mostly creeping woody rhizome.

Pygmaeothamnus zeyheri (Sond.) Robyns. Geoxylic suffrutex (White, 1978), rhizomatous suffrutex (White, 1976) suffrutescent shrublet (West, 1972). Stems in some clusters, short, 20–30 cm high (e.g. 4–8 cm long below the leaves and 14–20 cm up to plant summits). Leaves and flowering soon after fire, in August (on Plot 1) and later. Plants with fruits were found in September and October, and fruits were noticed in November as well as later, in March. Underground rhizomes, or branches occurred to be woody, in some parts horizontal, up to 1 cm in diameter. Chamaephyte or hemicryptophyte. Tab. 3, Fig. 31a – Appendix 1, 2, Fig. 32; Fl. Zamb.: Suffrutescent herbs, mostly under 30 cm tall, with several to many stems from a woody rhizome.

Spermacoce dibrachiata Oliv. = *Borreria dibrachiata* (Oliv.) K. Schum. Annual herb (on the studied plots), stems about 60 cm tall, in clusters. Flowers and fruits in March and

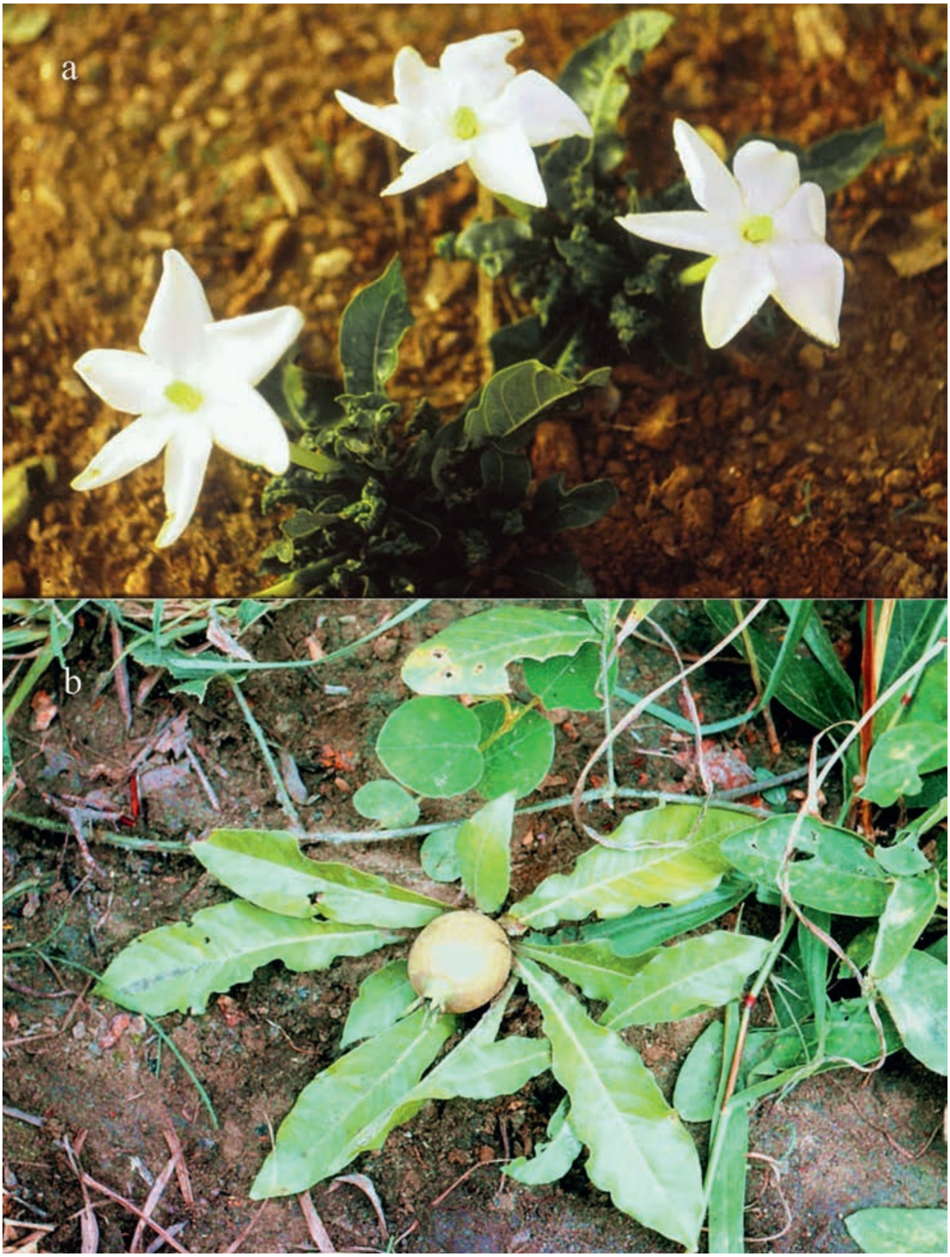

Fig. 28. Rubiaceae: *Gardenia subacaulis* – flowers near the soil surface, June (a); young fruits and leaves in January (b)

Fig. 30. Rubiaceae: *Psychotria* cfr. *spithamea* low plant with leaves and flowers, found scarcely on Plot 2, January

Fig. 32. Rubiaceae: *Pygmaeothamnus zeyheri* – plant with flowers, noticed on both studied plots, but scarcely, end of September

April; thin vertical root. Therophyte. Plot 1, rec. 9, 10; Fl. Zamb.: Annual or sometimes biennial or perennial very variable herb 6–90 cm tall, with simple or sparsely branched stems. Often (…) rosette of leaves; rootstock often swollen (…).

29. Santalaceae

Thesium unyikense Engl. Herbaceous perennial. Stems about 20 cm high (in stage of flowering and fructification), developed from the tillering base. Fire traces on plant were visible 2 cm above the ground. Flowers and fruits from October to January and February. Tap root was observed as thickened in the upper part, 5–8 cm below the soil surface, with side narrow roots about 30 cm long. Hemicryptophyte. Tab. 3, Fig. 31b, c, d – Appendix 1, 2; Fl. Zamb.: Perennial herb drying grey-green, with a woody caudex c. 20–40 mm in diameter crowned with very many short closely scaly shoots that elongate into stems up to 400 mm long.

30. Scrophulariaceae

Cycnium adonense E. Mey. ex Benth subsp. *camporum* O.J. Hansen. Perennial herb, 20 cm high, burned off stems were observed at the soil surface. Leaves fully developed and flowers noticed in October 2. Thickened tap root measured up to 5 mm in diameter. Hemicryptophyte. Plot 1 rec. 4, Plot 2. rec. 1'; Fl. Zamb.: Perennial herb with woody tuber; stems 5–35 cm long, prostrate, decumbent or erect.

31. Thunbergiaceae

Thunbergia aff. ***oblongifolia*** Oliv. Herbaceous perennial. Stems in clusters 30–40 cm high (during the rainy season), with thickened bases; tillering plateau in the soil, 3–4 cm deep. Flowers in part on soil surface, in September (about 3 weeks after fire and then also the young leaves) and afterwards in November the fruits, some of them observed also in July and August (on plot 2 after the second fire). Soft bottle like tap root thickened in the upper part up to ca 3 cm in diameter, side roots thick, not numerous. Shallow geophyte. Tab 3, Fig. 33a–b – Appendix 1, 2; Fl. Zimb. (electr.): Perennial herb with stems to 70 cm, arising from a woody rootstock. (…) in open grassland and at the edges of *Brachystegia* woodland, especially after fire.

32. Tiliaceae

Triumfetta heliocarpa K. Schum. Perennial herb. Shoots 20–40 cm high, in clusters, during flowering slightly lower, developed from the tillering base. Flowers and fruits in August, simultaneously with the development of young leaves and later through October, in part until February. Leaves in full development in the rainy season. Seedlings noticed in November and later. Soft, vertical bottle-like tap root mainly up to about 4 cm in diameter, but narrow in the upper part, there – below the soil surface – buds for tillering. Hemicryptophyte. Tab. 3, Fig. 34a, b – Appendix 1, 2; Fl. Zamb.: A species with a similar habit and general appearance to *T. welwitschii*, therefore: perennial herb sending up annual stems from a woody rootstock (…) stems 20–45 cm tall (…) var. *welwitschii* of this species: very common in *Brachystegia* woodland and grassland (…) particularly obvious after the grass is burnt.

33. Turneraceae

Tricliceras longipedunculatum (Mast.) R. Fernandes. = *Wormskioldia longipedunculata* Mast. Herbaceous perennial. Stems with flowers up to 30 cm high, their old burned off parts were 5, 10 up to 15 cm high. Beginning of flowering and new leaves soon after fire (in 10 days on Plot 1), thereafter flowers and fruits mainly from October to February and sometimes to April. Leaves in the rainy season. Long vertical root measuring 4–7 mm in diameter was found with side roots and was excavated up to 13 cm of length (and broken). Hemicryptophyte. Tab 3, Fig. 34c – Appendix 1, 2; Fl. Zamb.: Perennial, usually caulescent, with a long vertical woody rootstock. Stems 1 to numerous, erect or rarely procumbent, simple or branched.

34. Verbenaceae

Clerodendron pusillum Gürke. Geoxylic suffrutex (White 1976). The sprouts at flowering time about 3 cm tall later – with leaves – up to 20 cm. Tillering base on the soil surface. Buds, flowers and new leaves at the end of September, flowers still in October and then also fruits. Leaves maintained up to January – February (in a short time of plant full development). Thick woody vertical roots up to 1.5 cm in diameter, with ramifications, were excavated up to 35 cm of lenght. Hemicryptophyte. Tab. 3, Fig. 35a – Appendix 1, 2; Fl. Zamb.: Dwarf rhizomatous pyrophytic suffrutex 1 to 25 cm tall, from a woody rootstock with spreading, slender branches. Stems herbaceous, 1 – several, erect, simple or few-branched (…). In recently burned plateau and escarpment miombo, wooded grassland and dambo margins (…).

Vitex cfr. ***mombassae*** Vatke. Shrub up to 1.5 m high – new sprouts in February 40–50 cm high. Leaves and flowers from the beginning of October, fruits from December to January. Thick tap root with 2.5 cm in diameter, up to 75 cm of length was dig out up. Phanerophyte, or forced hemicryptophyte. Tab 3, Fig. 35b – Appendix 1, 2; Fl. Zamb.: Much branched shrub or small deciduous tree up to 8 (17) m tall. Note of Jan Kornaś: Normally a tree.

35. Vitaceae

Cyphostemma rhodesiae (Gilg & Brandt) Descoings. = *Cissus rhodesiae* Gilg. & Brandt). Small shrub or perennial herb, stems about 65 cm tall, tillering base at the soil surface. Buds, flowers and leaves in October, then a full development of plant.

Tap root tuberous in the upper part 2.5 up to 8 (?) cm in diameter, with some lateral roots. Hemicryptophyte. Tab. 3 – Appendix 1; Fl. Zamb.: Erected herb to c. 1–3 m tall; Herbarium of Zambia University (UNZA): Specimen defined as shrubs or subshrubs.

A notice: below in the text, after the plant names, in parenthesis are numbers – they indicate the plant's adherence to adequate family, according to the specification in the chapter above.

Common features of studied vegetation floristic composition

Number of plants in particular families

On both studied plots of savanna 95 species of vascular plants were noticed. They are shortly described above and mentioned in phytosociological tables No 2 and 3, or – in the case of sporadic species – in the text. All of those plants belong to 35 families, represented in the studied plots chiefly by a single taxon. Most numerous species – 22 were classified in the family of grasses – Poaceae (1), the lower number – 13 were found in Fabaceae (16), and 7 by Asteraceae (10), as well as in Cyperaceae (2), 6 other species were noticed in Rubiaceae (28), 3 in the families of Orchidaceae (4) and Acanthaceae (5), and at least 2 in Apiaceae (8), as well as in Polygalaceae (26). The comparison with data from temperate climate conditions may be interesting: the meadow *Arrhenatheretum elatioris* near Cracow (Poland), in time of investigations of Medwecka-Kornaś and Kornaś (1963), contained 71 plant species from 21 families, among them 18 various grasses, and a xerothermic grassland *Thalictro-Salvietum* on Małopolska Highland – 83 plant species from 23 families, with 12 species of grasses (Medwecka-Kornaś 1959). *Thalictro-Salvietum* belongs to a vegetation type formerly often burned off.

Quantitative share of observed species

On the first studied savanna plot apart from the 73 herbaceous plant species, 5 taxa of trees and chiefly shrubs were found, and on the second plot apart from 80 herbaceous species, 8 taxonomic units of shrubs and 3 of small trees were ascertained. The grasses included 22 species – 15 on the first and 19 on the second studied plot. The low share of trees was partly due to their exploitation – on the second studied plot the single felled trunks were observed. Several trees were growing in the adjacent, and further situated parts of the savanna; soil and climate conditions were, therefore, suitable for plants of this type.

The quantity of particular plant species in the two studied plots of vegetation was uneven, chiefly among the grasses (Tab. 2). The most important of them – *Hyparrhenia filipendula* attained the 4th degree of coverage (on Plot 2), other components of this group had a lower part, estimated even as only 1 or +. Among other species, belonging mostly to Magnoliopsida (Dicotyledones), the quantitative role was rather levelled – estimated as the 2nd or lower degree of coverage (Tab. 3 – Appendix 1). The second plot of investigations was distinguished by a slightly richer flora – only there were found e.g. the tree *Strychnos* cfr. *cocculoides* (19) and among the herbaceous plants e.g. *Indigofera vicioides* (16), *Vigna antunesii* (16), and *Thesium unyikense* (29). During the author's investigations in Zambia, the pyrophytes were noticed not only on the selected studied plots but also – chiefly by Jan Kornaś – in numerous other localities (see pages 48–52).

Ecological types and classification of plants on the studied plots

The observed plants were able to endure conflagrations owing to various features connected with their structure, seasonal development, and ways of regeneration. The type and structure of underground parts were very important (cfr. enclosed pictures), as well as the location of renovating buds, a basic criterium in the Raunkiaer's plant classification (considered here below and in chapter with plant descriptions). Concerning this, on the investigated plots the following groups of species can be distinguished:

Phanerophytes – trees, and shrubs – can survive fires owing to the resistant bark and sometimes also the resistant leaves or buds. Shrubs have more often also the possibility of regeneration by new sprouts regrowing from the parts in the soil. On the studied plots 11 species of the mentioned group were found, belonging – with some exceptions – to the family Fabaceae: e.g. the tree *Erythrina abyssinica* (16), as well as two taxa occurring as tree or shrub – *Albizia* cfr. *glaberrima* (16) and *Strychnos coculloides* (19). The tall shrubs with a height above 50 cm were represented chiefly by *Acacia pilispina* (16), *Dichrostachys cinerea* (16), and *Vitex mombassae* (34). As a small shrub *Desmodium velutinum* (16) was noticed.

Chamaephytes – plants with woody stems up to 50 cm high – were observed only in the additionally distinguished group of geoxylic suffrutices (located below on the last position) – to such chamaephytes there were classified e.g. *Lannea edulis* (6) and *Parinari capensis* (12).

Hemicryptophytes – perennial plants with regenerating buds on, or near the soil surface, where they can be protected by plant litter, small parts of the soil, old leaves, and some basic parts of stems. This group was the most numerous on the studied plots and numbered about 60 species. Owing to some differences in structure and the way of fire survival, the following ecological groups can be distinguished among them: plants with clusters of leaves and clusters of rather thin roots e.g. *Andropogon schirensis* (1), *Brachiaria humidicola* (1), and *Justicia elegantula* (5), plants with similar structure, but with stolons on the soil surface or rhizomes in the soil. To the group belongs a majority of noticed grasses (1), e.g. *Hyparhenia filipendula*, *Setaria sphacelata*, *Tragopogon spicatus*, and among non-grassy species *Annona stenophylla* (7). At least it can be mentioned a group with roots partially thickened (mostly in the upper part) and single shoots represented by species belonging to various families e.g. *Brachiaria* *brizantha* (1), *Aspilia pluriseta* (10), *Dicoma plantaginifolia* (10) and *Trichodesma ambacense* (11). The hemicryptophytes were distinguished also among further described "geoxylic suffrutices".

Geophytes (terrestrial part of a larger group – cryptophytes) – plants with renovating buds localised in the soil. On the studied plots, they were not numerous, numbered 7 species noticed chiefly sporadically. Among them there can be distinguished some plants with relatively small tubers, namely *Gloriosa superba* (3), with tubers about 1–1.5 cm in diameter: *Littonia littonioides* (3), *Eulophia pyrophila* (4), and only one species: *Adenia goetzei* (23) with larger tubers of about 6 cm in diameter, located deeper, 4–7 cm under the soil surface. As a plant of transitional character between geophytes and hemicryptophytes *Eulophia* cfr. *livingstoneana* (4) with tubers on the short rhizomes, situated on – or below – the soil surface, can be considered. To this group, it can also be included some part of "geoxylic suffrutices", distinguished additionally and treated here below. In spite of this, the share of geophytes in the vegetation of studied plots is considered as low. It is connected with the fact that unfavourable high soil temperatures (evolved under fire influence, noticed in the tropics) occur not so deep under the earth's surface as the frost impact in the regions with cold winter.

Therophytes – the annual plants regenerating (also after a fire) from the seeds protected by plant litter, or saved in the soil. This group was not numerous on the studied plots, numbered only 6 species, e.g. the grass *Dactyloctenium aegyptium* (1) and from Magnoliopsida e.g. *Polygala petitiana* (26) as well as *Spermacoce dibrachiata* (28). It is worth noting that several plant species can develop the perennating buds not only in one location and therefore represent more than one plant type in the Raunkiaer's classification. And so as hemicryptophyte or geophyte were classified e.g. *Abildgaardia filementosa* (2), *Cyperus margaritaceous* (2), *Eulophia livingstoneana* (4), and *Diplolophium zambesianum* (8). As chamaephyte or hemicryptophyte there were considered *Lannea edulis* (6) and *Pygmaeothamnus zeyheri* (28), as phanerophyte or hemicryptophyte *Ectadiopsis oblongifolia* (25) and as hemicryptophyte – geophyte *Eulophia livingstoneana* (4). Such a situation may be found also in the ecological unit described below.

Geoxylic suffrutices – a group of plants distinguished additionally, independently of the Raunkiaer's classification. This group includes plants with low, above-ground herbaceous stems (in the author's study noticed as 45–75 cm high) and with woody underground parts. Among them there can be distinguished the species with woody taproot relatively thin like *Hibiscus rhodanthus* (20, Medwecka-Kornaś 2013) or thickened, found e.g. in *Lannea edulis* (6), *Cussonia corbisieri* (9) – with root-trunk 4 cm in diameter and *Clerodendron pusillum* (34). A similar root, located horizontally was found in the case of *Ectadiopsis oblongifolia* (25). Some of the other groups of geoxylic suffrutices include plants with woody rhizomes or trailing rootstocks: namely *Parinari capensis* (12) and *Combretum platypetalum* (13) as well as *Ochna leptoclada* (22),

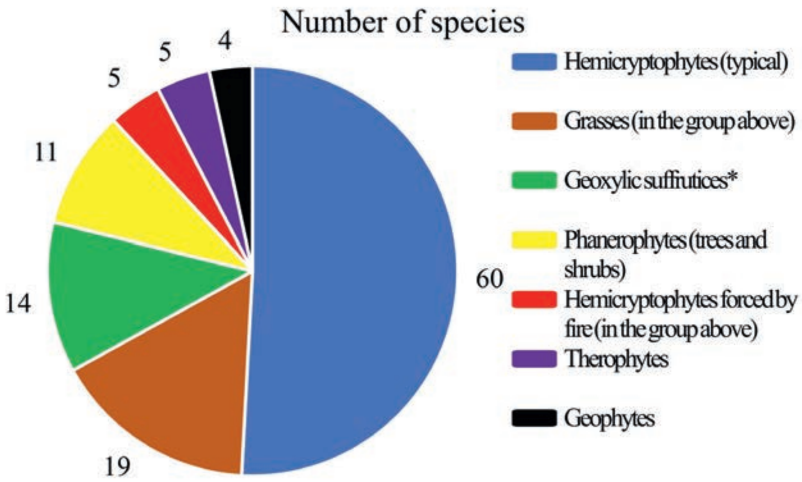

Fig. 36. Comparison of the contribution of plant species classified according to the ecological characteristics (according to the Raunkiaer's system) in the vegetation of the studied plots; *the group distinguished additionally

Tab. 4. Water content in the underground parts of selected plant species

Fam. No.	Plant names	Date	Fresh weight [g]	Data	Air dry weigh [g]	Difference [g]	Water loss [%]
3	*Gloriosa superba*	5VII	6.4	27 VIII	2.6	3.8	69
3	**Gloriosa superba*	5 I	8.4	29 VII	2.6	5.8	69
6	*Lannea edulis*	7 X	280.0	**19 II**	137.3	142.7	51
7	*Annona stenophylla*	5 I	149.0	28 VII	71.9	77.1	52
7	**Pachycarpus lanceolatus*	4 I	20.1	27 VIII	9.8	10.3	51
9	*Cussonia corbisieri*	8 XII	211.0	**28 VII**	67.5	143.5	68
9	*Trichodesma hockii*	13 X	6.4	**27 VII**	1.8	4.6	72
		27 I	30.4	28 VII	10.0	20.4	67
		13 X	22.7	19 XII	10.5	12.5	55
12	*Parinari capensis*	20 IX	547.3	20 XII	295.8	251.5	46
15	*Euphorbia oatesii*	5 I	31.3	27 VIII	8.8	22.5	72
16	**Cryptosepalum maraviense*	1 X	168.5	18 XII	99.5	69.0	41
16	**Physostigma mesoponticum*	29 IX	123.8	**19 II**	43.9	79.9	65
16	*Vigna antunesii*	4 I	9.9	27 VII	3.6	6.3	64
16	**Vigna antunesii*	13 X	22.7	**19 III**	10.0	12.7	52
16	*Vigna unguiculata*	30 IX	57.1	19 XII	22.1	61.3	61
16	**Vigna unguiculata*	4 I	9.9	27 VII	3.6	6.3	64
36	**Cyphostemma rhodesiae*	9 X	462.0	19XII	250.2	211.8	46
		"	"	**28 VII**	154.5	307.5	67

Explanations: on the left margin = family numbers according to the text on pages 18–38; * – samples taken from plants out the permanent studied plots; the water measurements apart from the plant roots, comprised samples of bulb and rhizome by *Gloriosa superba* and of a bulb by *Pachycarpus lanceolatus*; measurements carried out in the second year of investigations are bolded; XI–III – months of the rainy season

Pygmaeothamnus zeyheri (28) and *Psychotria spithamea* (28). The discussed group, specified as "African geoxylites", concerning plants belonging to Proteaceae in Southern Africa was described by Lamont et al. (2017). From the point of view of Raunkiaer's classification (1934), the particular geoxylic suffrutices can be considered as chamaephytes, hemicryptophytes, geophytes, or as combined – two or even three – ways of regeneration (Burt, Davy, 1972). Description according to their ecological features is illustrated in figure (36).

Water content in plant underground parts

The important features of plants – especially in dry, even seasonally climate conditions (as in Zambia), belong to their water regime and content of water (e.g., Wiliamson, 1987). This second feature was measured by the author concerning selected species (Tab. 4).

Plant roots and in some cases bulbs or rhizomes, parts the most important for fire survival and regeneration, were taken into consideration. Their samples were of various sizes regarding the different dimensions of particular species. The difference between fresh weight (at the beginning) and the dried samples was considered as the result of water loss and simultaneously as their former content in plants.

The mentioned values were in some parts depending on the time interval between the first and the second measurement. The important fact is that the majority of samples revealed higher than 50% or 60% and sometimes even about 70% of water content. Samples from the studied plots provided from the dry season (April to October) revealed similar values: 51–72%. For comparison the water content in potato bulbs may be quoted: it equals 77%.

Seasonal development of the observed species, occurrence of seedlings

Soon (in 2–3 weeks) after burning the degree of soil coverage by vegetation on the studied plots was low and measured 30–40%. Some plants were however in the stage of flowering and attained 20–30 cm high. The fires in August and October before the rainy season, with favourable plant living conditions, were very favourable for their further development. In the phenological development, there were, however, some similarities, as well as differences between species and species groups (cfr. Tab. 5 – Appendix 1 and data in chapter with plant descriptions).

Grasses (1) had (and usually play) the most important role in the development of savanna vegetation after a fire. About two weeks after conflagration (on the first plot at the end of August), and still in the dry season: their young leaves (usually in clusters) were up to 10 cm high. In the rainy season, at the beginning of January, their turfs attained 30–40 cm, and their flowering shoots 50–70 cm in height. At the end of this month, tufts of grasses were fully developed and some of them produced stolons. Near the end of February, the discussed plants were up to 2 m high on the first, and still taller on the second plot (see chapter – a structure of vegetation in full development). The fructification of grasses (like e.g. *Hyparhenia filipendula* on Tab. 5 – Appendix 1) was observed mainly in the rainy season, from November (or next months) until April.

Sedges (2) on the studied plots occurred scarcely. They were visible mainly in the rainy season (November-March). At the beginning of this time, new leaves appeared e.g. in *Abildgaardia hispidula*. In November the flowering and the beginning of fructification took place. Some flowers and fruits were observed also later – in December and January. In other sedges, e.g. *Cyperus margaritaceous* and *Scleria bulbifera*, flowers and fruits occurred mostly in January, and in *Abildgaardia filamentosa* they were registered in April. Those observations are consistent with the description and diagram of Medwecka-Kornaś and Kornaś (1985). Specimens of Cyperaceae from the described studied plots, as a rule, had distinct fire traces: burned up leaves and stems with charred remnants 1–1.5 cm above the soil surface.

In other species (families 3–35), it is worth noting that numerous observed plants developed flowers and often also fruits soon (in two-three weeks) after the occurrence of fire, at the end of the dry season. At the end of October, the fruits or seeds were observed e.g. in *Dicliptera melleri* (5), *Launaea nana* (10), and *Hibiscus rhodanthus* (20). Their dissemination took place therefore mostly before the rainy season. Owing to this, the following development of seedlings was possible in moist conditions. Noteworthy is the fact (also described in the literature) that plants flowering from short shoots after fire differ greatly from those that "escaped" and did not burn for two or more years.

The seedlings, which are of the greatest importance for the development of annual plants, were rarely noticed in the research plots. And so, e.g. the seedlings of *Diplolophium zambesianum* (8) with dimensions of 7 cm, were noticed in December. More complete observations concerned a rather common species *Triumfetta heliocarpa* (32). Its relatively large fruits were developed in the second half of October, as well as in November, then they fell on the soil surface. The seedlings appeared at the end of February. Seedlings of *Fadogia cienkowskii* (28) about 13 cm high were found at the end of May. Therefore the dissemination took place before the rainy season and the development of young plants afterward. The young plants can survive fires at least in some not burned fragments of vegetation.

Common phenological aspects of the studied savanna plots

In connection with the seasonal development of species quoted above, the whole plant community has changed its aspects, so that at least its three distinct phonological phases can be distinguished:

1) The early stage of development of vegetation, 1–2 weeks after a fire, which was the period of flowering of several non-grassy species; it fell in the second half of the

dry season, in August and September. Bare ground, covered with ash in places, was at this time visible between the low tufts of grasses which had been partly burned off, but already developed the first new leaves. About half of all non-grassy species were then in bloom. They produced flowers before the leaves or simultaneously with them. Most parts of the flowers were situated on the soil surface or just above it (in the so-called “basiflorous position”). Some plants set already fruits, but the main period of fructification occurred slightly later, just before or at the beginning of the rains in October and November (it does not concern the grassy species with seeds ripening afterward).

2) The stage of the optimal development of grasses, occurring from October through the middle of the rainy season, to February. At that time ground was completely covered with dense vegetation, dominated by flowering and fruit-bearing plants of Poaceae. Most of the dicotyledonous species, very low at the time of flowering, had well-developed assimilating organs of considerable dimensions (e.g. *Lannea edulis* (6) with leaves up to 40 cm long).
3) The period of gradual drying of vegetation after the rainy season, from April-May till the next conflagration; only some species had then flowers and/or preserved fruits. The grasses were turning yellow and wiry at the beginning of that time, and the majority of other plants lost their leaves or herbaceous shoots. There were only very few specimens that retained green leaves or flowers till the next fire. The soil remained then completely shaded by the densely crowded dead shoots of grasses.

The structure of the studied plant cover in full development

During the full development of studied vegetation (phase 2 in the chapter above) the coverage of ground by plants attained 90–95%. Some dominating grasses (cfr. family 1) were more than 1 m (up to 2 m) tall. To the highest ones belong *Brachiaria humidicola*, *Digitaria milanjiana*, *Hyparrhenia filipendula*, *Hyperthelia dissoluta*, *Setaria sphacelata*, and *Trachypogon spicatus*. Relatively tall was also *Psorospermum baumii* (17). Lower, a medium layer of vegetation about 40–80 cm high was formed e.g. by *Annona stenophylla* (7), *Cyphostema rhodesiae* (35), *Scutellaria schweinfurthii* (18), and *Sesamum angustifolium* (24). The lowest layer comprised plants up to 20–30 cm high and had some sedges, but occurring scarcely, as well as several other species e.g. *Indigofera vicioides* (16), *Hibiscus rhodanthus* (20), *Parinari capensius* (12), *Thesium unyikense* (29) and *Tricliceras longipedunculatum* (33). The soil surface was then covered by stolons of some plants, e.g. of grass *Brachiaria humidicola* (1) and dicotyledons: *Astripomea malvacea* (14), *Gardenia subacaulis* (28), *Pygmaeothamnus zeyheri* (28). The height of some registered plants was lower than that described in the literature, e.g. in Flora Zambesiaca. Perhaps the observations cited there were made at longer intervals after the fire or even in unburned places. It is noteworthy that other plants could grow underneath the plots, despite the relatively dense layer of grasses. This brings to mind some of the fields in Europe, in particular those with old tall cereal varieties and with numerous weeds, much lower.

Some phytosociological features of the observed vegetation

The floristic composition of plant communities on both studied plots is presented in the table (2) and (3) – Appendix 1. The first one contains the grasses, treated separately concerning the limited number of their concerning phytosociological records. Such a situation resulted from the difficulties related to the problem of species identification during their vegetative phases, without spikelets – flowers and seeds. Among grasses, the most important – in terms of quantity – turned out to be: *Hyparhenia filipendula*, *Eragrostis racemosa*, and *Setaria sphacelata*. Sedges were represented so scarcely that information about their occurrence is presented with one exception of *Cyperus margaritaceous* (2).

The phytosociological table contains the representants of Liliopsida and chiefly Magnoliopsida (Tab. 3 – Appendix 1). The highest constancy degree attained 4 species, e.g. a shrub *Securidaca longipedunculata* (26 – family number), and among the herbaceous plants 15 species, e.g. *Trichodesma ambacense* (11), *Triumfetta heliocarpa* (32) and *Annona stenophylla* (7). Perhaps species unnoticed in some records were – during the particular investigations – undeveloped or underdeveloped, without flowers or fruits, thus difficult to observe. The mosses Bryophytes were found very scarcely. Some phytosociological records revealed small differences between plots 1 and 2. The first one had a lower share of trees and shrubs and a slightly lower number of other species – 48, in comparison with 54 on Plot 2.

Additional information about the pyrophytic plants beyond the studied plots

The species which grew on the studied plots, as well as several other plants of a similar ecological character, were found in Zambia in various localities with the occurrence of fire: in savannas and grasslands, shrublands, and even in some parts of the miombo forests. There are two methods of determination of such species and their distribution: field observations on the burned plots and study of plants with fire scars in the herbarium. Both methods were applied to ferns, grasses and sedges, mentioned below. In the case of other plants, the first way of treatment was mainly adopted – concerning them the studies based on the large herbarium material would be too difficult.

Ferns and some others Pteridophyta

Information about the occurrence of those plants in Zambia may be found chiefly in several publications of Jan Kornaś; drawings of the mentioned plants and maps of their distribution are included in some of them. In the main paper (Kornaś, 1979), the fire is broadly taken into account. The author wrote that more than 20% of Zambian pteridophytes at least occasionally survive burning; information about their distribution is presented in the text and on dot maps. A list of 25 pyrophytic fern species is supplemented to the 1978 and 1988 publications. For 18 of them, detailed information about the localities in Zambia may be found in the schedule of Kornaś (1977a, b). To the described pyrophytic ferns belongs, e.g. *Pteridium aquilinum* a rhizome geophyte and cosmopolite, known in Europe, including Poland. The information – in the notebook of Jan Kornaś – about the presence of 9 species of ferns in the Forest Reserve with fire experiments near Ndola (Northern Zambia, Trapnell, 1959) is also interesting. There was reported, e.g. *Nephrolepis undulata*, a species highly fire-resistant, growing on sites that are burnt in each dry season (Kornaś, 1978).

In 1975 Kornaś drew attention to the ecology of a very interesting species of the Pteridophyta, a club-moss *Lycopodium carolinianum* var. *tuberosum*, which has subterranean tubers not accessible for fire. The large population of this species was found in Zambia (also by the present author) on the burned grasslands at the Great East Road.

Flowering pyrophytic plants – Anthophyta

In the list of their localities presented further the following abbreviations are used:

Air P.-Kas. – the area between the International Air Port, 17 km ENE of Lusaka, and the village Kasisi 8 km further to NEN, burned grassland (the region of Plot 1 in the author's investigations),

Bonan. – Bonanza, a village 13 km NW of Kabwe – a city situated 112 km N of Lusaka,

Camp. Eucal. – Campus of the Lusaka University, burned plot near the planted Eucaliptus trees; in 1972 fire appeared there in September,

Camp. sav. – Campus of the Lusaka University, some savanna plots preserved there, in 1972 burned before 10 October,

Chil. – Chilanga small town 16 km S of Lusaka,

Chil. – Chip. – between the town Chilanga (as above) and Chipongwe – the village in a distance of 12 km further to S, burned grassland and bushland nearby the road,

Chita. R. – Chitakata Riverbank 25 – 50 km NW of Kabwe – a city situated 112 km N of Lusaka, mostly burned woodland,

Chis Res. – Chisamba Forest Reserve, 70 km N of Lusaka, miombo woodland,

Chon. R. – Chongwe River bank, about 40 km NE of Lusaka, burned grasslands,

Great E. Rd. – Great East Road running E of Lusaka, various burned places near this highway,

Kab. – Kabwe, a city 100 km N of Lusaka, Kap.-Mpun. – between Kabwe, see above and Mpunde – see below,

Kaf. N. P. – Kafue National Park, 210 km W from Lusaka, recently burned grasslands,

Kas. – Kasisi, a village and Polish Catholic Mission, 22–24 km NE from Lusaka,

Kas.-Const. – between Kasisi (as above) and Constantia, a village 26 km NEN from Lusaka (distance between both localities ca 7 km). Open woodland and shrubland, 1972 burned in October,

Leop. H. rd. – at the road to Leopards Hill, the height area about 24–26 km ESE of Lusaka with interesting landscape and miombo forests, near the road chiefly burned pastures (fire observed e.g. on the end of September),

Lus.-Chil. – between Lusaka and Chilanga, a small town located 16 km further to S from the first place, near the road,

Lus. env. – Lusaka environment, area between the city and the International Air Port, situated at the distance of ca 17 km to ENE. Savannas (in 1972 burned on September 18), and open woodlands,

Lus.-Kas. – between Lusaka and Kasisi – the village situated at a distance of 22 km to NE. Burned grassland and woodland, fire observed at various places, in 1972 on July15, September 5, and October 9,

Mpun. – Mpunde, a village ca 55 km NW from Kabwe, a city 100 km N of Lusaka. Open woodland, in 1972 fire appear on August 25 and 30,

Mpun.-Kab, the area between Mpunde and Kabwe – see information above,

Mwin. – Mwinilunga – a city ca 460 km NW from Lusaka, near the upper Zambezi river,

Res. Ndola – Forest Reserve 3.2 km W of Ndola, a city about 280 km N from Lusaka, miombo woodland with burning experiments.

The list of pyrophytic species is submitted below according to their adherence to particular plant families, arranged alphabetically in two groups Liliopsida and Magnoliopsida (analogically as in the chapter on pages 18–38); plants and families not mentioned in this chapter are marked by *. In the schedule of localities, abbreviations specified above are used.

Liliopsida (Monocotyledones)

Poaceae. *Brachiaria brizantha*: Kas.-Const., *B. humidicola*: Camp. Eucal., *Cynodon dactylon*: near Kas., Kas.-Const., *Digitaria gazensis*: Camp. Eucal., *D. milanjiana*: Camp. sav., **Eragrostis aspera*: Camp. sav., *E. racemosa*: Camp. Eucal., Camp. sav., Lus.-Kas., **Hyparrhenia cymbaria*: Camp sav., *H. filipendula*: Camp. sav. (dominating grass), **H. rufa*: Camp. sav., **H*. sp.: Camp. Eucal., *Hyperthelia dissoluta*: Camp. Eucal., **Paspalum commersoni*: Camp. Eucal., *Setaria sphacelata*: Lus.-Kas., *Sporobolus pyramidalis*: Camp. Eucal., **Urochloa* sp.: Camp. Eucal.

Cyperaceae. *Abildgaardia filamentosa*: Kas.-Const., *A. hispidula*: Camp. sav., *A. macra*: Kas., Chon R., Lus. env., **Bulbostylis* cfr. *macra*: Chon. R., **Cyperus angolensis*: Leop. H., C. *ciliato-pilosus*: Chon. R., Kas.-Const., *Cyperus margaritaceous* (incl. var. *nduru*):

Fig. 37. Amarylidaceae: *Ammocharis* cfr. *tinneana* on the burned plot near Liempe, about 12 km E of Lusaka, middle of December

Fig. 38. Costaceae: *Costus* cfr. *spectabilis* at Chongwe River near Kasisi, the rainy season, in December

Air P.-Kas., Chon. R., Leop. H., Lus.-Kas., **Fimbrystylis hispidula* subsp. *brachyphylla* Camp. Eucal., *Kyllingiella microcephala*: Air P.-Kas., Camp. Eucal., Camp. sav., Great E. Rd., Scleria bulbifera: Air.P.-Kas.

***Amarylidaceae**. **Ammocharis tinneana*: Lus.-Chil. (Fig. 37).

***Costaceae**: **Costus* cfr. *spectabilis* Chon. R. near Kas. (Fig. 38).

***Iridaceae**. **Gladiolus* sp.: Leop. H. rd. (Fig. 39a–b – Appendix 2).

Liliaceae. **Albuca cfr kirkii*: Chon. R., Kas.-Const., Leop. H. (Fig. 40a – Appendix 2), *Littonia littonioides*: Kas.-Const., **Schizobasis interacta*: Mpun. (Fig. 40b – Appendix 2), **Scilla rigidifolia*: Kaf. N.P.

Magnoliopsida (Dicotyledones)

Acanthaceae. *Blepharis caloneura*: Bonan., *Dicliptera melleri*: Camp. Eucal., **Hypoestes forskalei*: Leop. H. rd., *Justicia elegantula*: Camp. Sav., Bonan., Chon. R., **Nelsonia canescens*: Camp. Eucal. (Fig. 41 – Appendix 2).

Anacardiaceae. *Lannea edulis*: Camp. sav., near Kas., Great. E. Rd., Leop. H. rd.

Annaonaceae. *Annaona stenophylla*: Air P.-Kas., Chis. Res., Chon. R.

Apiaceae. *Diplolophium zambesianum*: Lus. env., Lus.-Kas., Kas.-Const., Leop. H. rd., near Mpun.

Araliaceae. *Cussonioa corbisieri*: Chon. R., Leop. H. rd. Mpun.-Kab.

***Asclepiadaceae**. **Odontostelma welwitschii*: Chis. Res. (Fig. 42a – Appendix 2), **Pachycarpus lanceolatus* Chon Riv. (Fig. 42b, c – Appendix 2).

Asteraceae. *Aspilia pluriseta*: Air P.-Kas., Lus. env., *Dicoma plantaginifolia*: Lus.-Kas., *Elephantopus scaber*: Leop. H. rd., *Launaea nana*: Camp. Eucal., Chon. R., Great E. Rd., Leop. H rd., **Vernonia oligocephala*: Chil.

Boraginaceae. **Tapiphyllum discolor*: Air P.-Kas., Great E. Rd., Kas.-Const., *Trichodesma ambacense* subsp. *hockii*: Camp. Eucal., Camp. sav., Chil.-Chip., Great E. Rd., Leop. H. rd.

Chrysobalanaceae. *Parinari capensis*: Lus. env., Chon. Riv., Kas.-Const., near Mwin.

Combretaceae. *Combretum platypetalum* subsp. *platypetalum*: near Kab., *Terminalia sericea*: Air P.-Kas.

Convolvulaceae. *Astripomea malvacea*: Camp. sav., Lus. env., *Convolvulus sagittatus*: Camp. sav.

Euphorbiaceae. *Euphorbia oatesii*: Camp. sav.

Fabaceae. **Adenodolichos punctatus*: Leop. H., *Albizia glaberrima*: Kas.-Const., *Alysicarpus zeyheri*: Camp. Eucal., Leop. H. rd., **Citisus ciliato-pilosus*: Chon. R., Kas.-Const., *Crotalaria kapirensis*: Lus. env., Kas.-Const., *C. pallidicaulis*: Lus. env., Kas.-Const., **Cryptosepalum maraviense*: Chit. R., Kab.-Mpun., near Mpun (Fig. 43)., **Eriosema psoraleoides*: Camp Eucal., *Indigofera hilaris*: Camp. sav., Lus.-Kas., **Peltophorum africanum* (a tree): Kas.-Const., **Physostigma mesoponticum*: Chon R., **Piliostigma thonningii*:

Camp. Eucal., **Rhynchosia minima*: Great E. Rd., **Sphenostylis marginata* subsp. *erecta*: Leop. H. rd. (Fig. 44 – Appendix 2), **Strychnos* sp.: Kas.-Const., *Tephrosia radicans*: Camp. Eucal., Lus.-Kas., *Vigna antunesii*: Bonan., Leop. H. rd., Chon. R., **V. esculenta*: Leop. H. rd., **V. forskalei*: Leop. H. rd., **V. macrorhyncha*: Kas., **V. pygmaea*: Camp. sav., Kas., **V. unguiculata* subsp. *dekindtiana*: Camp. sav., Chon. R.

*****Geraniaceae**. **Pelargonium luridum*: Leop. H. rd. (Fig. 45 – Appendix 2).

Lamiaceae. **Boecium* sp.: Chil., Leop. H. rd. (Fig. 46a, b – Appendix 2), *Scutellaria schweinfurthii* subsp. *paucifolia*: Kas.

Loganiaceae. *Strychnos* cfr. *cocculoides*: Kas.-Const.

Malvaceae. *Hibiscus rhodanthus*: Camp. Eucal., Camp. sav., Chis. Res., Kas.-Const., Leop. H. rd., Lus. env. and other sites (Fig. 25b – Appendix 2) (cfr. Medwecka-Kornaś 2013).

***Moraceae**. **Dorstenia benguellensis*: near Mpun. (Fig. 46c – Appendix 2).

Ochnaceae. **Ochna* cfr. *angolensis*: Kas. surrounding, *O. leptoclada*: Chita. R., Kab.-Mpun., Leop. H. rd. (Fig. 26a, b – Appendix 2), **O. pulchra*: Chita R.

Passifloraceae. *Adenia goetzei*: Air P.-Kas., **A. lanceolata*: Leop. H. rd., **A. lanceolata* subsp. *scheffleri*: Leop. H. rd.

Fig. 43. Fabaceae: *Cryptosepalum maraviense* – small plant with leaves and flowers; between Kabwe and Mpunde, on the burned plot; end of September

Pedaliaceae. *Sesamum* cfr. *angustifolium*: Kas.-Const.

Periplocaceae. *Ectadiopsis oblongifolia*: near Kas.

***Rosaceae**. **Afrormosia* sp: Kas.-Const.

Rubiaceae. **Canthium crassum*: Kas.-Const., **Cheilanthes multifida*: Chis. Res., **Fadogia odorata*: Chis. Res., Chita R., *Gardenia subacaulis*: Air P.-Kas., Leop. H. rd.(cfr. Medwecka-Kornaś 1980), **Kohania* sp.: Kas.-Const., **Peltophorum africanum*: Kas.-Const., *Psychotria* cfr. *spithamea*: near Kab., Kas.-Const., *Pygmaeothamnus zeyheri*: Air P.-Kas., on the termite hill in burned grassland, *Spermacoce dibrachiata*: Lus.-Kas., **Tapiphyllum discolor*: Air P.-Kas., Kas.-Const., Chon. R., Great E. Rd.

Santalaceae. *Thesium* cfr. *unyikense*: Leop. H. rd.

Scrophulariaceae. *Cycnium adonense* subsp. *camporum*: Chil., **C. tubulosum* subsp. *tubulosum*: Kaf. N. P.

Thunbergiaceae. *Thunbergia* aff. *oblongifolia*: Camp. sav., Leop. H. rd.

Tiliaceae. **Trumfetta geoides*: Chita R., *T. heliocarpa*: Camp. Eucal., Camp. sav., Great. E. Rd., Leop. H. rd.

Turneraceae. *Tricliceras longipedunculatum*: Air P.-Kas. (Fig. 34c – Appendix 2), **Wormskjöldia* sp. Camp. Sav..

Verbenaceae. *Clerodendron pusillum*: Chon. R., *Vitex mombassae*: Chis. Res., Chon. R.

Vitaceae. *Cyphostemma rhodesiae*: Kas.-Const.

Plant observations on the roadsides

It is interesting that some pyrophytic species, growing on the author's studied plots, were found also on the road embankments, especially those graded (levelled) mechanically. In this group the following species can be mentioned e.g. *Hyperthelia dissoluta* Poaceae (1), *Littonia littonioides* Liliaceae (3), *Diplolophium zambesianum* Apiaceae (8), *Lannea nana* and *L. rarifolia* Asteraceae (10), *Trichodesma ambacense* subsp. *hockii* Boraginaceae (11), *Indigofera hilaris* and *Vigna esculenta* Fabaceae (16), *Hibiscus rhodanthus* Malvaceae (20), *Sesamum angustifolium* Pedaliaceae (24), *Gardenia subacaulis*, *Psychotria spithamea* and *Sparmatoce dibrachiata* Rubiaceae (28), *Thunbergia* aff. *oblongifolia* Thunbergiaceae (31), as well as *Triumfetta heliocarpa* Tiliaceae (32). Such occurrence of plants may be interpreted as their advantage over the conditions of the open places, without competition of other species.

Discussion and conclusions

Remarks on the literature

The publications about fire features and their role in nature are very numerous and of a different character. Frequent or regular burning of vegetation has been documented from various regions of the world with seasonal drought, chiefly from Africa, Australia, some parts of Southern and Northern America, and Europe – mostly its Mediterranean regions. To fire-prone vegetation belong various types of savannas, shrub communities (chapparal, fynbos, maquis), dry forests, and even some heaths in Northern Europe. Several of the facts they concern may be compared with the situations ascertained on the burned plots near Lusaka.

The books with descriptions of fire features and their consequences (concerning usually also the savannas) are e.g. "Biogeography and ecology (…)" by Werger (ed. 1978), the "Tropical savannas" of Boulière (1983), the volumes of Dansereau (1957), Daubenmire (1959), De Vos (1975), Knapp (1973), Kozłowski, Ahlgren (eds. 1974) – the last paper with information about Zambia. They are also in the publication of Schnell (1970–1971) related to the former country – Rhodesia. Here, additionally, the volumes of Groves (ed. 1981), Pate, McComb (1981) about Australia, a continent with the important role of the burning of vegetation, should be mentioned. Another author – H. Walter (1973) was dealing with here discussed problems e.g. in the volume about the vegetation on the Earth and other books (e.g. Walter, Breckle, 1991). The publications of Lawson (1985), Numata (ed. 1979), Whelan (1995), White (1983), and the book by Kornaś, Medwecka-Kornaś (2002) quoted in the introductory chapter, as well as above-mentioned paper of Schnell are also noteworthy.

The information about the features of fire and its role in nature may be found in very numerous, detailed publications. Many of them are mentioned in the following chapters and/or in the quoted reviews of other authors, e.g. Bourlière (1983), Bond, Keeley (2005), Baudena et al. (2015), Awuah (2017 – 6 pages of literature) or La Malfa (2018).

Worthy of attention are international conferences (with printed contributions) taking into account the fire problems. Here, one can mention, e.g. the volume of Komarek (ed. 1972a, b) concerning Africa, a paper from a symposium about the fire in tropical biota (Goldamer, 1990), or from the International Conference in Brazil (Solbrig, et al., eds., 1996) – some further information can be found on the Internet.

The features of fire, its impact on the natural environment and vegetation

It is worthy of attention that Africa is called the "fire continent" (e.g. Philips, 1971; Komarek, 1972a, b; Trollope, 1982; Trollope, Trollope, 2010) because over its vast areas this factor is very important; only fire-resistant species can there exist. Zambia is one of the most heavily burnt regions (Caruso, Chandler, 2000). In the data of the author, it is confirmed by a number of localities of pyrophytic plants, mentioned in the chapter concerning the observations beyond the studied plots. The importance of fire was emphasized by many authors, among others by Archibald et al. (2018), who talked over – concerning various regions – the problem: interdependence of climate, vegetation, and fire, as well as ecosystem flammability; here can be mentioned also

Kuhnoholz-Lordat (1938) and Fidelis (2020). The impact of fire on the vegetation is therefore very ancient and important – it "*may influence the structure and dynamics of plant populations and communities*" (e.g., Gagnon et al., 2015) as well as of the whole ecosystems, and change the environment features: soil and air chemical composition, the rise of temperature, burning of plant litter, ash accumulation, etc. The raised temperatures affect plant survival in various ways and may be important for their post-fire development (e.g. Van Wilgen, 2009). Grass fires have usually high rates of speed – there are distinguished "jumping fires" and common in the savannas swiftly passing fires, which can leave some patches of vegetation untouched – it is very profitable for the survival of plants. Fire helps to shape global biome distribution and to maintain the structure and function of fire-prone communities (Bond, Keeley, 2005), first of all, savannas. Descriptions of those facts from Southern Africa (with Zambia) are supplemented by Werger, Coetzee (1978) as well as by Philips (1971, 1974) from Africa, and Schnell (1970, 1971, 1976, 1977) from various regions. The features of fire, important for plant survival, were discussed e.g. by Brandstock et al. (1992) and the meaning of various fire characteristics in many respects – e.g. by Beale et al. (2018), Fidelis (2020), Trollope (1982), and Trollope, Trollope (2010).

The intensity and results of conflagrations depend on various factors, such as wind speed, the character of vegetation, the amount of accumulated dry matter, and – what is especially important – the intervals between successive times of burning and seasonality (Céspedes et al., 2014 ; Miller et al., 2019). Fire occurring near (or at the end) of the dry season (as in the present investigations – cfr. page 10) is for many reasons less harmful to the plants than its impact after the end of this period (e.g. Laris et al., 2016). Soil heating (not measured in the present study) was estimated by several authors. Here, you can mention, e.g. the investigations of Choczyńska, Johnson (2009), who checked some soil features, mainly temperature on the tallgrass prairie in Wisconsin (USA), but their results have however some larger, geographical importance. These authors ascertained that the temperature during conflagrations may rise to several hundred degrees near the ground level, but it decreases rapidly in the uppermost layers of the soil. The temperature lethal for buds of the considered grass species was not found below ca. 2 cm under the ground level. At least 39% of rhizome buds remained below the lethal temperature. Similar information was given by Brandstock, Auld (1995), Gillon (1971), Masson (1948), and Stromgaard (1992) – the last data concerning the miombo woodland.

The secondary effects of fire are no less significant for plants than the direct impact. Fire can stimulate plant flowering (described by various authors and observed in the author's studies), removes the accumulated dry matter, and accelerate nutrient cycling. It can change their concentration in the environment and availability (Garnier, Dajoz, 2001; Lamont, Dovness, 2011), as well as the competitive relations between plant species and the intensity of animal impact. The open burned ground becomes directly accessible for wind, light, and rains. This may highly increase soil erosion, but at the same time, it is greatly favourable to many fire-tolerant and light-demanding species and facilitates both flower pollination and the dispersal of seeds (owing to easier access for wind and insects). The impact of fire on the vegetation was described by numerous authors, e.g. by West (1965) from tropical and subtropical Africa.

Fire is used by farmers to stimulate resprouting of graminoids on the pasturages. Its role is however controversial. Fire may be destructive for the ecosystems not adapted to its impact, e.g. for some coniferous pine forests – such a situation was studied, e.g. in Poland (Central Europe) by Dzwonko et al. (2018). There are however numerous opinions about the positive role of this factor in nature (e.g. Fidelis, Blanco, 2014; Lüttge, 2008), e.g. in the maintenance of fire-prone plant communities (Bond, Keeley, 2005). There are also the opinions that "*Fire suppression has led to the loss of plant species*" and that even periodically burned forests and scrubs (brushwood) are more complex in composition than those unburned (e.g. Naveh, 1975). The practical use of fire, e.g. in pasture management (Overbeck et al., 2005), is an actual problem until now and has found application in the areas destined for animal protection (cfr. page 63). Numerous authors describe the influence of fire on vegetation from tropical and subtropical Africa, e.g. West (1965). A review of the discussed problems here may be found, e.g. in the paper of Kozłowski, Ahlgren ed. (1974) with chapters of various authors concerning features and role of fire. Its role can increase as a result of climate warming, mentioned still at the end of the present paper. Below there is some other, additional information from the large literature.

The importance and characteristics of fire are presented by Cahoon et al. (1992) in Africa and by Walter, Breckle (1991) for the tropics. Effects of fire were described (mainly from the USA) by Malanson (1987), and some general information is provided by Bond, Keane (2017). Bond (2001) wrote e.g. that "*many plants and some animals depend on fire for their continued existence*".

General information about features of fire is contained, e.g. in the publication from East Africa (Burtt et al., 1942), from the Guinean region (Dwomoch, Wimberly, 2017) – the last two mentioned authors reported that investigations about "knowledge of fire" are necessary for understanding its ecological effect. Interesting data – apart from the African continent – are also from Madagascar (Kull, 2004) and Brazil (Bloesh, 1999). The importance of fire season was taken into account, e.g. by Cespedes et al. (2014) in the Mediterranean region. Post-fire plant germination was taken into account, e.g. by Brandstock, Auld (1995), Brown (1993), Gill (1981), Buhk et al. (2007), Van Wilgen (2009), Van Wilgen et al. (1985), and more recently by Leonard et al. (2018). The last authors discussed broadly the mentioned problems concerning Erica species in South Africa and called attention, e.g. to the differences in germination between pyrophytic species and others determined as "pyrofuges".

Adaptations of plants to survive fires and species defined as "seeders" or "resprouters" were described, e.g. by Buhk et al. (2007) who were dealing also with plant community resilience, and by Driscoll et al. (2010) as well as Gill (1981). Attention to fire-resistant species was paid by Exell, Stace (1972), West (1972), and Van Wilgen (2009). Fire impact was studied also in the relation to the selected species, e.g. of the genus *Erica* (information of Leonard et al. l.c. – above), *Combretum* (Exel, Stace l.c. – as above), and members of the family Proteaceae (by several authors).

Various problems connected with those topics are presented by Bond, Keane (2017), Garnier, Dajoz (2001), Lamont, Downes ed. (2011) – mainly from the USA – by Malanson (1987), as well as from various continents by Goldamer ed. (1990). Impact of fire on plant diversity was described by Brockington (1961, part III) and concerning south African grasslands by Uys et al. (2004). Practical use of fire and its role in limiting the development of climax vegetation, chiefly forest formations, was discussed e.g. by West (1972). A large review of the literature concerning the history and importance of fire was published relatively recently by Baudena et al. (2015) and Stavi (2019).

Occurrence of savannas and their connection with fire

The mentioned type of vegetation (being the object of the author's studies) forms a particular aspect of landscapes and covers about 1/6 of the Earth's surface (Dantas, Pausas, 2013; Exel, Stace, 1972). It plays also an important role in the existence of many peoples and some animals (La Malfa, 2018). Savannas are however only in small part natural, connected with special site conditions (e.g. Belsky, 1990) – they are maintained chiefly in the places of former forests and shrublands, eliminated by fire impact. Such statements are confirmed by numerous observations (and field experiments) described, e.g. by Brockington (1960, 1961), Lüttge (2008), Walter, Breckle (1991), who presented information from various parts of the Earth. Worthy of attention are data of Schnell (1971) from the tropics, Burtt et al. (1942), Vesey-Fitz Gerald (1963), Cuni-Sanchez et al. (2016), D' Onofrio et al. (2017), and Knapp (1973) from Africa, Krohmer et al. (2012), La Malfa (2018) from Kenya, Ribeiro et al. (2019) from Mozambique, as well as Bourlière (1983) from Zambia.The authors Frost, Robertson and Medina, described very broadly the problems discussed here in a booklet of Walker (1987). Dealing with them was also undertaken by West (1965), as well as Abreu et al. (2017) in the tropical parts of Brazil, and Silva et al. (1990) in Venezuela. Several authors, e.g. Dantas, Pausas (2013) stressed that "*fire plays a fundamental role in the maintenance of savannas*". Their old history, mainly in the Miocene time, was described by Bond (2015) based on fossil charcoal.

Abreu et al. (2017) described the value of savannas maintenance and conditions needed for it (also fire). The role of fire was defined also by Baudena et al. (2015), Vogl (1974) and Case, Staver (2017) who wrote "*fire decreases tree density in savanna*" and " *fires are management tool for preventing wood encroachment*". Savannas are classified as fire dependent system (Devine et al., 2017) – those authors ascertained also that "*fire (and herbivory) can reduce woody encroachment which decreases landscape and vegetation heterogeneity*" – it is the opinion of several authors and object of various studies, e.g. by Carlsson (2005).

Effects of different burning regimes on the discussed type of vegetation are described, e.g. by Stavi (2019), Uys et al. (2004), and – based on experiments – by Mbangilwa et al. (2020). Worthy of attention are several theoretical models of savanna function, included in some publications (e.g. Belsky, 1990). The temporal and spatial distribution of savanna fires over the African continent is nowadays determined by satellite imagery (Cahoon et al., 1992).

The importance of savannas, their types, and definitions were described, e.g. by Campbell (2013), who wrote: "*Savanna is the most common tropical landscape unit*". A similar opinion was published by Huntley, Walker (ed. 1982), Dantas, Pausas (2013). The review of problems: fire and vegetation – savannas (and forests) may be found in the book of Numata (ed. 1979). The structure and function of tropical savannas were described: e.g. by Lamote (1975), Menaut – in the book of Bourlière (1983), Walter (1971, 1973), and Walter, Breckle (1986). Savannas, as a result of fire and human activity, were presented also, apart from the above-mentioned authors, e.g. by Swaine (1992) from Ghana and Trapnell (1959) from Zambia.

The fire as the management tool in savannas was discussed by Awuach (2017) and the problem of how pyro-diversity affects biodiversity – by Beale et al. (2018). A similar role of fire was dealt with by Cole (1974) based on the observations in Sierra Leone (West Africa) and De Vos (1975), who defined African savannas as ecosystems influenced by fire; similar is the opinion of Montgomery and Askew (1983). According to some former publications, Mutch (1970) wrote: "*grasslands and savannas might not exist at all without fire*". Dantas, Pausas (2013) also wrote that fire played a fundamental role in the maintenance of savannas. Shaffer (2010) called attention to the fact that this factor was used in the management of savanna landscapes. Some fire problems concerning savannas (and steppes) from various geographical regions were described by Adam, Jaeger (1976), and Tishkov (2010). The present author discussed the influence of fire on the savanna vegetation in a separate publication (Medwecka-Kornaś, 1993).

The mutual, spatial relation between savanna and forest, was investigated and described by several scientists. Borders between the both mentioned formation were described by Adam, Jaeger (1976) as well as Beale et al. (2018), Fournier (1983), and Hoffman, Orthen (2003). Here, e.g. the opinion of Schmidt (1973) based on the observations from Lamto Reserve (Ivory Coast) may be quoted – as soon as bush fires are terminated, there occur changes of savannas in favour of forest. There is also a statement (from West Africa) that without fire the savannas would have supported forest vegetation and that savannas were therefore the result of human activity (Swaine, 1992) – a similar opinion of Trapnel (1959) from Zambia was mentioned above. Woody plants and grasses as competitors are described by Walter, Breckle (1986).

The practical meaning of fire as the management tool in tropical savannas was talked over, e.g. by Awuah (2017) and on the base of some ethnographical investigations in the rural communities of Mozambique – by Shaffer (2010). There is an opinion that savannas are a "*valuable tool in the management of field for livestock production and wildlife management*" (Huntley, Walker, ed. 1982). Worthy of attention are various experiments made for estimation of fire effects upon the tropical savannas described, e.g. by Pelegrini et al. (2015). Theoretical models concerning the fire impact on savannas and the tree-grass dynamics were presented, among others, by Belsky (1990) and Uys et al. (2004).

Adaptations of plants to survival fire, their regeneration and seasonal development

It is very important that "*over vast areas of Africa only fire-resistant species can exist*" (Exell, Stace, 1972). Numerous plants can survive fires owing to their various features. The aerial parts of non-woody species are usually burned at 1–2 cm above the ground. The basal buds, and some other parts of plants, e.g. the creeping stems and the seed deposited on the soil surface, enable them to survive conflagrations. For herbaceous taxa, the regeneration from seeds (eventually with fruits) surviving on the soil or deeper, is the most important. Various adaptations of plants to fire are discussed, e.g. by Bond, Keane (2017). Worthy of attention is e.g. the statement: "*Buds buried in the soil or protected by a base of tillers and leaf sheaths, are fire-resistant*" (Boulière, 1983 – information from the savannas on Ivory Coast). The mentioned author described the underground parts of plants and noted that "*geophytic and hemicryptophytic forbs, in general, are sprouting after a fire*" (as was also observed in the own studies of the author). The heavy fire can however destroy the buds on the soil surface, then the regeneration starts in its deeper layers – from underground plant parts (e.g., Bond, Keeley, 2005).

Many authors paid special attention to the features of grasses as the most important components of savannah vegetation. The terminal buds in the centre of their tussocks are protected enough and the regeneration can occur from there and also from the below-ground plant parts (Linder, Ellis, 1990; Lüttge, 2008; Van Wilgen, 2009). Many species in the discussed group (and not only in it) developed the "knotty tillering base" (mentioned in the chapter with plant descriptions). This fact is different from the features of grasses in shrubby fynbos formation in Cape Province (Van Wilgen et al., 1985). The main difference between savanna, e.g. near Lusaka, and fynbos is the lack of geophytes among the grasses in the first type of vegetation and their presence in the second one – in investigations carried out near Lusaka, it was also the difference between grasses and other species.

In the sprouting of plant shoots and leaves after the destruction by fire, the parts in the soil provide the necessary resources for the renovation (Bond, Keeley, 2005). Shallow geophytes can resprout readily after a burn (Overbeck et al., 2005, l.c.; Overback, Pfedenhauer, 2007; Lamont, Downes, 2011) and are called "postfire resprouts", which means vegetative recovery after fire. The species in the plots of vegetation described here represented chiefly this group. The others, called "seeders", regenerating mostly or simultaneously from seeds, were not numerous, as well as the seedlings (cfr. Pate et al., 1991).

Observations near Lusaka can lead to similar conclusions as in other similar investigations. Thus, Overbeck et al. (2005) wrote "*we presume that resprouting has a substantially higher importance than seed germination for post-fire regeneration in S-Brazilian grassland*". Resprouting from basal buds was described, e.g. by Dantas, Pausas (2013), and a cycle of plant development after fire – by Fournier (1982) from West Africa and by Fidelis, Blanco (2014) concerning above-mentioned subtropical Brazilian grasslands. Dantas, Pausas (2013) called attention to the fact that several species might grow enough during the inter-fire period (as was observed by the present author near Lusaka, mainly in the rainy season). This fact is consistent with the opinion that "*geophytes usually escape the fire as it occurs when they have reverted to a dormant rhizome, corn, bulb or tuber in the dry season*" (Overbeck, Pfadenhauer, 2007). In the descriptions of the regeneration strategies of plants after conflagrations, there are distinguished post-fire resprouts (or sprouts) and post-fire seeders – those terms are explained and discussed, e.g. by Buhk et al. (2007) and Fournier (1982, 1983).

In relation to woody plants, Overbeck and Pfadenhauer (2007 l.c.) noticed that they escaped the fire by early high growth – dank strategy or early bark growth – the corky strategy; resprouting from basal buds (observed also in the studied plots described here) is possible. In the seasonal development (phenology) of pyrophytic plants, their development soon after the fire is the most significant and interesting. The grasses have then new leaves (which is important for several animals) and numerous plants develop flowers. Such observations from plots near Lusaka have confirmation in papers from different regions, e.g. South Africa as well as Australia (Lamont, Dovness, 2011) and subtropical grasslands in Brazil (Fidelis, Blanco, 2014) and Madagascar (Kull, 2004).

Usefulness of Raunkiaer's classification – selected problems and opinions

The mentioned method of plant features description seems to be less adequate concerning here discussed part of Africa, than in Europe, where it was established. Such a statement results from the high plasticity of the forms of plant life in the tropics and others existing there harmful influences (dryness, fire, and impact of big animals) instead of low winter temperatures. Despite this, the mentioned classification has been universally used (cfr. information of Hopkins, 1977) and is irreplaceable. This system was adapted, e.g. in South Africa (Van Rooyen et al., 1990), in the Mountains of Sierra Leone (West Africa), where detailed studies connected with plant underground parts were performed (Cole, 1974). It was adapted too in the region of Tombouctou (NW Africa) by Hagerup (1930). Chapman, Crow (1981) wrote about its usefulness to pyrophytic plants. The discussed classification was used also for a distinction of Paleotropis and Holarctis in the area of North Africa and Europe, after the presence of species representing the particular Raunkiaer's forms (Frankenberg, 1978).

There are also some interesting suggestions concerning the adaptations of discussed system to the description of tropical grasses, e.g. proposal for additional distinction, apart from morphological types, some complementary definitions: species cespiteux, rhizomateux, and stolonifere. The combined definition of "biomorphological types" would be, e.g. hemicryptophytes cespiteux or stolonifère (Descoings, 1975a, b). The modifications proposed by other authors are quoted by Van Rooyen et al. (1990). Worthy attention is their opinion resulting from the investigations in South Africa that "*in spite of the criticism that has already been expressed against Raunkiaer's life form system, it is the only one that has been applied to a variety of vegetation types and still enjoys a certain degree of universal acceptance*". There is also the statement of above-mentioned Descoings that "*the classic biological types of Raunkiaer (1905; 1934) form a very important structural element*" (in vegetation description). Some general discussions concerning the value of Raunkiaer's conception, its comparison with other methods of ecological plant classification, and the possibility of use in the tropics were published by Lebrun (1966) – this discussion can also refer to the vegetation in the savannah plots near Lusaka.

Remarks on the evolution of pyrophytes

The particular feature of pyrophytes – their resistance to fire – is connected with their origin and evolution. This fact should not be omitted here but is in some part controversial. In relation to savanna vegetation, the pressure of other stress factors: seasonal drought, excessive heat, poverty of the soil, and animal overgrazing should also be taken into consideration (White, 1976) and on the margins of South Africa also the frost is relevant (Pausas et al., 2017). There is, however, no reason to doubt the evolutionary importance of fire because its impact upon vegetation has not lasted (owing to natural lighting) shorter than those of the other environmental factors and there are several features of plants distinctly connected with conflagration (Bond, Keeley, 2005, Pausas, Keeley, 2009; Bond, 2015; Archibald et al., 2018 – a large description and literature with consideration of history). Here, you can mention e.g. the rhythm in the pyrophytes flowering (observed also near Lusaka), which depends much more upon the time of burning, than upon the season of the year (cfr. Lamont, Downes, 2011), the existence of underground organs not damaged during conflagrations enabling the plant regenerations and several others features in the group of trees, making their survival possible.

Among the pyrophytic plants, the most interesting from the ecological and evolutionary point of view, are the "underground trees" – the geoxylic suffrutices (geoxyles), known chiefly from South Africa and in similar form from the caatinga in Brazil. Their distinctive features may be understood as fire-induced modifications of the ancestral forms which had the normal tree habit (cfr. e.g. Medwecka-Kornaś, 1980). Those features are taken into consideration e.g. by Exell, Stace (1972) who wrote, based on detailed studies about geoxylic suffrutices from the family Combretaceae (13) "*the evolutionary pressure (of fire) seems to have been in the direction of a rapid change in habit, accompanied by little change in the morphology of leaves, flowers, and fruits*". More recently Lamont et al. (2017) wrote: "*many geoxyles have had a long association with fire that has promoted evolutionary changes in their sexual reproduction, phenology as well as in their vegetative recovery*". Numerous plants from the discussed group have relatives among trees growing in places that normally are not submitted to fires, e.g. riverside forests. Couples of such ecologically vicarious taxa (defined by Jan Kornaś) are present in Zambia, e.g.

Family no.	Suffrutices	Trees
9	*Cussonia corbisieri*	*C. arborea*
28	*Gardenia subacaulis*	*G. jovis-tonantis*
22	*Ochna manikensis*	*O. pulchra*
12	*Parinari capensis*	*P. curatellifolia*
21	*Syzygium guinense* subsp. *huilense*	*S. guinense* subsp. *guinense*

The observations that some trees may develop green offsets from the very strong woody underground parts are important. When burning is frequently repeated these offsets significantly resemble the growth form of suffrutices. This seems to indicate the way in which the hereditary fixed form of a true geoxylic suffrutices has been developed.

It is noteworthy that the pyrophytes forming fire-prone shrublands which can even stimulate fires, are known from various regions (Mutch, 1970; Zedler, 1995; Bond, Keeley, 2005). According to some opinions such pyrophytic plant formations are considered as "Fire climax" – Trapnell's definition from 1933, accepted later by other authors, e.g. Brockington (1961), Naveh (1975). In a sense of the classical definition of Clements (1916), it is rather a subclimax because the vegetation maintained by burning will be changed upon the termination of this impact. Thus, its durability is so important.

Additional opinions can also be cited here. The authors Lamont and Downes (2011) pay the attention to "*the role of fire in directing the evolution traits in fire-prone regions*" and Christensen (1985) wrote that in the shrub-dominated ecosystem investigated by him "*fires (…) have been selective forces in the evolution of plant form and life history*".

Also worthy of attention is the note of Pausas, Keeley (2009) under the title: *The role of fire in the history of life*" – those authors called attention to the strong ecological and evolutionary consequences of this factor and its "*historical perspective from the origin of land plants to the present*". A vast review of literature about fire and evolution is published by Archibald et al. (2018) and Ribeiro et al. (2019).

Plant communities in savanna areas – suggestion for the establishment of a new association

In the numerous existing descriptions of African savannas, mostly their generally defined formations are taken into account (Aubreville, 1965; Bourlière, 1983). There are however also some studies, carried out according to the European method of Braun-Blanquet, similarly to the present work. Here, the opinion of Schmidt (1985) – the author of a publication from Tanzania, may be cited: "*the phytosociological method is much more laborious, but yields more precise and more detailed information and data too*". Plant associations with their higher phytosociological units, the lists of species from different parts of Africa (with some, but not numerous species in common with plots near Lusaka) may be found in the publication of Werger, Goetze (1978). As an example of a phytosociological approach worth quoting is, e.g. the book of Numata (ed. 1979) and the publication of Schmitz (1963) from Katanga (Kongo), with the distinction of the class *Hyparrhenietea* containing "groupements savannicoles", and other, more recent studies of Mandago, Kayumba (1996), with phytosociological records of communities – these included the class *Hymenocardietea* and their lower units. Knapp (1973) described plant associations from the dry savannas in Africa, and Leistner with Werger (1973) published the surveys from Kalahari Gemsbok National Park with information about the way of work, plant associations, and phytosociological tables – which are also quoted by Werger, Coetzee (1978).

According to the methods discussed here, Schmidt (1973) described savanna of Lamto Reserve (Ivory Coast – Elfenbeinküste) and Bouxin (1975) savannas in Rwanda, in Akagera Park. Some species occur there, such as: *Hyperthelia dissoluta*, *Hyparrhenia filipendula* as well as – these species are common with vegetation near Luaka. The associations in that area cannot, however, be identified with plots described by the present author. Worthy of attention data and conclusions are contained in the phytosociological study of Schmidt (1985) from the Serengeti N.P. (Tanzania). This author found some grass species: *Brachiaria dictyoneura*, *Eragrostis racemosa*, *Hyparrhenia dissoluta*, *H. filipendula*, and other plant genera common with plots near Lusaka. The publication of Van der Meulen (1979) concerning South Africa, with a description of the phytosociological method of investigations, plant associations, and the consideration of fire factor is also very significant. Apart from the mentioned studies, Coetze et al. (1976) conducted the investigations on the selected plots of burned tree savanna and grasslands in Nylsvley Nature Reserve, situated north of Pretoria, where the incidental fires occur. Those authors distinguished several plant communities, with their lower units. In some of them the species common with plots near Lusaka, e.g. *Trachypogon spicatus* or *Eragrostis racemosa* were found. Generally, the vegetation was different in this place and the phytosociological units from there cannot be joined together with plots of plant community described here. Such statement concerns also the phytosociological records and tables with information about the meadows and savannas on the Monts Nimba in Central Africa published by Schnell (1987), as well as with data from Sahara (Kaabeche, Gharzouli, 1994), Mt. Kilimanjaro (Beck et al., 1986) and Afroalpine plant communities on Mt. Kenya (Rehder et al., 1988). The classification of grassy formations as types of vegetation, based on the structure of vegetation, differs from the phytosociological concepts discussed here (Descoings, 1975a, b).

Information about plant communities quite similar in composition to vegetation on the plots near Lusaka was not found. Therefore it seems to be proper to distinguish the type of vegetation (described in the present paper) as a new association. The name *Hyparrhenio-Gardenietum* is proposed for it, in reference to two species with an important role (dominating) in its plots belonging to the already described class *Hyparrhenietea* (Schnell, 1987). In all probability, a large part of the burned savannas, at least in Zambia, could be included to this new phytosociological unit. Classified here should be (as a separate sub-association) the plots of open, often burned forests "miombo" with the participation of the same grasses in the herb layer and the dominating trees from the genus *Brachystegia* and *Julbernardia*. However, in the described new unit, further investigations with the establishment of characteristic species are required.

Practical use of fire in nature conservation, final remarks and conclusion

Apart from the traditional use of fire, the relatively new conceptions of its application in nature conservation are worthy of attention (cfr. Kozłowski, Ahlgren, 1974; Lawson, 1985). Those ideas concern a high degree of Africa – its nature reserves and national parks. The main aim is to maintain the savannas and their open landscapes, important to visitors as well as some animals, and to protect the green pastures, developed after conflagrations for their herbivorous. Attention should also be paid to the problem: adaptation of pyro-diversity for biodiversity conservation (Parr, Andersen, 2006).

There are already numerous studies and publications about the problem of fire use in protected areas. They concern the various national parks in Tanzania, Uganda, Rhodesia (Komarek, 1972a), the Akagera N.P. in Rwanda (Bouxin, 1975), Biguar N.P. in Angola (Caterino et al., 2020), Limpopo N.P. in Mozambique (Ribeiro et al., 2019), Mole N.P. in Ghana (Awuah, 2017), South African Savanna Park System and particularly the largest Kruger N.P. with their existing experiments and already constantly adopted the use of fire (Caruso, Chandler, 2000; Bond, Archibald, 2003; Driscoll et al., 2010). There is also similar information from Lamto Reserve in Ivory Coast (Schmidt, 1973), Madikwe Game Reserve (Caruso, Chandler l.c.), and Nylsvley National Reserve in Transvaal, near Pretoria (Coetze et al., 1976), as well as from Madagascar (Bloesh, 1999). Burning should be based however on the ecological criteria and controlled, as stressed e.g. by Gagnon et al. (2015) or Gillon (1983). Other authors – Caterino et al. (2020), wrote that documentation of burned areas helped to "*(…) define conservation priorities and management strategies*".

The already existing problem of climate change, i.e. warming cannot be omitted. It must stimulate the fire occurrence and its impact on the vegetation (cfr. Baudena et al., 2015; Bond, Keane, 2017; Cuni-Sanchez et al., 2016; Mbangilwa et al., 2020). This mentioned problem was discussed, e.g. during the international conference with information of Solbrig et al. (1996).

It is generally considered that for the maintenance of particular species in the given area (and in consequence the adequate plant communities as well as the whole ecosystems), the knowledge of their features is needed. It concerns to a high degree the areas with fire occurrence and the pyrophytes. Such knowledge is also important in the strategy of nature conservation mentioned above. As wrote Driscoll et al. (2010, l.c.): "*knowing how species respond to fire regimes is essential for ecologically sustainable management*". For those reasons, the author hopes that this work including fire and plants descriptions will have not only theoretical but also practical value.

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Conflict of interest

The author declares no conflict of interest related to this publication.

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Tab. 3. Phytosociological records on the studied plots (for grasses see Tab. 2); * degree of constancy on one plot: no 1 or 2

Family no.	Plot location	1–10 Lusaka-Kasisi										1'–8' Kasisi-Bonamza								Constancy
	Number of record	1	2	3	4	5	6	7	8	9	10	1'	2'	3'	4'	5'	6'	7'	8'	
	Day	30	5	18	24	30	4	27	17	21	28	9	24	30	4	24	1	25	29	
	Month	VIII	IX	IX	X	XI	I	I	II	III	IV	X	X	XI	I	III	IV	V	VII	
	Year	1972	1972	1972	1972	1972	1973	1973	1973	1973	1973	1972	1972	1972	1973	1973	1973	1973	1973	
	Vegetation coverage [%]	30	30	40	45	50	65	70	90	90	95	45	45	50	60	95	95	95	95	
	Trees and shrubs layer																			
26	*Securidaca longipedunculata*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	+	V
13	*Terminalia sericea*	+	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	V*
35	*Cyphostemma rhodesiae*	.	.	.	+	+	+	+	+	+	+.2	+	+	+	+	+	+	+	+	V
34	*Vitex* cfr. *mombassae*	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	V
17	*Psorospermum baumii*	.	.	.	+	+	1.1	+	+	+	+	+	+	+	+	+	+	+	.	IV
16	*Desmodium velutinum*	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	IV
16	*Acacia* cfr. *pilispina*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	V*
16	*Albizia* cfr. *glaberrima*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	V*
16	*Dichrostachys cinerea*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	V*
19	*Strychnos* cfr. *cocculoides*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	V*
16	*Crotalaria pallidicaukis*	.	.	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	II
16	*Erythrina abyssinica*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	II*
	Herbaceous species layer																			
11	*Trichodesma ambacense*	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.2	1.2	2.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	.	V
32	*Triumfetta heliocarpa*	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.1	1.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2	.	V

7	*Annona stenophylla*	+	1.1	+	1.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.1	.	V
16	*Indigofera hilaris*	2.1	1.1	2.1	2.1	2.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	+	+	+	.	.	V
5	*Dicliptera melleri*	1.1	1.1	2.1	1.1	1.1	1.1	1.1	+	+	+	2.2	2.2	2.2	1.1	1.1	+	+	+	V
10	*Aspilia pluriseta*	+	+	+	2.1	2.2	2.2	2.2	2.2	2.2	2.2	+	2.1	2.1	2.1	2.1	1.1	1.1	.	V
6	*Lannea edulis*	+	+.2	+	+.2	+	1.2	1.2	1.2	1.2	1.2	1.2	1.2	2.2	2.2	2.2	2.2	+	.	V
28	*Fadogia cienkowskii*	.	.	+	2.1	2.1	2.2	2.2	1.2	1.2	1.2	2.2	2.2	2.2	2.2	2.2	2.2	1.2	.	V
18	*Scutellaria schweinfurthii*	+	1.1	+	1.1	1.1	1.1	1.1	1.1	+	+	+	+	+	1.1	1.1	+	+	+	V
20	*Hibiscus rhodanthus*	2.1	1.1	2.1	+	+	1.1	+	+	+	+	+	+	+	+	+	+	+	+	V
8	*Diplolophium zambezianum*	+	+	+	+	+	+	1.1	1.1	1.1	1.1	+	+	+	1.2	2.2	2.2	2.2	2.2	V
15	*Euphorbia* cfr. *oatesii*	+	+	+	+	+	+	1.1	1.1	1.1	+	+	+	+	+	1.1	1.1	+	.	V
16	*Tephrosia radicans*	+	+	+	+	+	+	1.1	1.1	1.1	1.2	+.2	.	.	.	+	+	+	+	V
14	*Astripomea malvacea*	+	+	+	+	+	+	+	+	+	+	1.2	1.2	1.2	1.2	1.2	1.2	+	.	V
28	*Gardenia subacaulis*	+	+	+	.	+	+	+	+	+	.	2.1	2.2	2.1	3.2	3.2	2.3	2.3	2.3	V
28	*Pygmaeotamnus zeyheri*	+	+	+	+	+	+	.	.	.	.	+	+.2	1.1	1.1	.	1.1	1.1	1.2	IV
31	*Thunbergia.oblongifolia*	.	+	+	+	+	+	+	+	+	+.2	1.1	1.1	1.1	1.1	+	.	.	.	IV
33	*Tricliceras longipedunculatum*	.	.	+	+	.	.	.	.	.	.	+	+	1.1	1.1	1.1	+	+	+	III
24	*Sesamum angustifolium*	.	.	.	+	+	+	+	+	1.1	1.1	+	+	+	+	1.2	1.2	1.2	+	V
34	*Vitex cfr. mombassae*	.	.	.	+	+	+	+	+	+	.	+	+	+	+	+	+	+	+	IV
35	*Cyphostemma rhodesiae*	.	.	.	+	+	+	+	+	+	+.2	+	+	+	+	+	+	+	.	IV
16	*Crotalartia rhodesiae*	+	+	+	.	.	+.2	+	+	+	+	.	.	.	.	.	+	+	+	IV
5	*Blepharis caloneura*	.	.	.	+	.	.	.	.	.	.	+	+	+	+	+	+	+	.	III
27	*Clematopsis scabiosifolia*	.	.	.	.	.	.	+	+	+	+	.	.	.	.	+	.	.	.	II

12	*Parinari capensis*	+	+	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	III
10	*Dicoma plantaginifolia*	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
2	*Cyperus margaritaceous*	.	.	.	+	+	+	.	.	.	.	.	.	+	+	.	.	.	.	II
34	*Clerodendron pusillum*	+	+	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	II
22	*Ochna leptoclada*	+	+.2	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	II
16	*Crotalaria kapirensis*	.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	II
3	*Gloriosa superba*	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	+	.	.	II
4	*Eulophia* cfr. *pyrophila*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	II
5	*Justicia elegantula*	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	II
16	*Alysicarpus zeyheri*	.	.	+	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	II
13	*Ipomea barteri*	.	.	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	II*
18	*Leucas* cfr. *nyassae*	.	1.1	.	1.1	1.1	1.1	1.2	1.1	1.1	1.2	.	.	.	.	.	.	.	.	V*
13	*Combretum platypetalum*	+	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	V*
14	*Convolvulus sagittatus*	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	III*
16	*Vigna antunesii*	.	.	.	.	.	.	.	.	.	.	1.1	+	1.1	1.1	1.2	1.2	1.2	1.2	V*
29	*Thesium unyikense*	.	.	.	.	.	.	.	.	.	.	1.2	1.2	1.2	1.2	1.2	.	.	.	IV*
16	*Indigofera vicioides*	.	.	.	.	.	.	.	.	.	.	1.2	1.2	1.1	1.1	+	+	+	+	V*
25	*Ectadiopsis oblongifolia*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	V*
28	*Psychotria spithamea*	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	1.2	IV*
10	*Pleiotaxis eximia*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	IV*
23	*Adenia goetzei*	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	III*
9	*Cussonia corbisieri*	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	III*

Tab. 5. Phenological phases of selected plant species from the two studied plots and some other localities; family numbering according to the chapter "*List of species (...)*"

No. of family	Names of plants	Duration of the rainy season/ Months of observations											
		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII
1	*Hyparhenia filipendula*			●▼	●▼	●▼	●▼	●▼	●▽	▽	▽		
1	*Setaria sphacelata*						●▼	●▼	▼	▽			
2	*Abildgaardia hispidula*				●▼	●▼	●▼	▼	▽	▽			
2	*Cyperus margaritaceous*				●▼	●▼	●▼						
3	*Gloriosa superba*	●	●▼	▽			●						
3	*Littonia littonioides*				●	●	●▼	●▼		●	▼		
5	*Dicliptera melleri*	●	●	●▼	●▼	●▼	●	▼		●			
6	*Lannea edulis*	●	●▼	●▼	●▼	●▼	●▼	▽		●			
7	*Annona stenophylla*	●	●	●▼	●▼	●▼	●▼	▼	▽	▽			
8	*Diplolophium zambesianum*	●	●	●▼	▼	▼	▽						
10	*Aspilia pluriseta*	●	●▼	●▼	●▼	●▼	●▼	▼	▽	▽			
10	*Launaea nana*	●	●▼	●▼	▽								
11	*Trichodesma ambacense*	●	●▼	●▽	●▽								
12	*Parinari capensis*		●▼	●▼	●▼	▼	▼	▽	▽	▽			
14	*Astripomea malvacea*	●	●▼	●▼	●▼		●	●		●	●		●
16	*Crotalaria rhodesiae*	●	●▼				●▼	●▼	●▼	▽			
16	*Desmodium velutinum*					●▼	●▼	●▼	●▼	▽	▽	▽	
16	*Indigofera hilaris*	●▼	●▼	●▽	●▽				●	●	●		
16	*Tephrosia radicansi*	●▼	●▼					●▼	●▼	▼			
18	*Scutellaria schweinfurthii*	●	●▼	●▼	●▼								
20	*Hibiscus rhodanthus*	●	●▼	●▼	●▼	▼	▽			●	●▼	●▽	▽
25	*Ectadiopsis oblongifolia*				●▼	●▼	●▼	▽	▽	▽			
28	*Fadogia cienkowski*		●▼	●▼	●▼	▼	▼	●▼	▼	▼			
28	*Gardenia subacaulis*		●▼	▼	▼		●▼	●▼	▼	▼			
28	*Pygmaeothamnus zeyheri*	●	●▼	●▼	●▼	●▼	●▼	▼	▼				
29	*Thesium unyikense*			●▼	●▼	●▼	●▼	●▼					
31	*Thunbergia oblongifolia*	●	●▼	●▼	●▼	▽	▽				●	●▼	▽
32	*Triumfetta heliocarpa*	●	●▼	●▼	●▼	●▼	▽						
33	*Tricliceras longipedunculatum*	●	●▼	●▼	●▼	●▼	●▼	●▼	●▼	▽			
34	*Vitex mombassae*			●	●	▼	▼						

Explanations: ● buds and flowers, ▼ fruits, ▽ phase after dissemination

Appendix 2

Fig. 7. Poaceae: *Brachiaria humidicola*, stolons with sprouts in the nodes, February

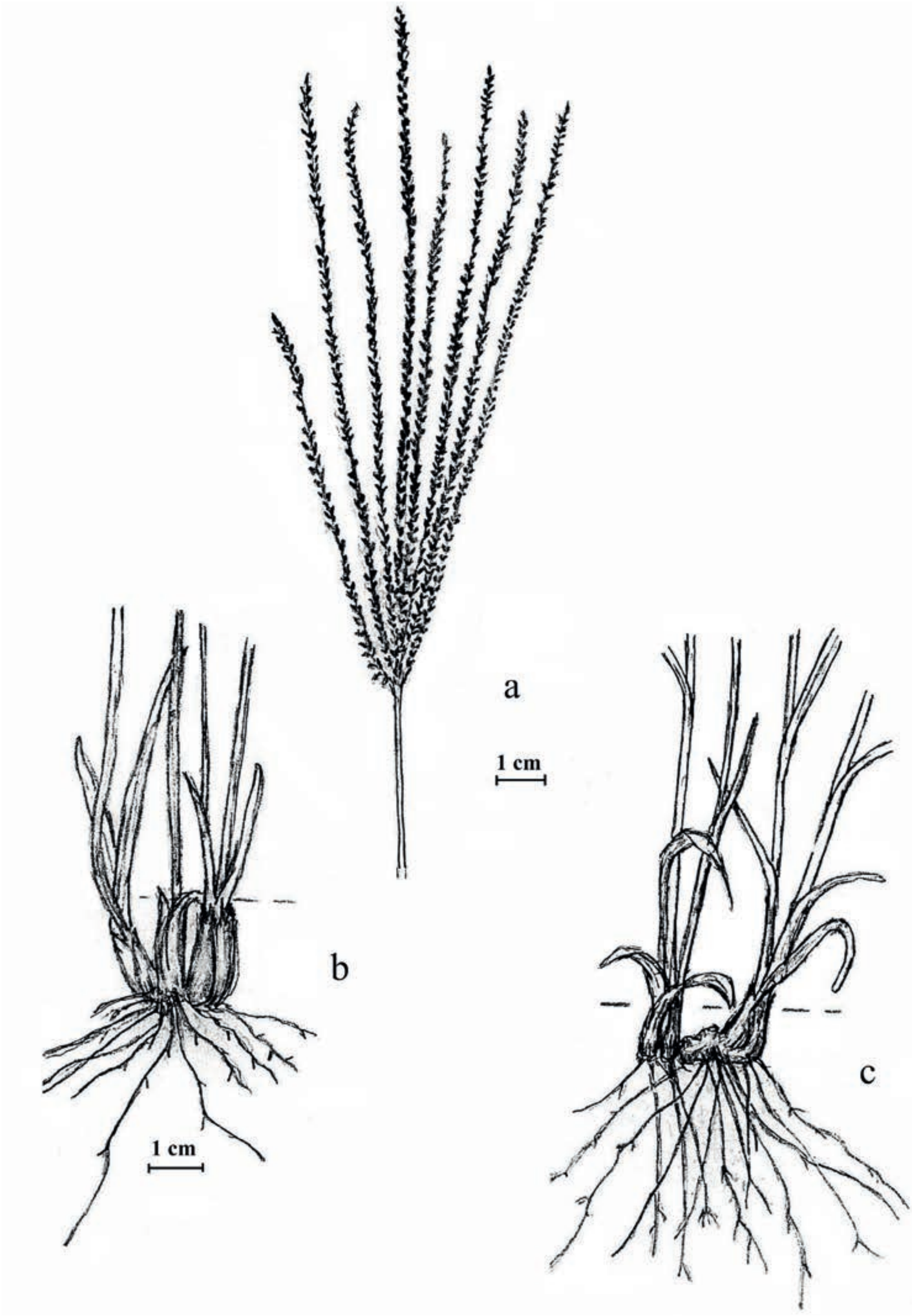

Fig. 8. Poaceae: *Digitaria gazensis*, inflorescence (a), underground parts (b, c), January

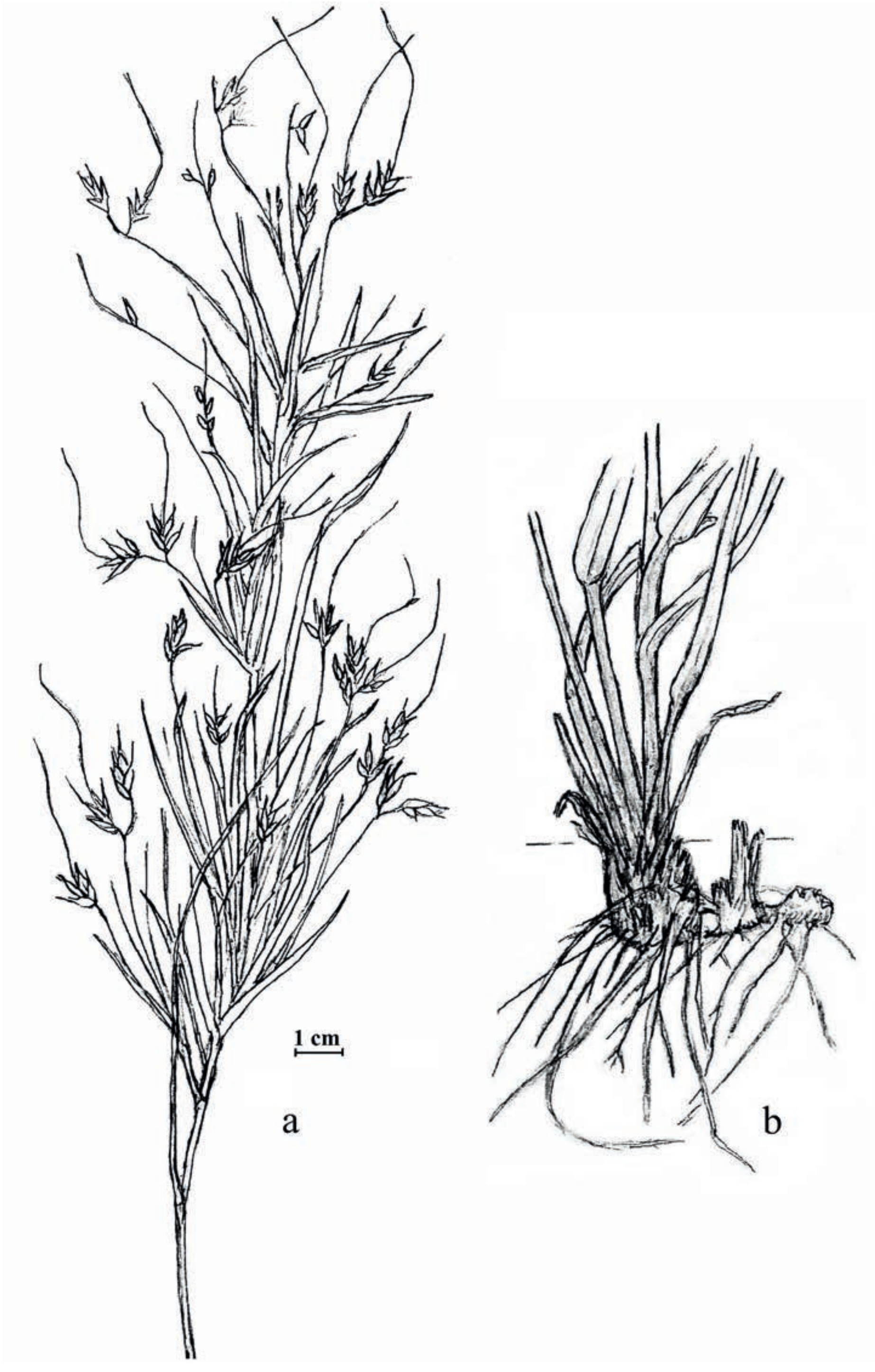

Fig. 9. Poaceae: *Hyparrhenia filipendula*, inflorescence (a), underground part (b), February

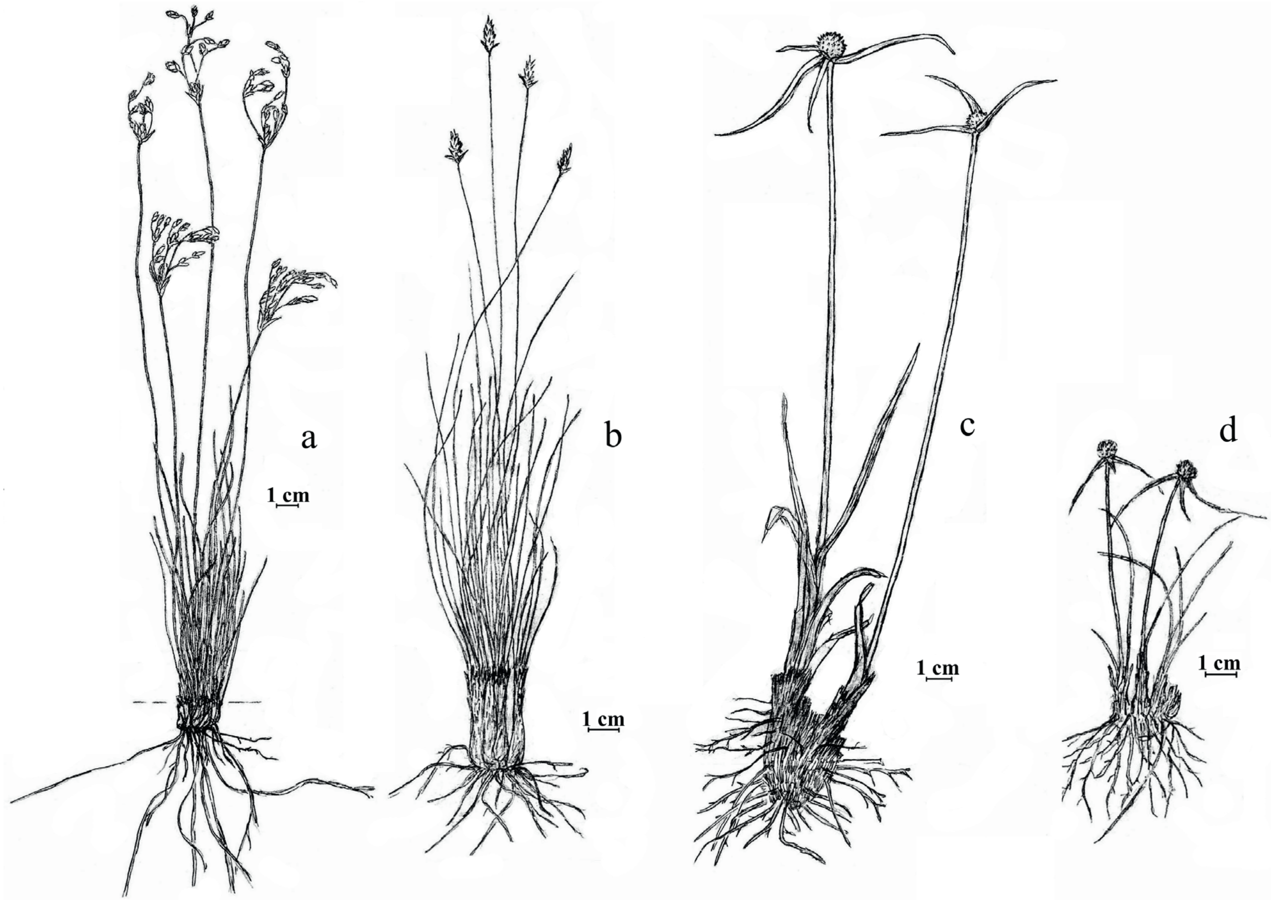

Fig. 10. Cyperaceae: *Abildgaardia hispidula* (a), *A. macra* (b), *Cyperus ciliato-pilosus* (c), *Kylingiella microcephala* (d), all pictures in January

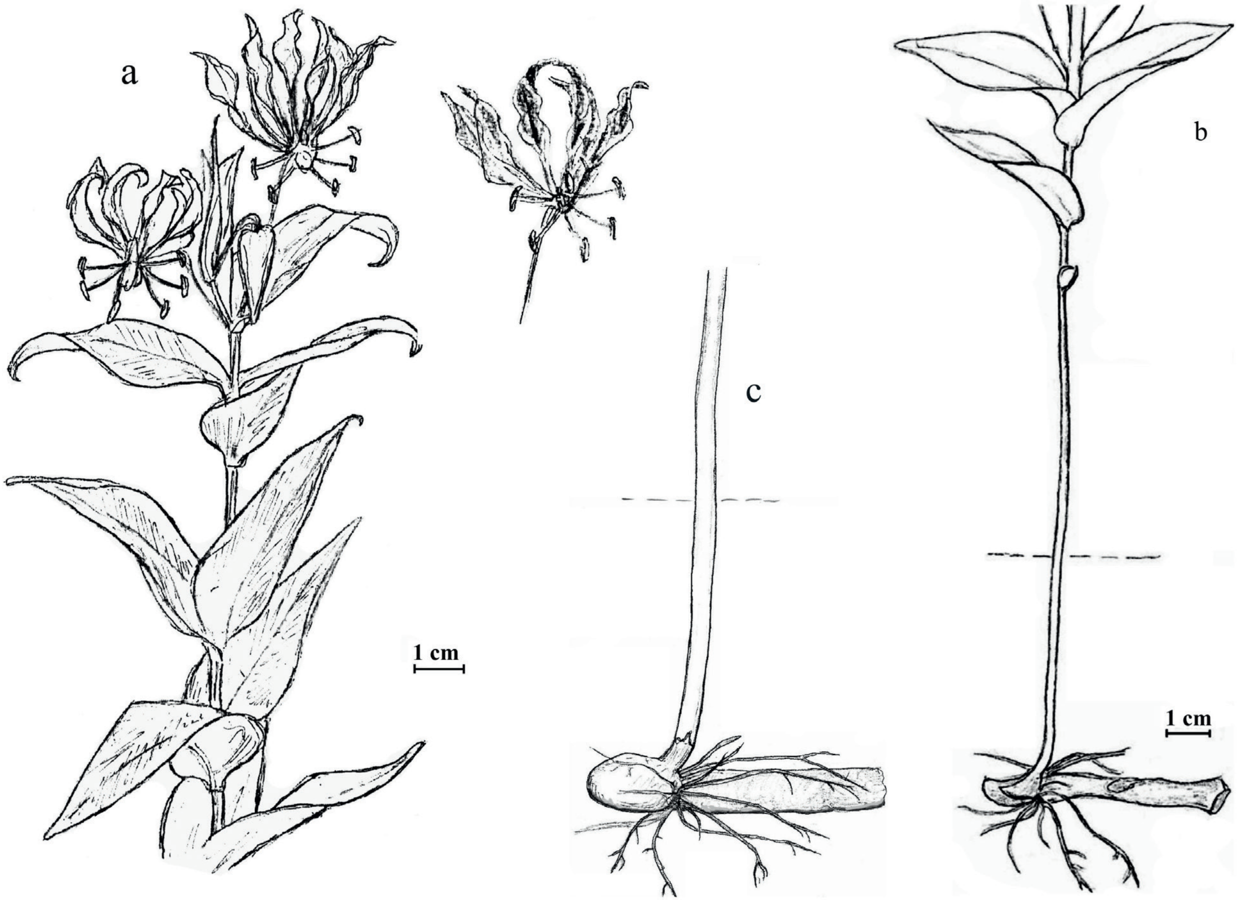

Fig. 11. Liliaceae: *Gloriosa superba*, stem with flowers (a), stem with leaves (b), the underground part (c); all pictures in January

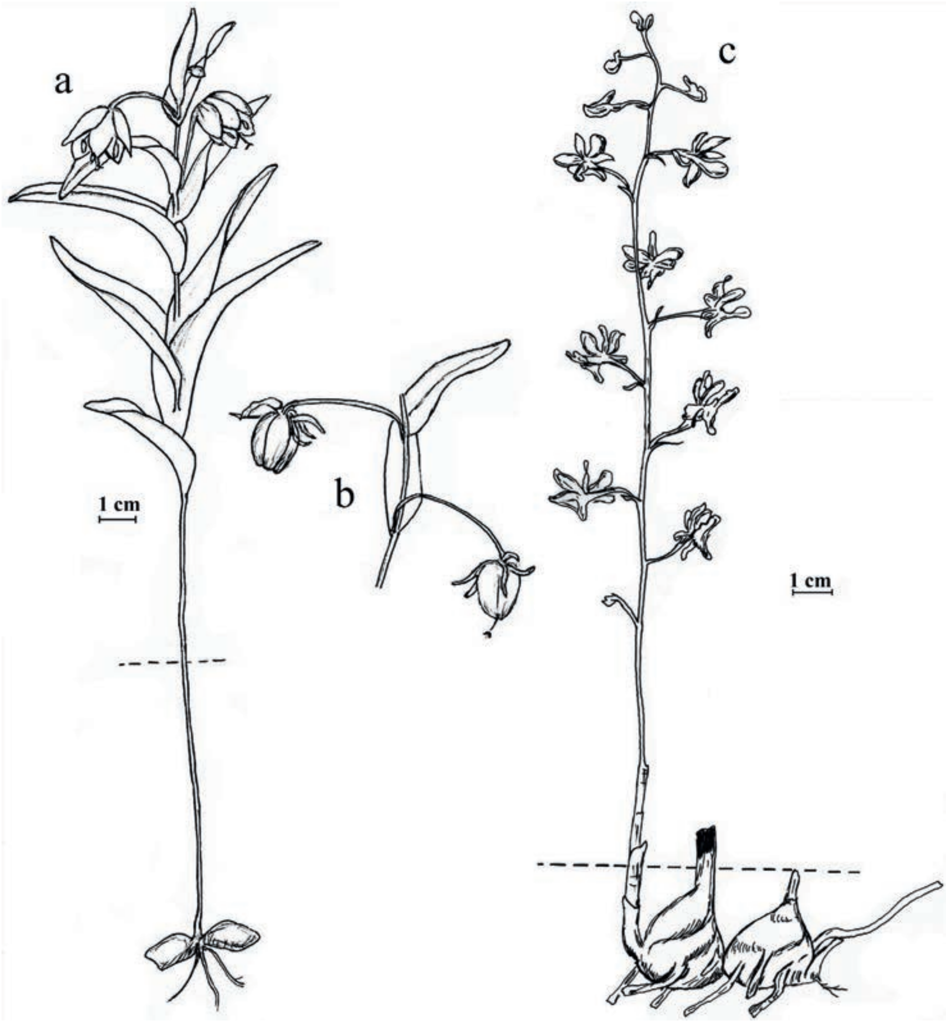

Fig. 12. Liliaceae: *Littonia littonioides*, stem with flowers (a), fruits (b), in January; Orchidaceae: *Eulophia* cfr. *pyrophila*. (c), end of September

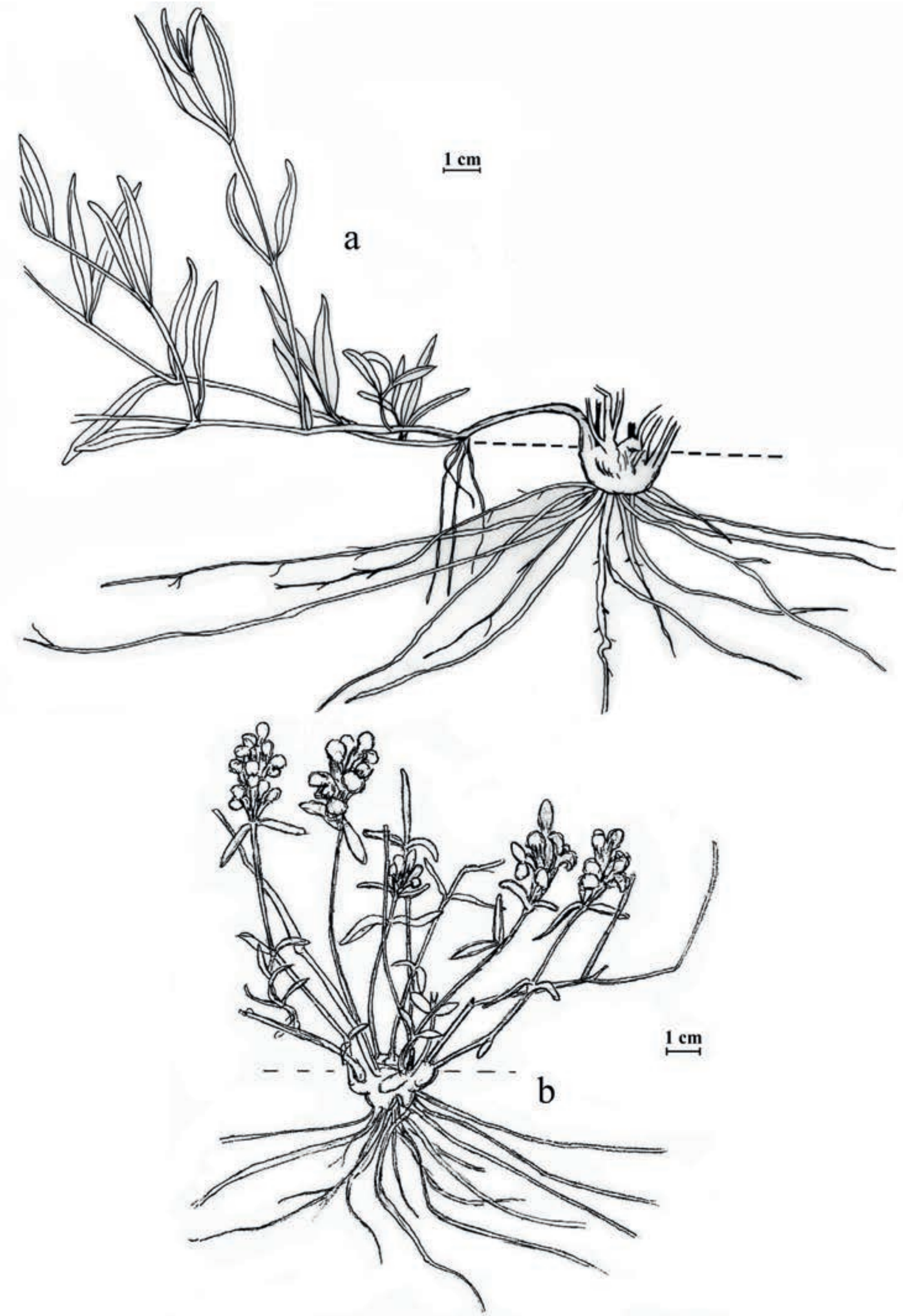

Fig. 13. Acanthaceae: *Dicliptera melleri*, plant with stolons in January (a), with flowers (b), in October

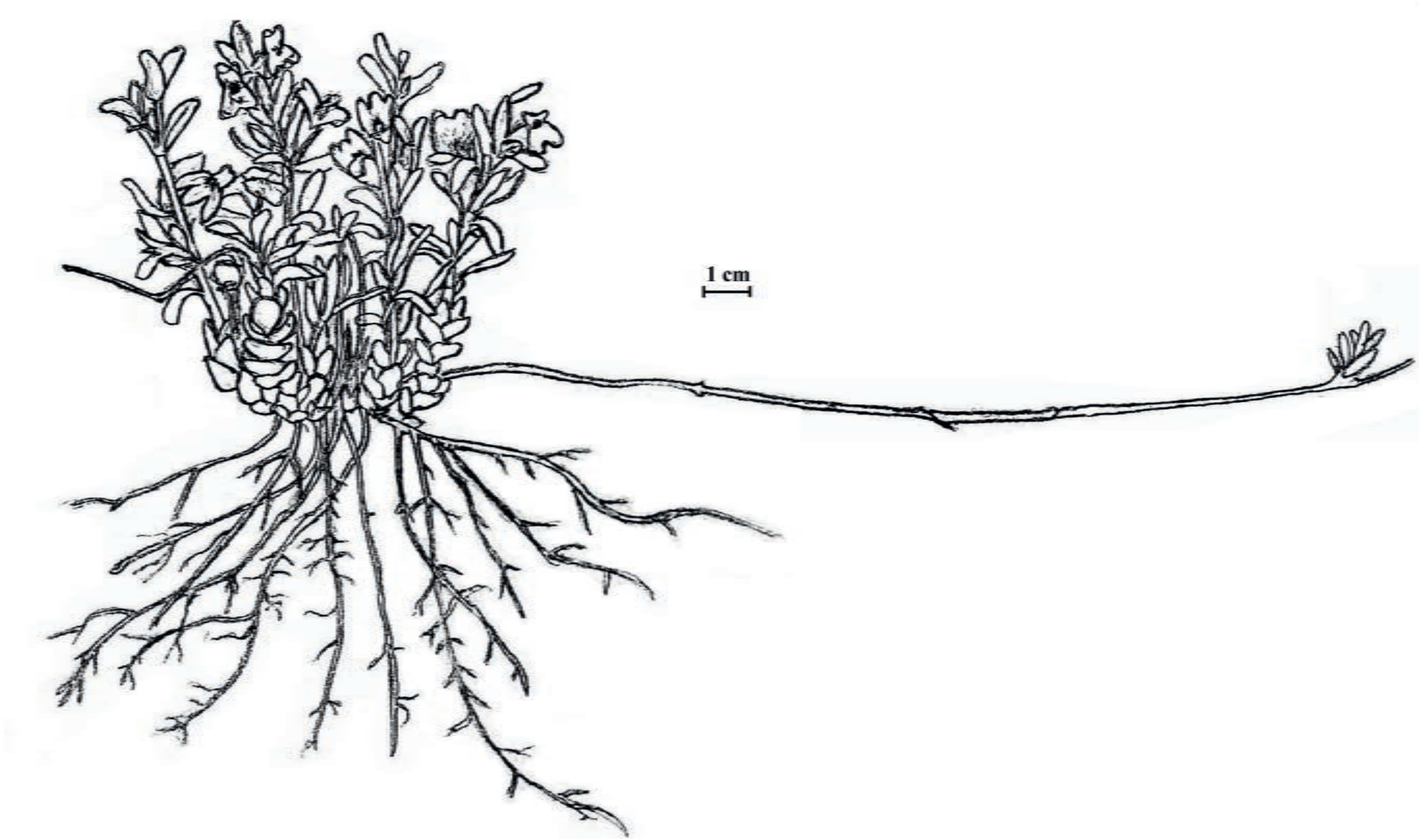

Fig. 14. Acanthaceae: *Justicia elegantula* in September/October

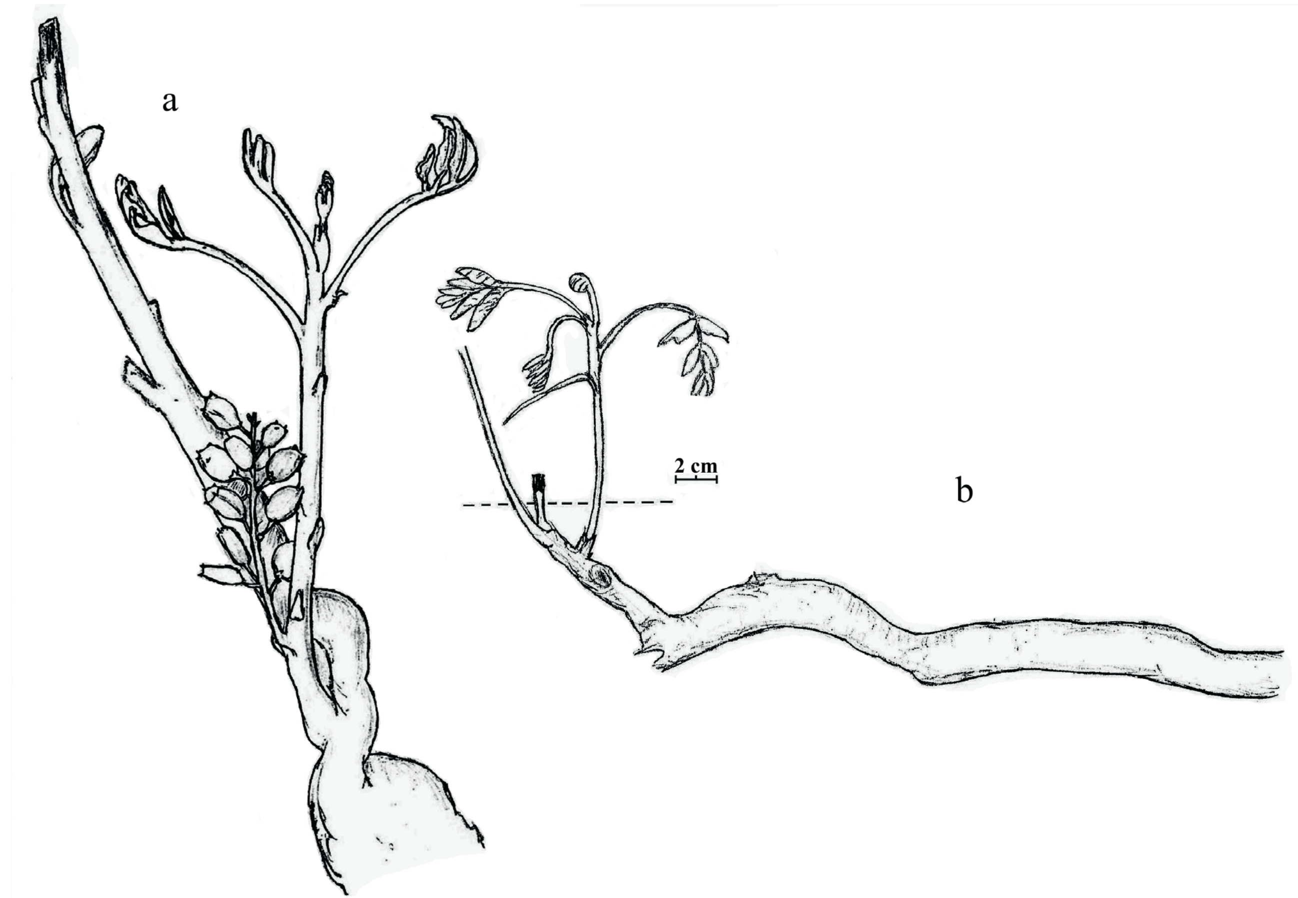

Fig. 15. Anacardiaceae: *Lannea edulis*, young leaves and flower buds (a), end of August, a sprouce and underground part (b), September

Fig. 16. Annonaceae: *Annona stenophylla* with fruits and underground rhizomes

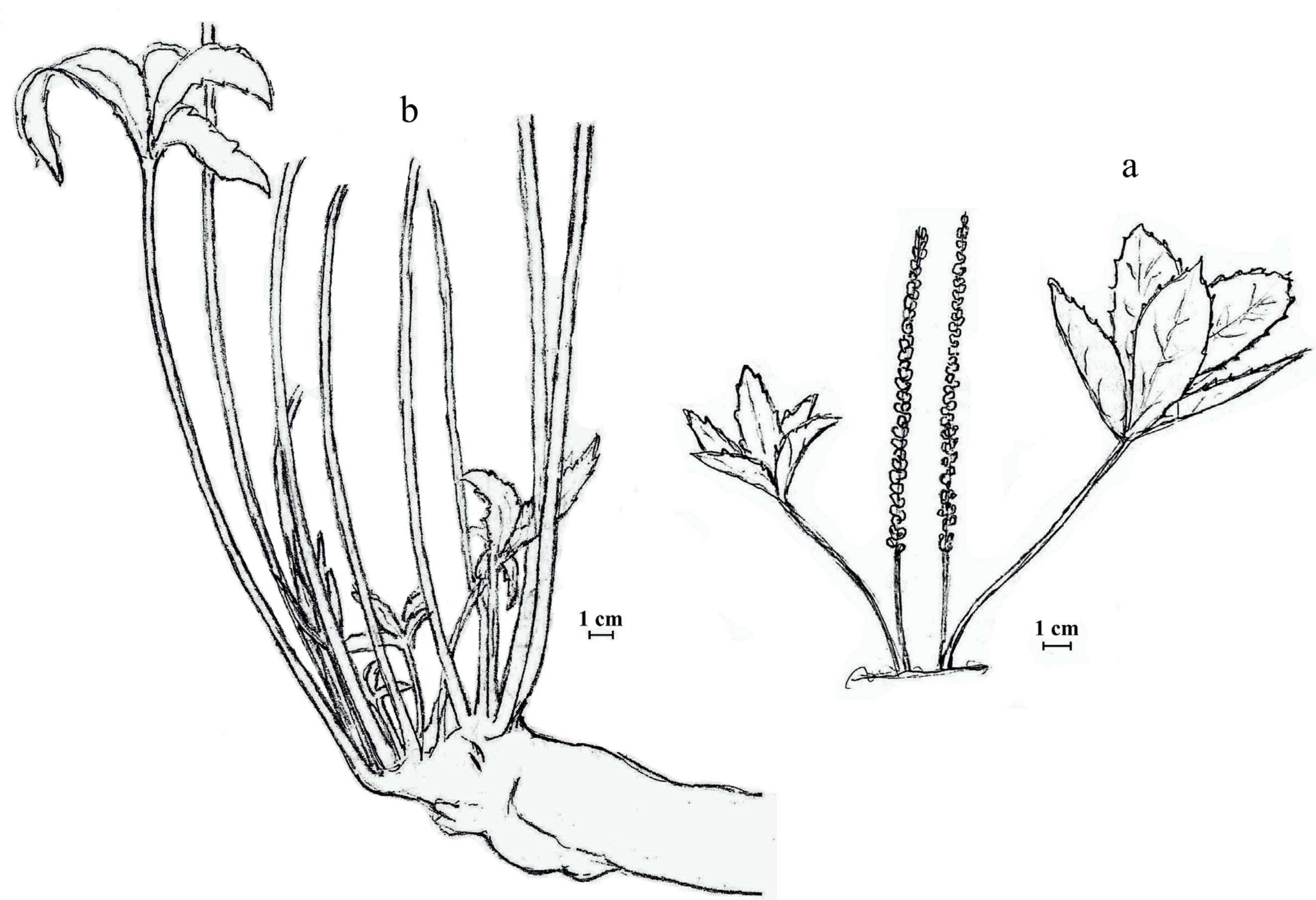

Fig. 17. Araliaceae: *Cussonia corbisieri*, the erect inflorescences (a), basal part of plant with thick underground segment (b), beginning of December

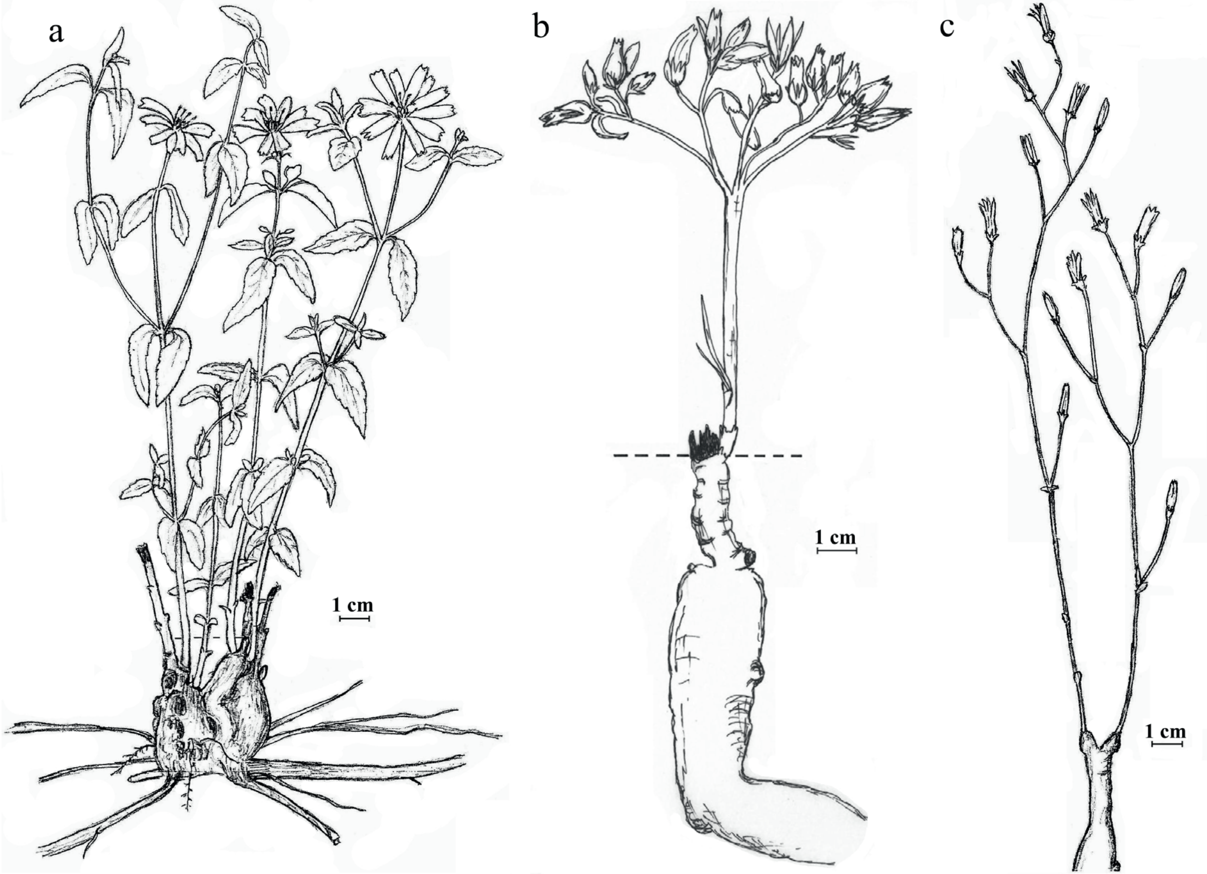

Fig. 18. Asteraceae: *Aspilia pluriseta*, with the bulbs and horizontal roots (a), end of October, *Launaea nana* (b), *L. rarifolia* (c), both plants with thickened roots, end of October

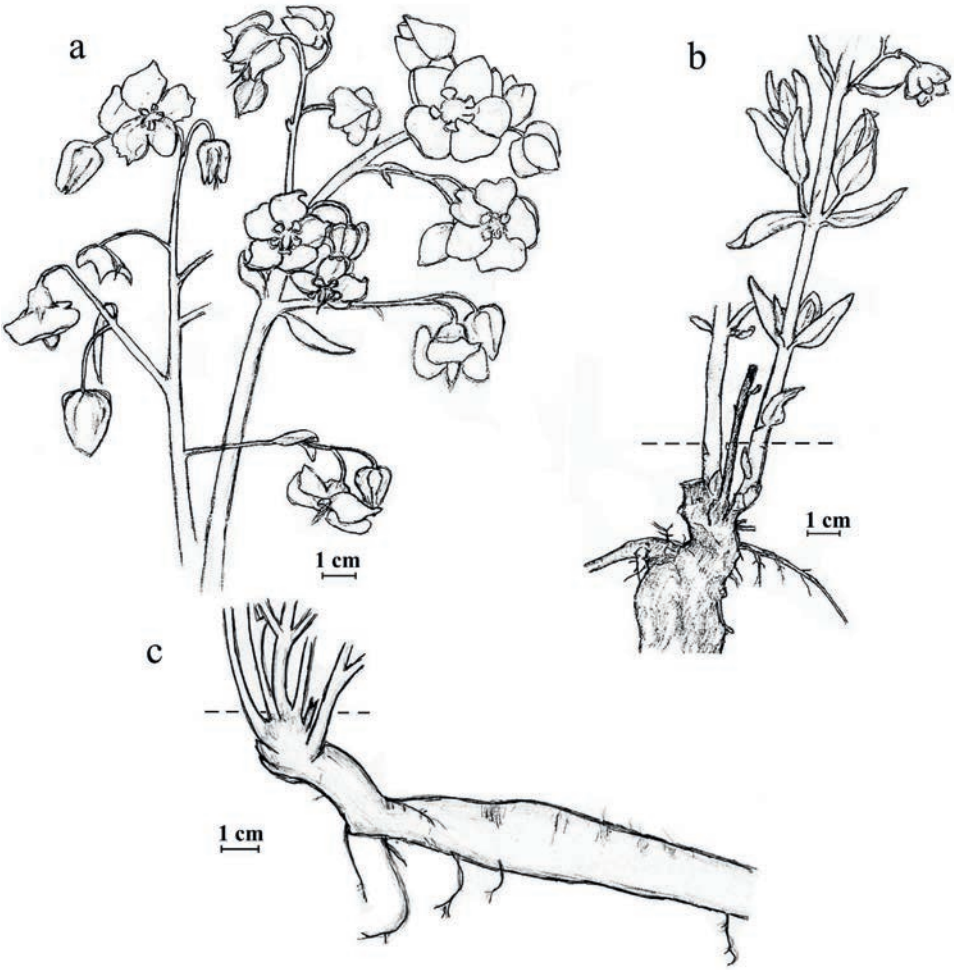

Fig. 20. Boraginaceae: *Trichodesma ambacense* subsp. *hockii*, flowering plant (a), in August, stem with thickened roots (b, c), October and January

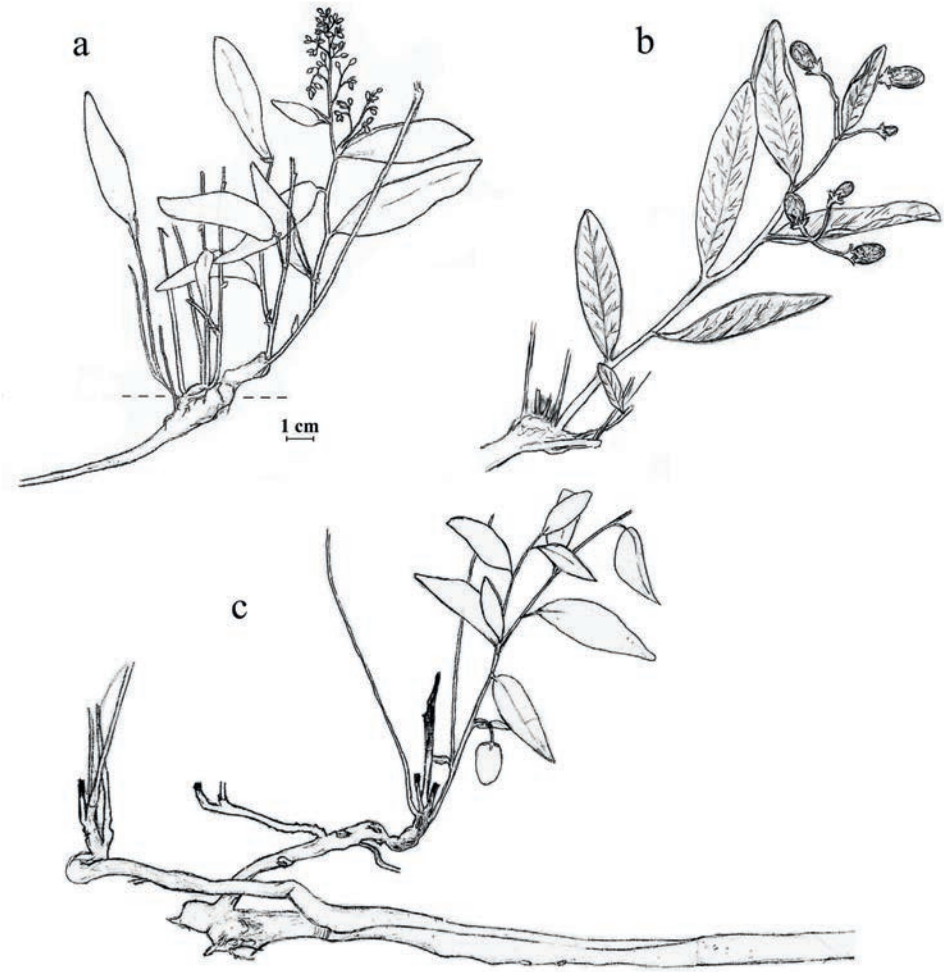

Fig. 21. Chrysobalanaceae: *Parinari capensis*, a branch with flower buds (a), in October, with fruits still in January (b), with long roots (c), end of November

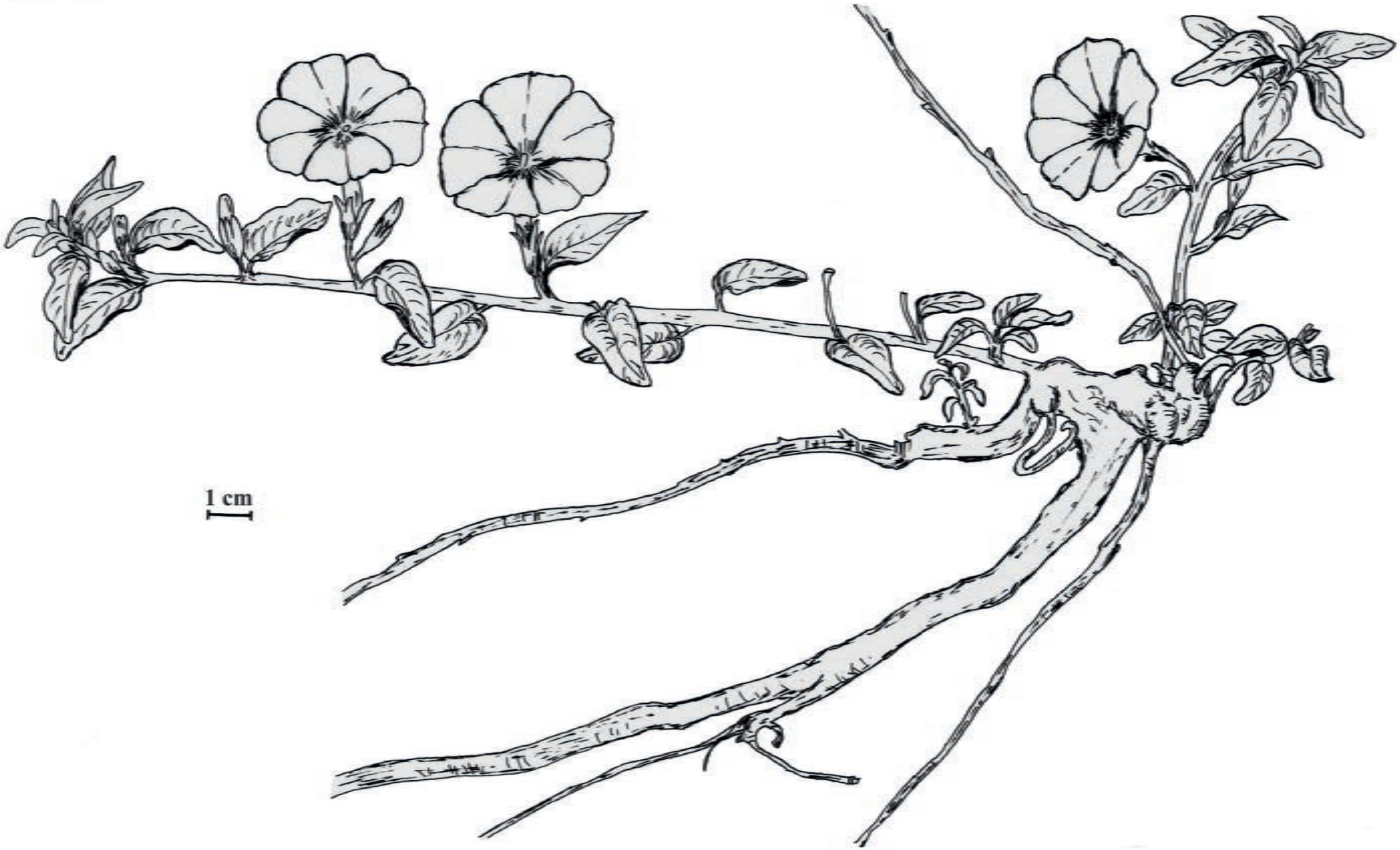

Fig. 22. Convolvulaceae: *Astripomea malvacea*, plant with creeping stem and thickened roots, end of August

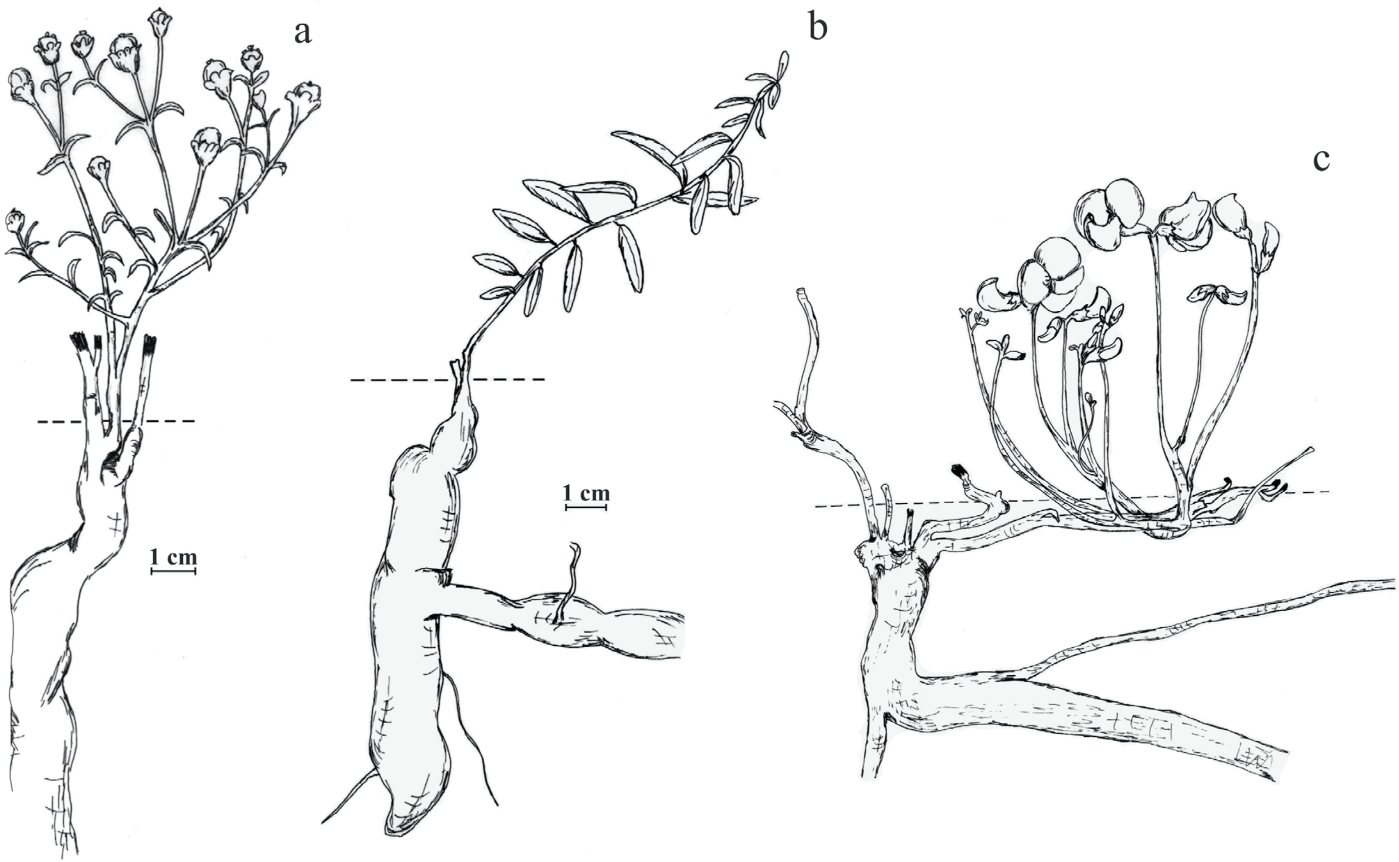

Fig. 23. Euphorbiaceae: *Euphorbia oatesii*, plant with thick root (a), plant with fructification (b), in September, Fabaceae: *Vigna antunesii* – flowers soon after fire, thick root (c), end of September

Fig. 24. Lamiaceae: *Leucas* cfr. *nyassae*, stem with flowers (a), the vertical root (b), September

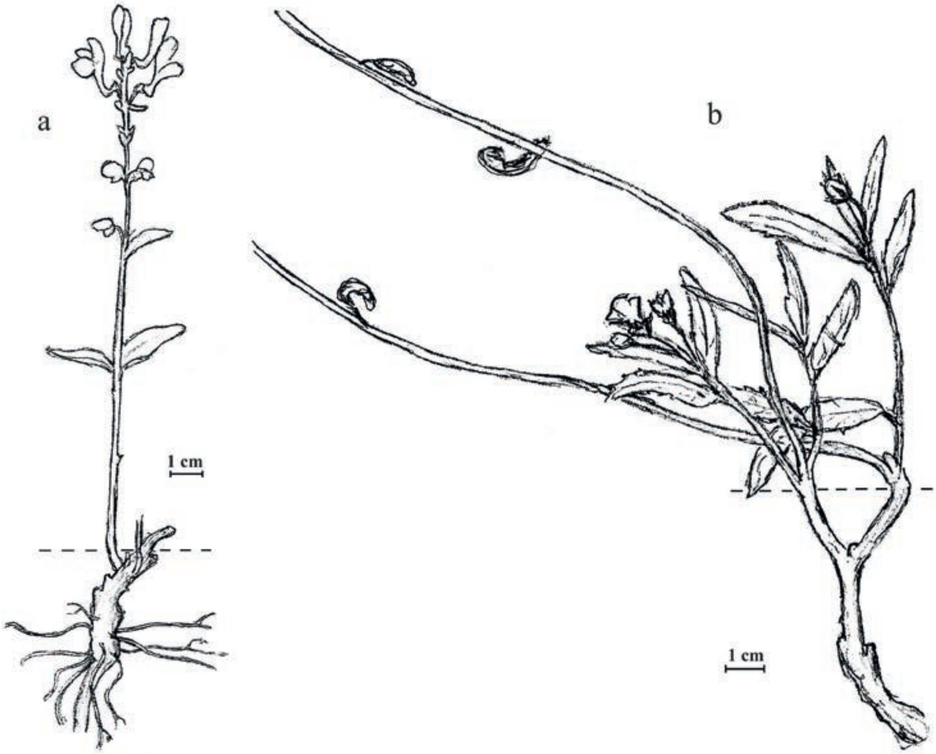

Fig. 25. Lamiaceae: *Scutellaria schweinfurthii*, plant with flowers and thick root (a), September, Malvaceae: *Hibiscus rhodanthus*, with flowers and remnants of old stems (b), September

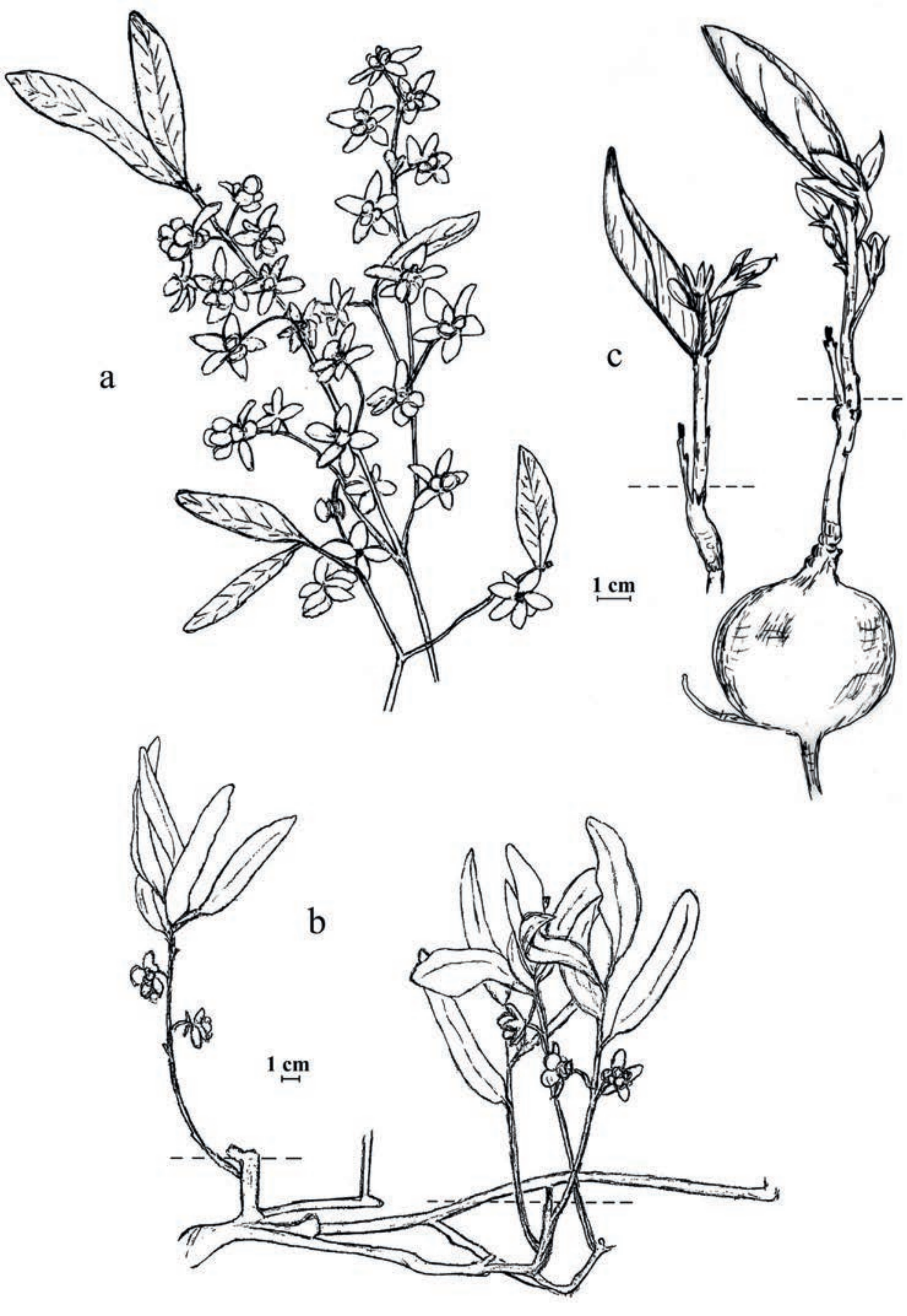

Fig. 26. Ochnaceae: *Ochna leptoclada*, flowers (a), sprouts with leaves and underground rhizomes (b), between Kabwe and Mpunde, beginning of December, Passifloraceae: *Adenia goetzei*, a part of sprout with underground bulb (b), end of November

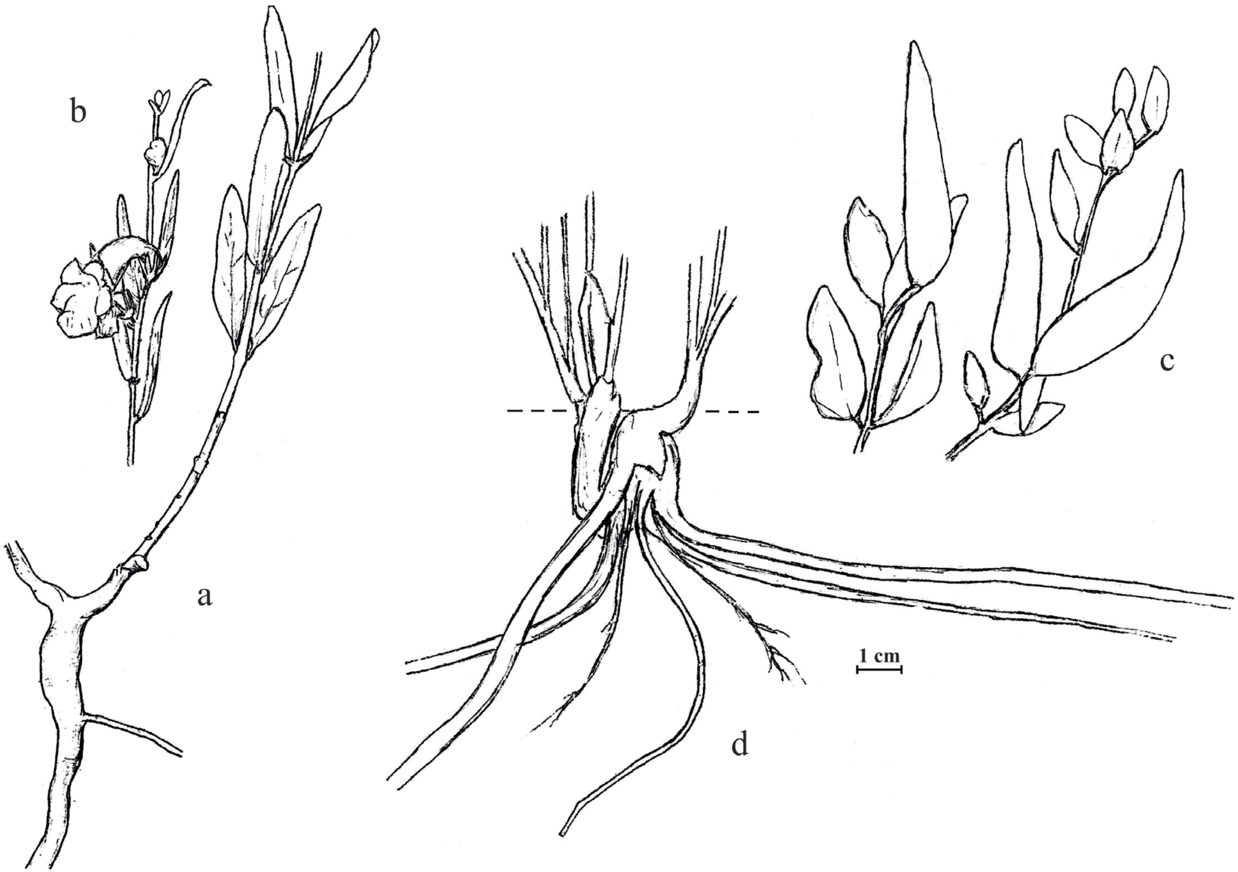

Fig. 27. Pedaliacea: *Sesamum* cfr. *angustifolium*, sprout with root (a), flower (b), February, Periplocaceae: *Ectadiopsis oblongifolia*, leaves (c), the underground parts (d), February

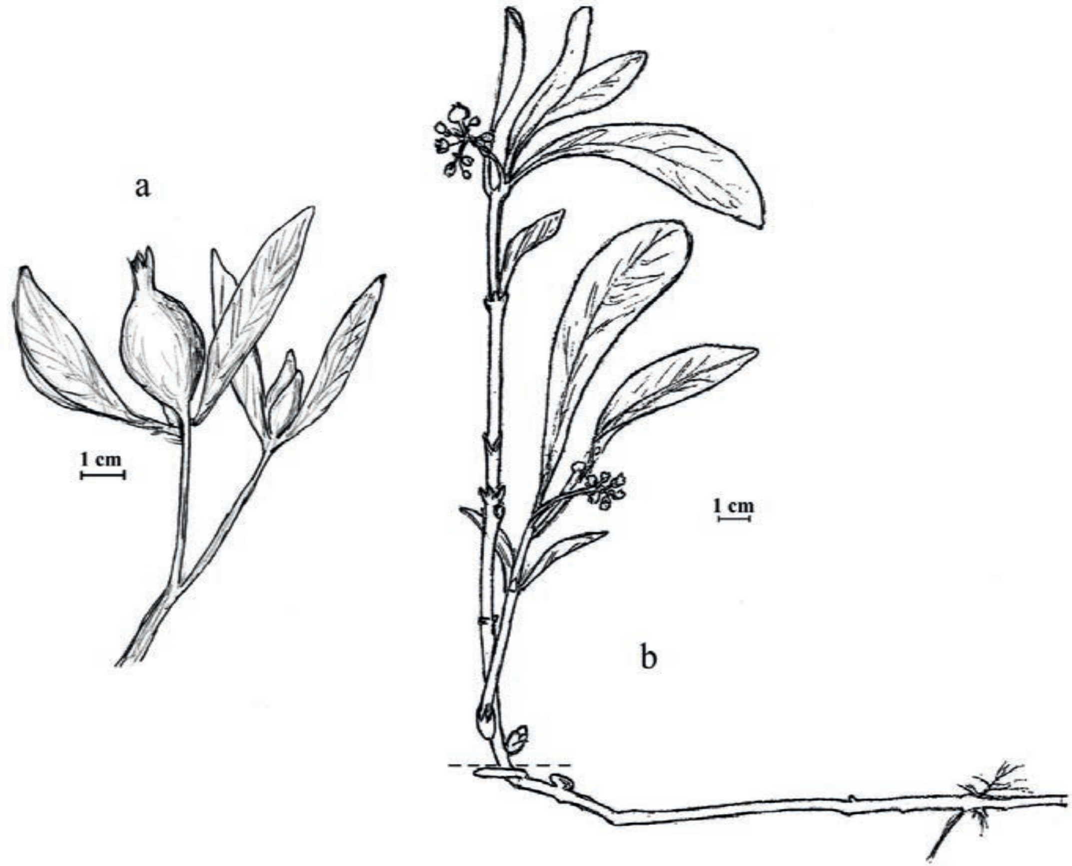

Fig. 29. Rubiaceae: *Gardenia subacaulis*, a branch with young fruit (a), end of January, *Psychotria* cfr. *spithamea* (cfr. Fig. 28a, b), a plant with flowers and rhizome (b), end of January

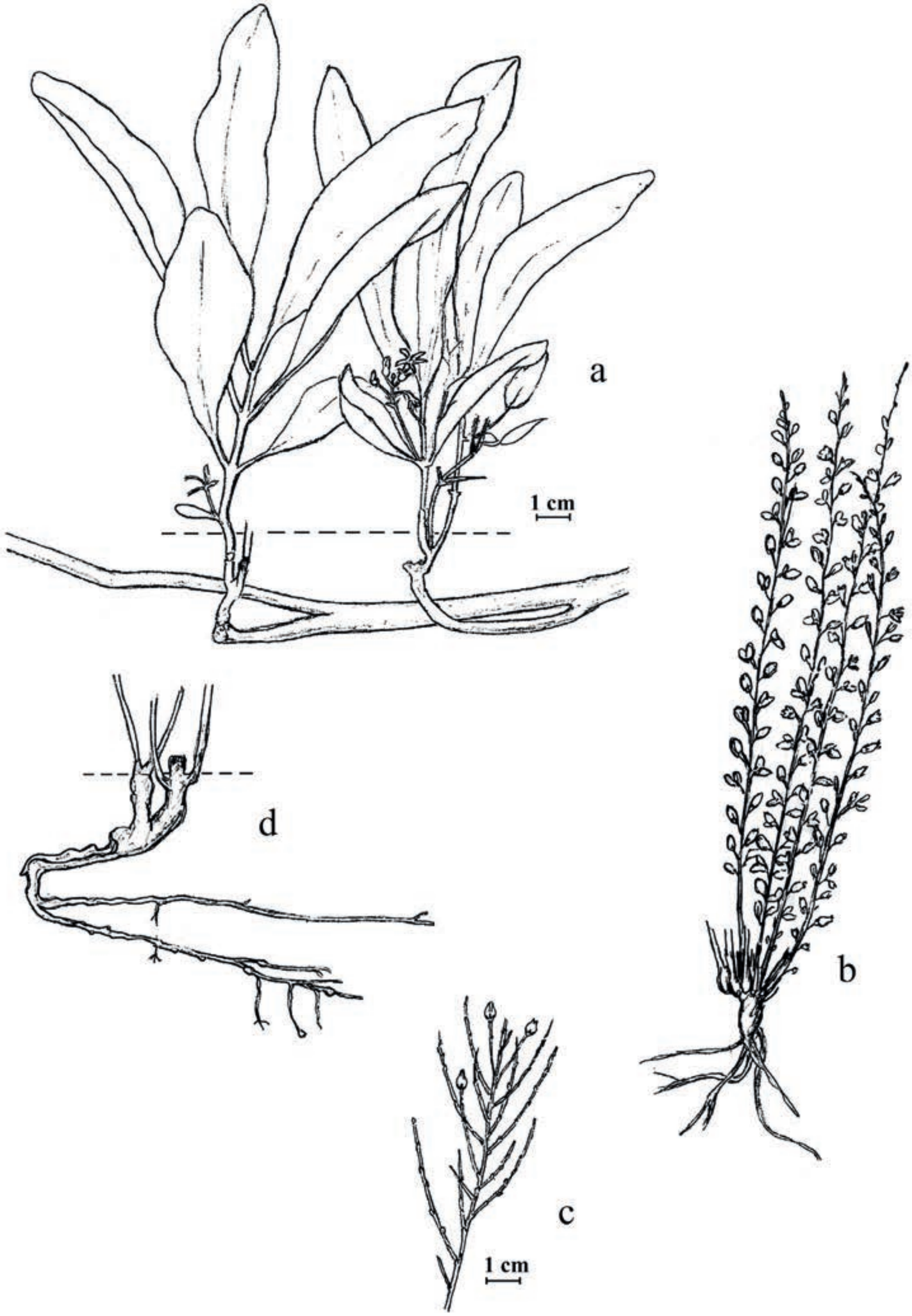

Fig. 31. Rubiaceae: *Pygmaeothamnus zeyheri*, branches with roots (a), September, Santalaceae: *Thesium unyikense*, sprouts with leaves and flowers (b), October, a branch with fruits in January (c), underground parts (d)

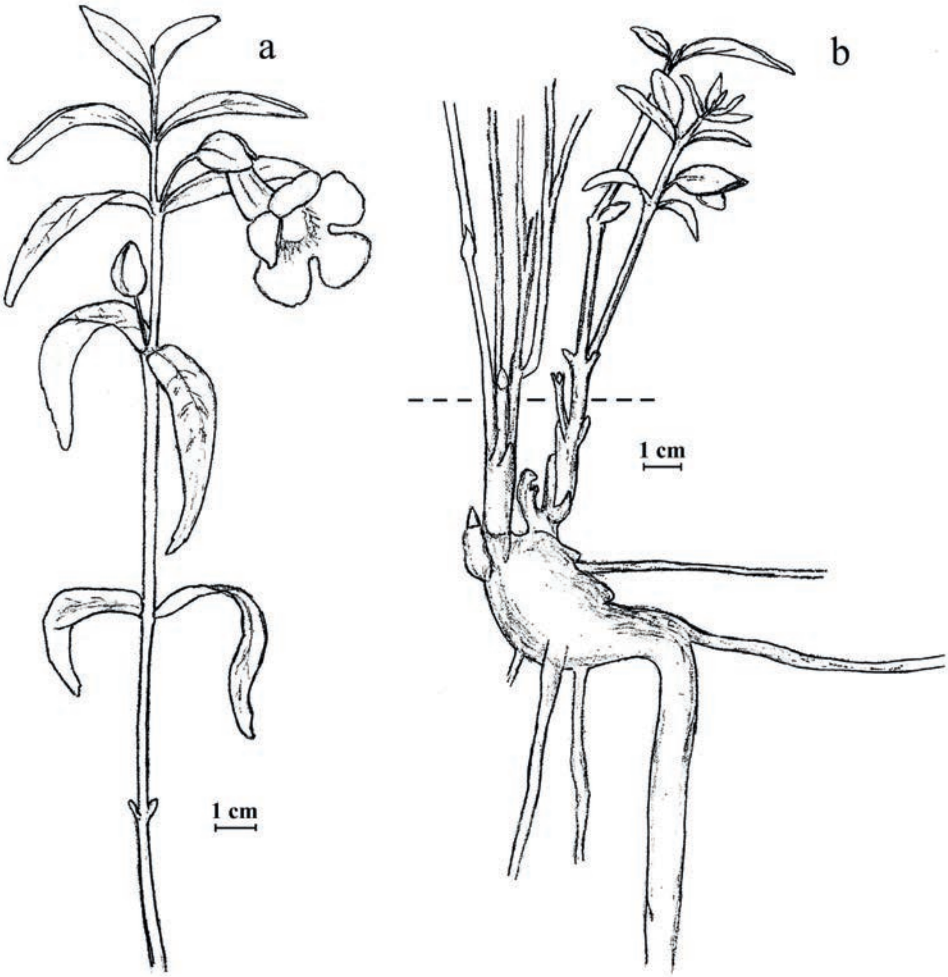

Fig. 33. Thunbergiaceae: *Thunbergia* aff. *oblongifolia*, a shoot with flowers (a), the underground parts (b), both pictures end of October

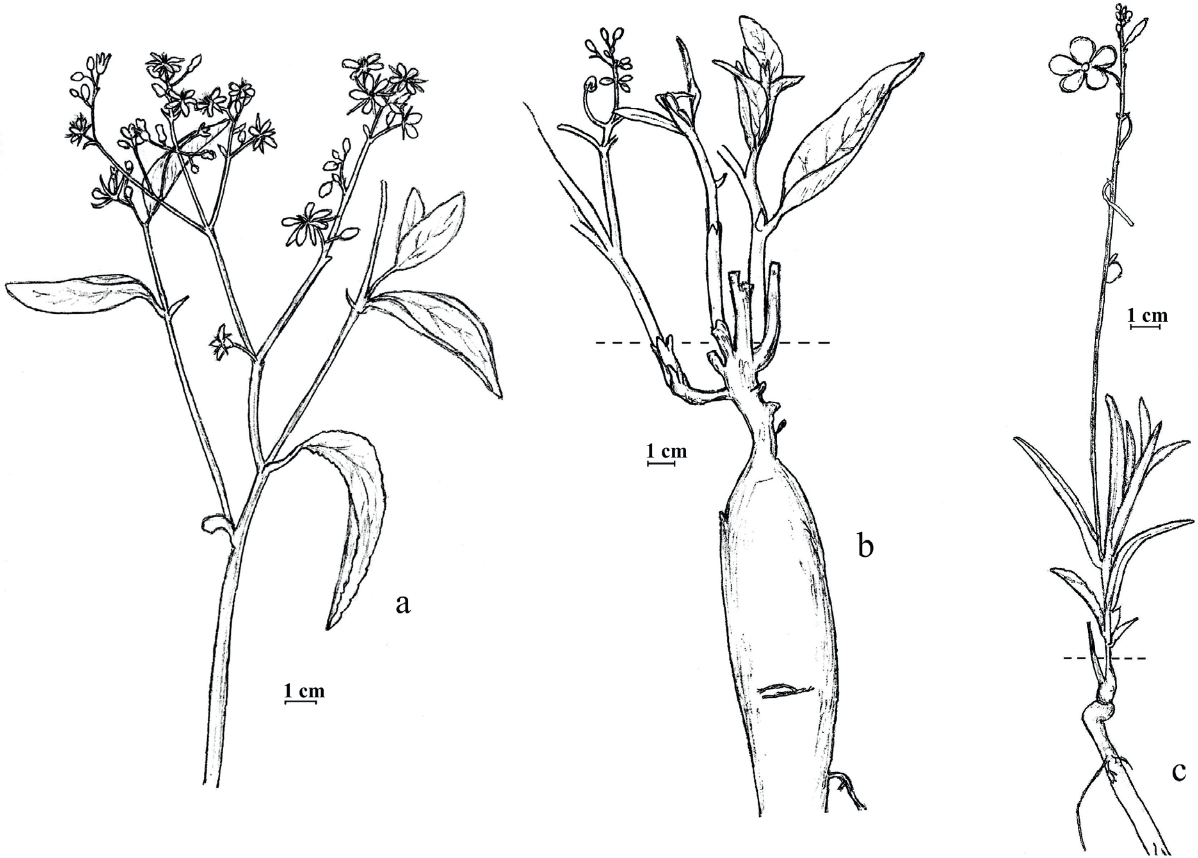

Fig. 34. Tiliaceae: *Triumfetta heliocarpa*, plant with flowers (a), end of October, a thick root (b), end of September, Turneraceae: *Tricliceras longipedunculatum* with flowers and root (c), in January

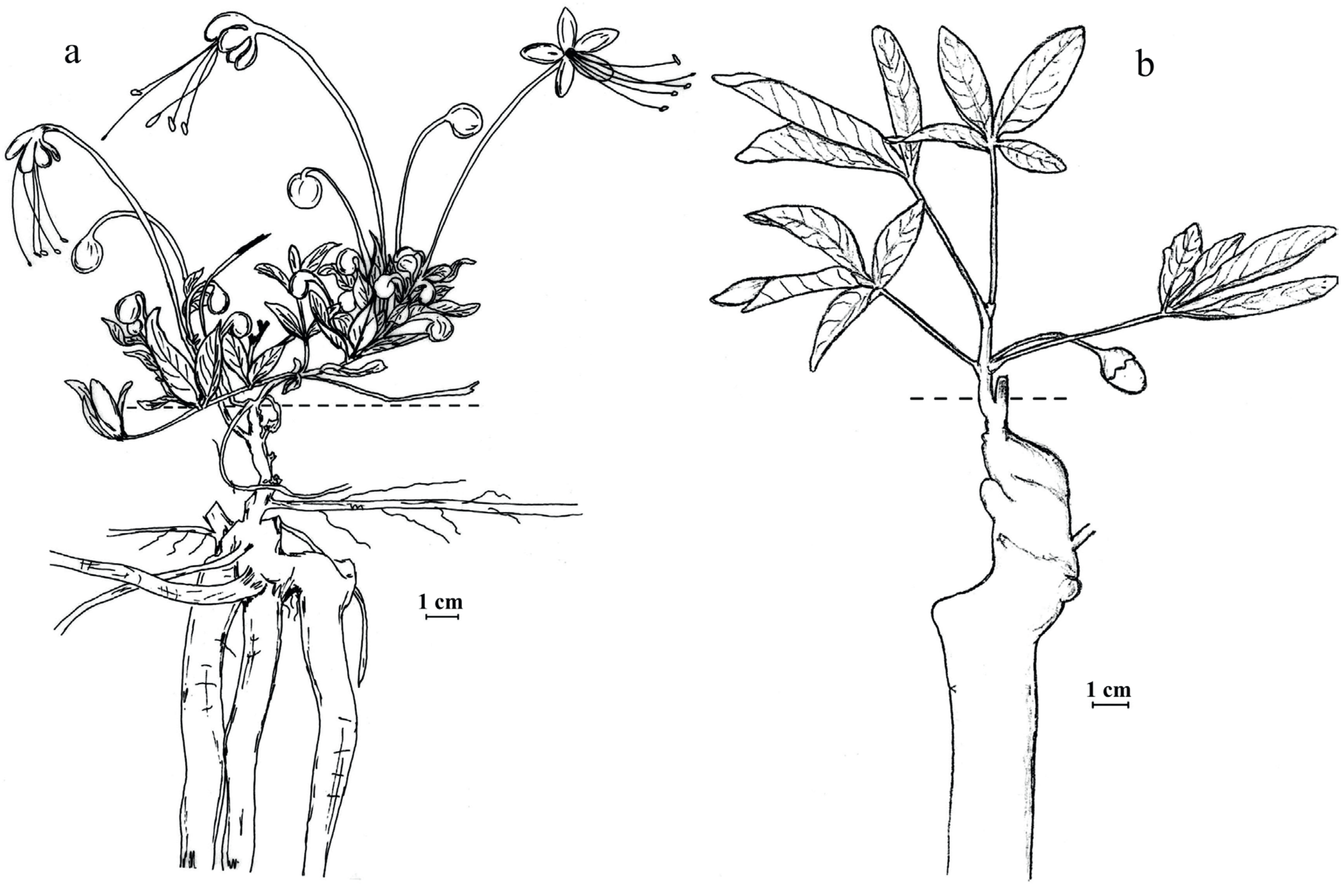

Fig. 35. Verbenaceae: *Clerodendron pusillum*, leaves, flowers and large roots (a), end of September, *Vitex* cfr. *mombassae*, plant with fruit and large root (b), end of January

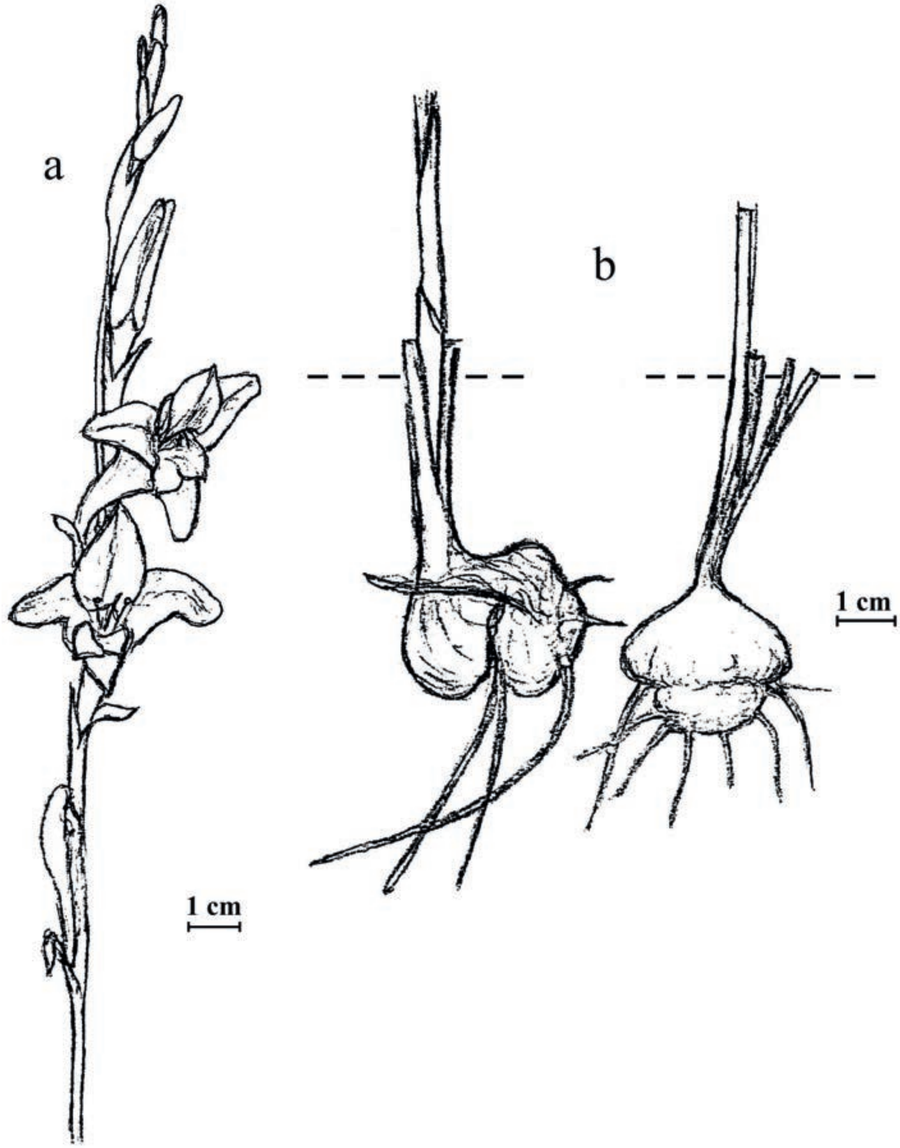

Fig. 39. Iridaceae: *Gladiolus* sp. (more than 10 species in Zambia), flowers (a), underground bulbs (b), the Leopards Hill Road, end of September

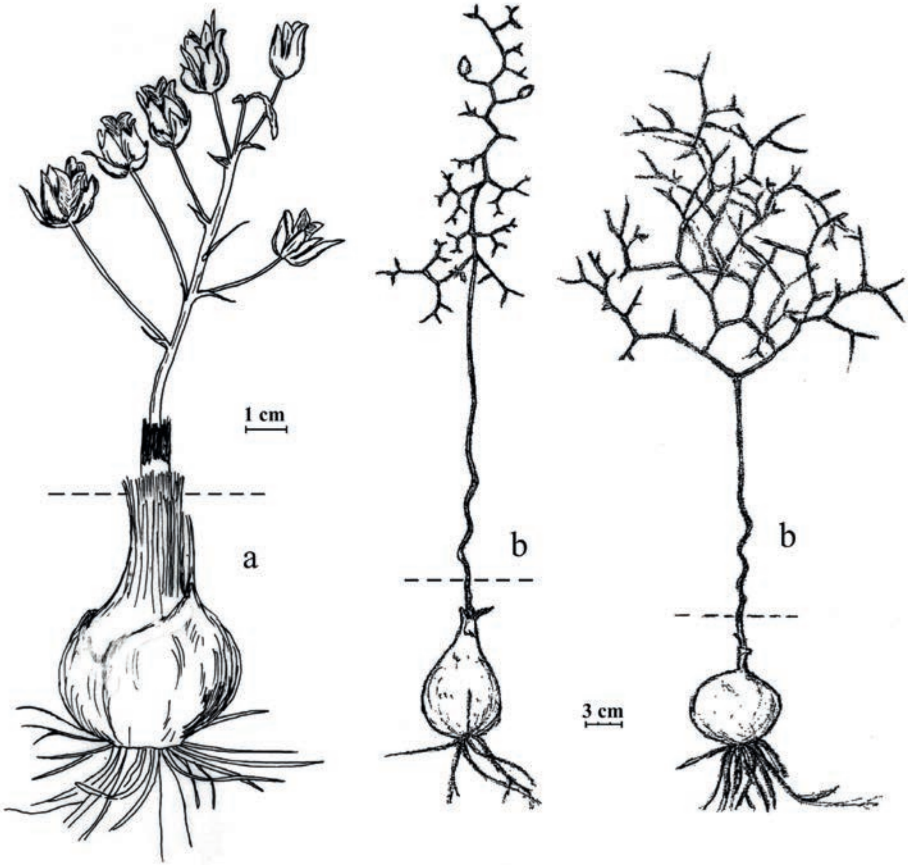

Fig. 40. Liliaceae: *Albuca* sp., recently burned pasture on the roadside (a), Leopards Hill, end of September, *Schizobasis intricata*, plants with watery bulbs (b), burned plot near Mpunde, beginning of October

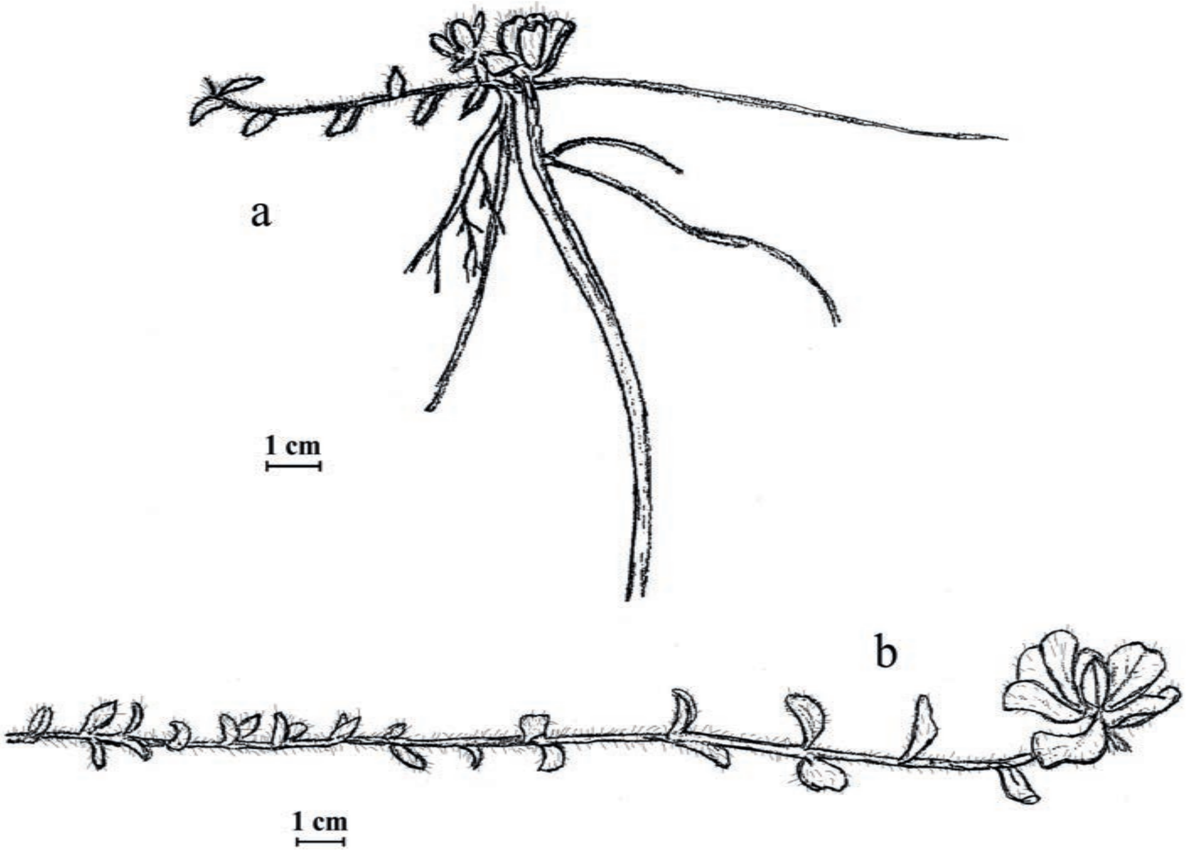

Fig. 41. Acanthaceae: *Nelsonia canescens*, above and underground parts (a), creeping stem with leaves (b), burned plot in University Campus, beginning of October

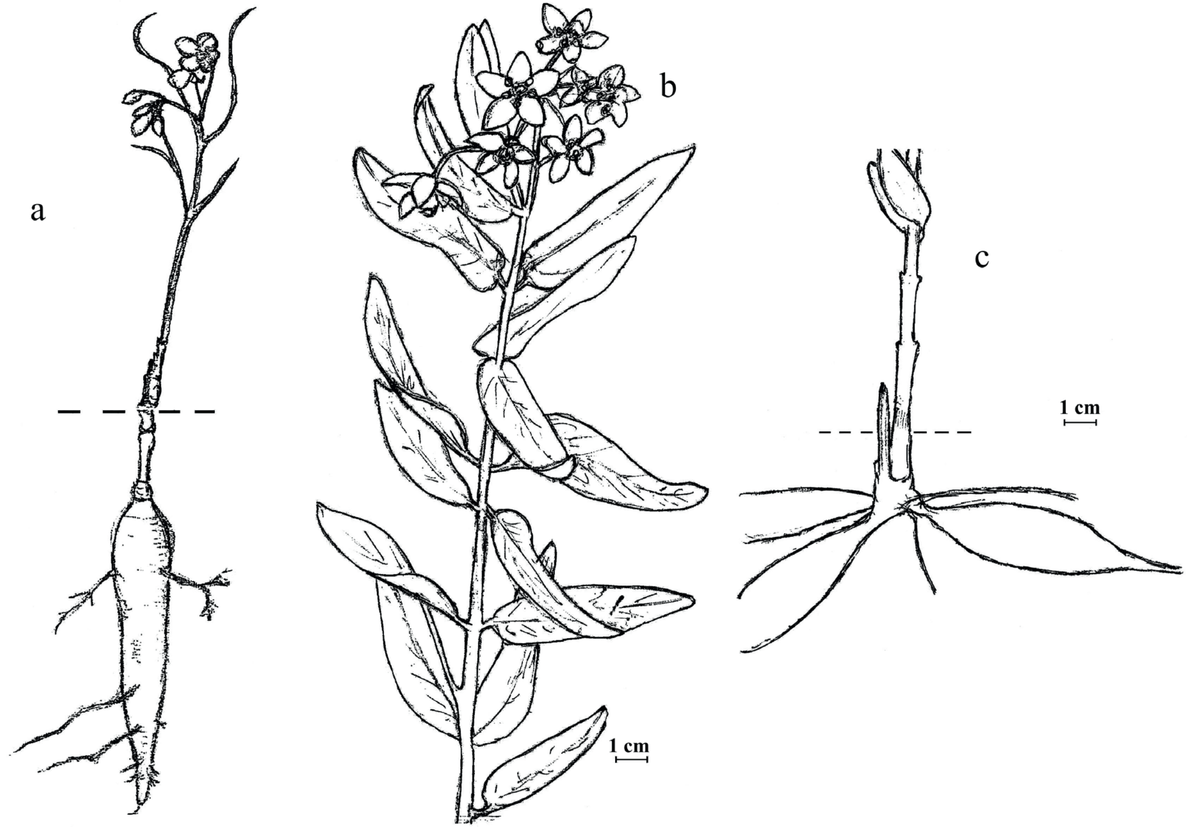

Fig. 42. Asclepiadaceae: *Odontostelma welwitschii*, plant with underground parts (a), on the sand near Chisamba Forest Reserve, first half of October, *Pachycarpus lanceolatus*, a relatively tall plant with thickened underground parts (bulbs) (b, c), near Chongwe River, north of Kasisi, beginning of December

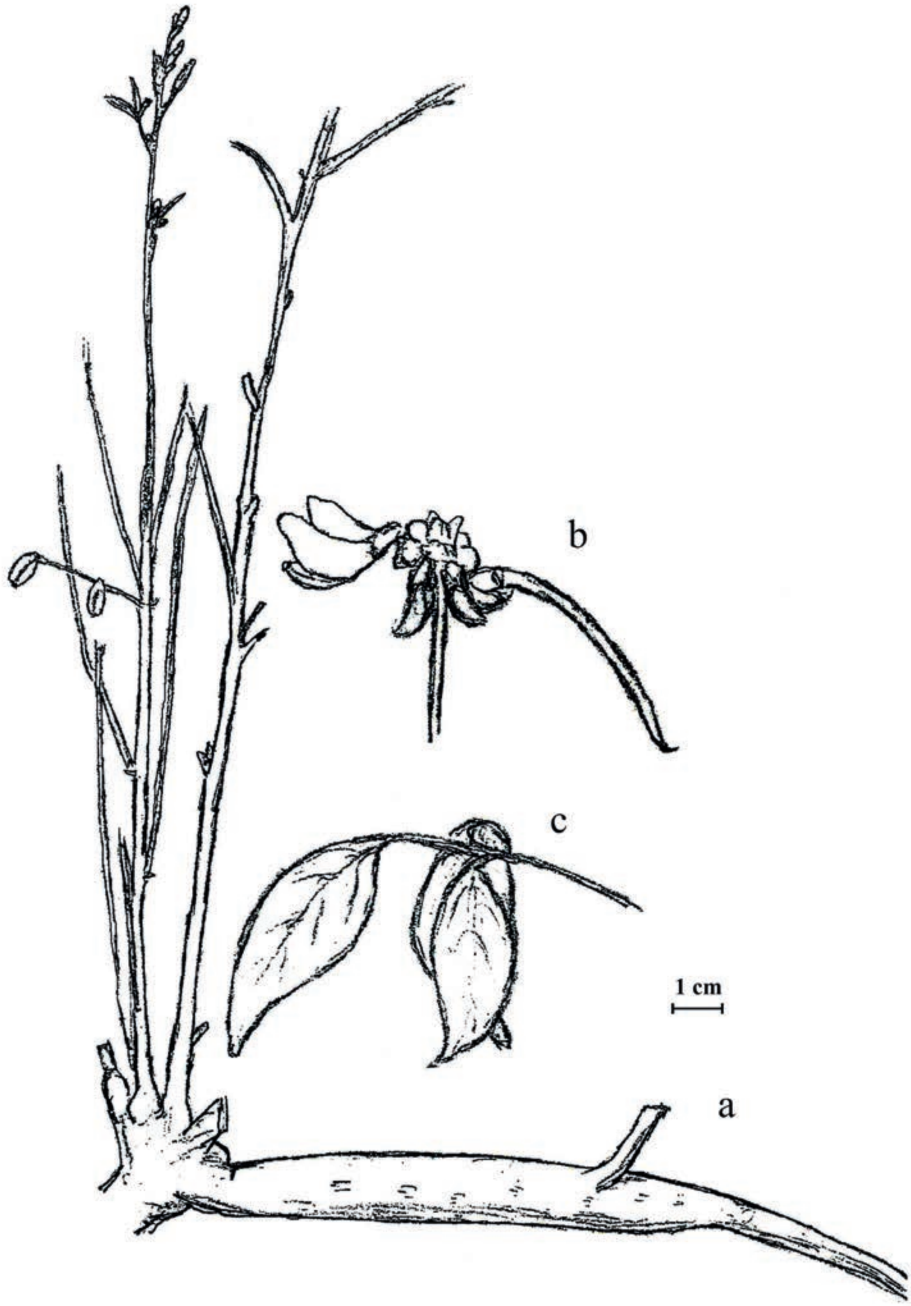

Fig. 44. Fabaceae: *Sphenostylis marginata* subsp. *erecta*, A1 plant with underground parts (a), flowers (b), leaves (c), recently burned grassland between Lusaka Airport and Kasisi, end of July

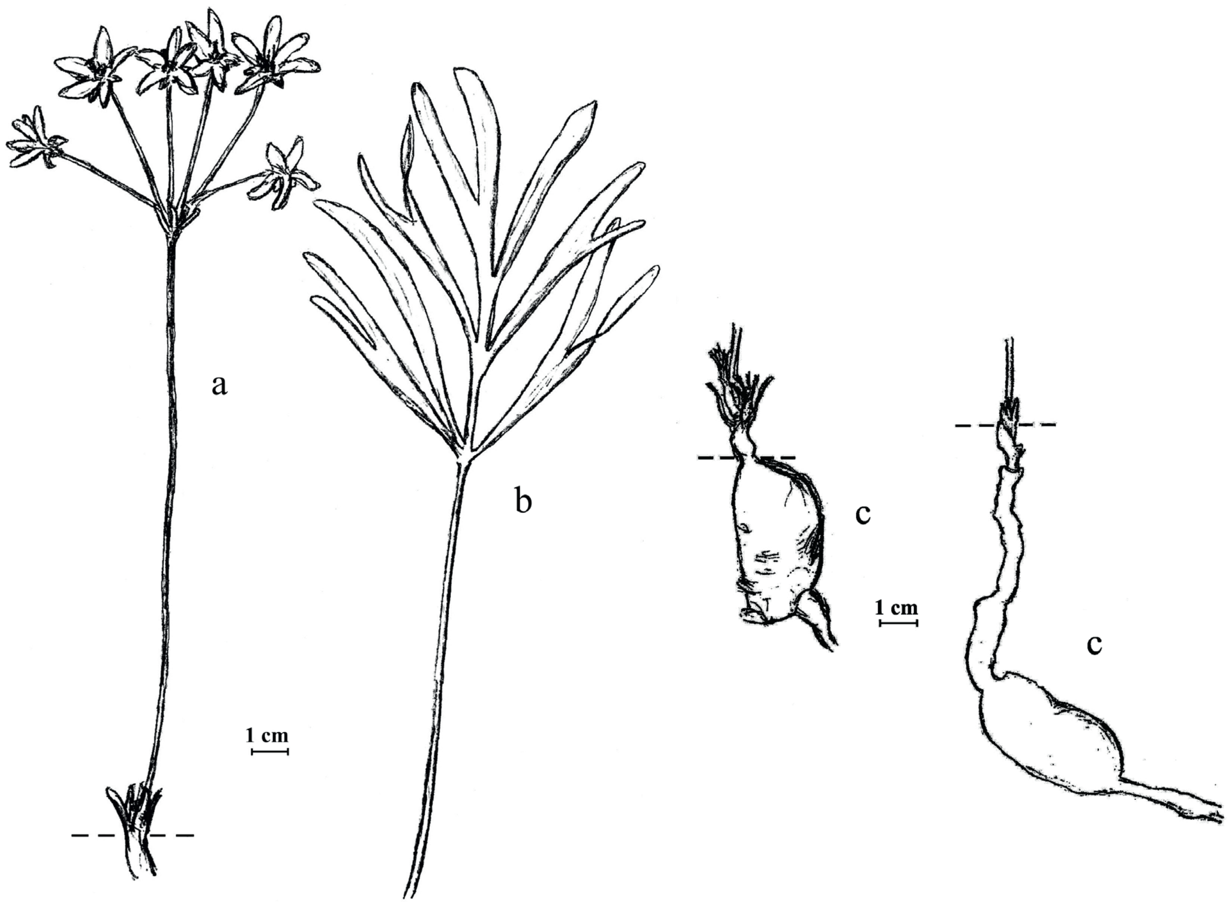

Fig. 45. Geraniaceae: *Pelargonium luridum*, flowers and leave (a, b), the underground bulbs (c), beside the Leopards Hill Road, end of October

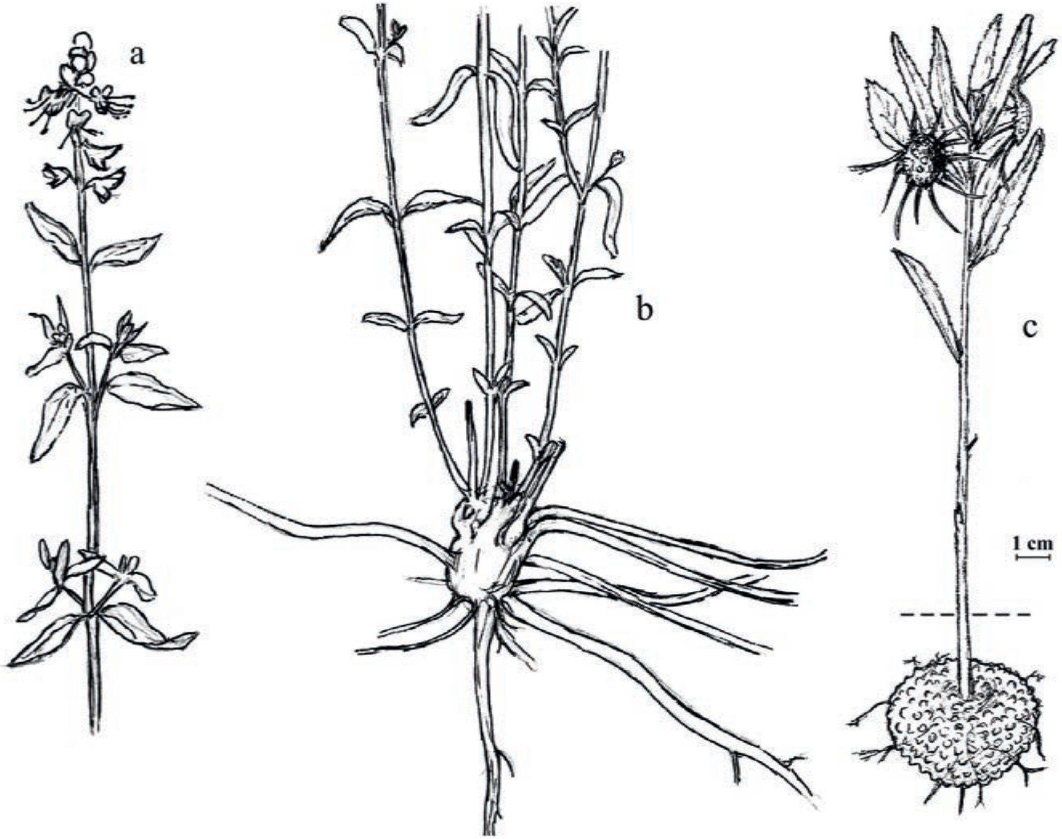

Fig. 46. Lamiaceae: *Boecium* sp., with flowers (a), with underground parts (b), Moraceae: *Dorstenia benguellensis*, plant with flowers and underground parts (c), burned savanna near Mpunde, beginning of December

Abstract

The observations, lasting above one year, have concerned particular plant species and plant communities on two selected savanna plots burned earlier, situated near Lusaka, and additionally some other localities. After the opening remarks, some information about fire's influence on vegetation is given, with a quotation of papers connected with the area of investigations, as well as the author's and Jan Kornaś's publications. Those texts are followed by a short description of the geographical conditions in the region taken into account, of the studied plots, and information about the methods of investigations. Subsequently, there is a list of noticed species, with short descriptions and some pictures. Phytosociological data are presented in tables (2) and (3). The following chapters contain the joint characteristic of the studied vegetation: data about its floristic composition, phenology (Tab. 5), and morphology of species. The Raunkiaer's plants classification is considered here; afterward data on the water content in some roots and rhizomes are presented (Tab. 4). The next chapter contains the description of common features of vegetation on the studied plots. Thereafter may be found information about the pyrophytic plant species noticed elsewhere in Zambia. In the discussion publications supplementing the author's study are mentioned. Further, more detailed descriptions of the features of fire, its occurrence in nature, distribution, and structure of savannas are included. Plant regeneration on the burned plots, the usefulness of Raunkiaer's classification in the tropics, and problems of evolution of pyrophytes are presented. There is also some evidence of phytosociological studies in Africa and proposals for the establishment of a new association *Hyparrhenio-Gardenietum*. In the end, some conceptions concerning the rational use of fire, particularly in nature conservation, are mentioned, as well as arguments for the protection of pyrophytic species.

Keywords: fire, features of pyrophytes, Lusaka, nature conservation, observation plots, phytosociological studies

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Wpływ ognia na roślinność sawannową w Zambii i problemy związane z rolą tego czynnika

Streszczenie

Opisywane badania były prowadzone w czasie pobytu autorki w Zambii, gdzie jej mąż Jan Kornaś został zatrudniony jako profesor uniwersytetu w Lusace. Obserwacje, trwające około roku, dotyczyły roślinności na dwóch wypalonych poletkach; objęły też notowania roślin poza nimi. Tekst pracy, po uwagach o celu i okolicznościach badań, zawiera wstępne dane o wpływie ognia na roślinność i o wcześniejszych publikacjach, m.in. autorki i Jana Kornasia, uwzgledniających to zagadnienie. Następnie podany jest krótki opis warunków geograficznych wchodzącego w grę terenu i poletek (z analizami glebowymi – Tab. 1) oraz metody badań. Informacje fitosocjologiczne przedstawiono w tabelach (2) i (3). Dalej znajduje się charakterystyka ponad 90 gatunków roślin występujących na poletkach, z nawiązaniem do „Flora Zambeziaca", a w miarę potrzeby także do innych flor. Z kolei podane jest omówienie łącznych cech składu florystycznego badanej roślinności, ekologicznych typów roślin z rozróżnieniem – zgodnie z klasyfikacją Raunkiaer'a – chamefitów, hemikryptofitów (szczególnie licznych), terofitów i dodatkowej grupy "geoxylic suffrutuces" z zielnymi częściami nadziemnymi i zdrewniałymi podziemnymi; dane o zawartości wody w częściach podziemnych roślin zawiera Tab. 4. Przedstawiony jest też sezonowy rozwój omawianych gatunków (Tab. 5), z osobnym ujęciem (w tekście) traw, turzyc, innych składników flory i siewek (nie licznych). W kolejnym rozdziale omówiono łączne aspekty fenologiczne badanej sawanny z rozróżnieniem stadium wczesnego, optymalnego i końcowego (wysychania traw). Następnie opisana została struktura roślinności na poletkach przy pełnym rozwoju i niektóre jej cechy fitosocjologiczne. Dalszą część pracy stanowią obserwacje pirofitów poza wybranymi poletkami, na różnych stanowiskach. Należą do nich paprotniki, opisane przez J. Kornasia (1979) i wymienione w tekście gatunki z innych grup systematycznych (rodzin). Całość podsumowuje dyskusja. Obejmuje ona, z nawiązaniem do istniejących publikacji szereg zagadnień: cechy ognia, jego oddziaływanie

w przyrodzie i zastosowania praktyczne. Opisano też występowanie sawann i ich powiązanie z ogniem, przystosowania roślin do przetrwania ognia, ich regeneracje po pożarze i rozwój sezonowy. Przedstawiono użyteczność klasyfikacji Raunkiaera i uwagi na temat ewolucji pirofitów, zbiorowiska roślinne opisywane z sawann i propozycje wyróżnienia nowego zespołu *Hyparrhenio-Gardenietum* występującego na opisanych poletkach. Końcowy rozdział dotyczy praktycznego użycia ognia w ochronie przyrody; badania na jego temat są niewątpliwie potrzebne. W zakończeniu autorka dziękuje za pomoc w pracy, zwłaszcza Ś.P. Janowi Kornasiowi. Całość zamyka obszerny spis literatury, a ilustrują fotografie i rysunki roślin.

Słowa kluczowe: pożar, cechy pirofitów, Lusaka, ochrona przyrody, powierzchnie obserwacyjne, badania fitosocjologiczne

Information about the author

Anna Medwecka-Kornaś

Professor of botany, phytosociologist, phytogeographer, plant ecologist, and nature protection activist, particularly interested in plant geography. She was employed at the Institute of Botany of the Jagiellonian University in Kraków (Cracow) and for some years at two institutes of the Polish Academy of Sciences – the Institute of Botany and chiefly at the Institute of Nature Conservation (there, as a director for some years). She participated in numerous scientific expeditions, also outside Europe, including to North America (1959), South America (1967), and Africa (1972–1973) – together with her husband Prof. Jan Kornaś. The trips to North America resulted in studies on the geographic replacement of deciduous forest communities from Canada and Central Europe. She had scientifical relations with SIGMA – Geobotanical Station in Montpelier and studied at the Centre of Geobotanical Cartography in Toulouse (France). After exploring Africa (Zambia, Tanzania, and Nigeria) she wrote original articles on the role of fire in the functioning of plant communities in savannah and dry forests (e.g. 1980, 1993, 2013). The result of her cooperation with the University of Skopje was a phytosociological study on the forests in Macedonia, in which warm oak forests were characterised publication of 1986. From Africa and other journeys, she brought abundant floristic collections, which she donated to the herbarium of the Institute of Botany of the Jagiellonian University. Author of over 160 scientific works, about 80 other publications, including more than 35 scientific reviews, co-author of some books, chiefly two editions of “Vegetation of Poland” and “Plant geography”.

Professor Anna Medwecka-Kornaś with her husband, Professor Jan Kornaś (Source: the Author's own collection)