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THE COPPER FLORA OF KATANGA: A PHYTOGEOGRAPHICAL ANALYSIS

La flore cupricole du Katanga: une analyse phytogéographique

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RESUME

Après avoir brièvement évoqué la diversité des groupements végétaux des anomalies métallifères de l'arc cuprifère katangais, le point sur la récolte du matériel végétal des différents gisements a été réalisé. Se discernent ainsi aisément des zones fortement prospectées d'un point de vue botanique, alors que d'autres sont méconnues. Sur base de ces récoltes, des aspects évolutifs se rapportant à cette flore (diversité, taxons endémiques et hyperaccumulateurs) sont développés au sein du système de Stebbins. Leur analyse a permis de mettre en évidence une bonne représentation des familles les plus évoluées au sein de la flore cupricole.

ABSTRACT

After a brief summary of the metalliferous anomalies vegetation units diversity of the Katangan copper bow, an in-depth look at the vegetal material collection effort on the outcrops has been done. Areas most prospected from a botanical point of view can easily be distinguished from unknown others. On the basis of these collections, some evolutionary aspects regarding the flora (diversity, endemic and hyperaccumulator taxa) are developed according to the Stebbins system. Their analysis showed a good representation of the more advanced families among the copper flora.

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INTRODUCTION

The earliest mention on the existence of a particular flora on Katangan mineralised outcrops appears in a paper of DE WILDEMAN (1921) who commented on the observation by prospectors of the yellow chlorotic colour of leaves of a dwarf fig just before leaf fall. We now know that it was almost certainly copper which was responsible for this chlorosis, as was observed in the case of *Uapaca robynsii* by DUVIGNEAUD & DENAEYER-DE SMET (1963) and BROOKS *et al.* (1992).

As early as 1932 already ROBYNS presented a first study dealing with this flora as well as with copper vegetation. If plant geographical comments have to be found in several papers of DUVIGNEAUD and its co-workers (DUVIGNEAUD 1958, 1959, DUVIGNEAUD & DENAEYER-DE SMET 1963) as well as in BROOKS & MALAISSE papers (BROOKS & MALAISSE 1985, 1989, MALAISSE 1983, 1984, 1995, MALAISSE *et al.* 1998), no phytogeographical study, based on a strong floristic list, has taken place until today.

The aim of our paper is to fill this gap.

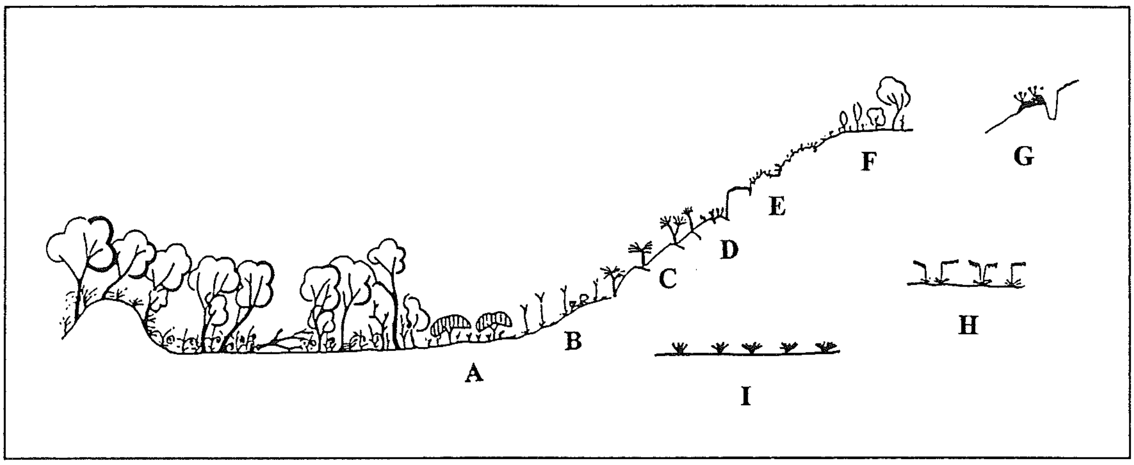
MILIEU DIVERSITY

DUVIGNEAUD (1958), DUVIGNEAUD & DENAEYER-DE SMET (1963), BROOKS & MALAISSE (1985) and finally LETEINTURIER *et al.* (1999) provide, successively, a better knowledge of the various vegetation units present on Katangan copper outcrops as well as regarding their respective ecology.

Until now, for the area concerned, some seventeen vegetation profiles (transects) have been published (DUVIGNEAUD 1958, 1959, DUVIGNEAUD & DENAEYER-DE SMET 1963, MALAISSE & GREGOIRE 1978, MALAISSE *et al.* 1979, 1985, 1994, 1999). Their global patterns have been pinpointed by LETEINTURIER *et al.* (1999), who have recognised seven major vegetation units.

Recently a pioneer stage on copper rocks, already known to exist but, according to our knowledge, never studied in any detail, was sampled from siliceous cellular rocks covered by malachite at Kwatebala hill. Unfortunately, taxonomic determinations regarding the diverse lichens growing on this particular niche is not yet available.

Nevertheless a relative diversity of situation arises in Katanga regarding heavy metal and namely copper soils (Fig. 1). This seems, to some extent, a strong difference with the copper bearing soils of the Copperbelt. Indeed the copper vegetation occurs mainly in the so-called “copper clearings” that are scattered through the miombo open forests and woodlands. It should be noted that some rare sites, distributed in the southeast of Katanga administrative Region, are of this last type (Kipapila, Kimpe, Mabaya and Musoshi), most of copper outcrops of this belt being Zambian.



A: *Uapaca robynsii* shrubby savanna belt ;

B: *Loudetia simplex-Monocymbium ceresiiforme* steppe savanna with *Acalypha cupricola* as characteristic copper differential ;

C: *Xerophyta* spp. stone packed steppe ;

D: Lichens pioneer stage on copper rocks ;

E: Crevace vegetation on rocky outcrops ;

F: *Hymenocardia acida* wooded savanna ;

G: *Haumaniastrum robertii* sward on reworked copper soil ;

H: *Rendlia altera* sward on compacted soil ;

I : *Bulbostylis pseudoperennis* sward.

Fig.1. - Main vegetation communities of the Katangan copper bow's metalliferous anomalies (after LETEINTURIER *et al.* 1999)

COLLECTION EFFORT: HISTORICAL BACKGROUND AND VOUCHER AMOUNTS

MALAISSE (1995) presents some preliminary information on the main botanists who have been involved in collecting plants on copper vegetation anomalies in Katanga. Tab. I summarises the main diverse collections that have been set up.

Regarding an approach of the total amount of plant voucher specimens collected on Katangan copper outcrops, several difficulties are encountered. As is generally the case, field notes of the various collectors are, evidently, not all available. Nevertheless, due to the courtesy of Mrs. Laure DUVIGNEAUD-BLERET, Professor Paul. DUVIGNEAUD's widow, we have had the opportunity of a first hand documentation regarding this principal collector.

Tab.I. - Main collections and Katangan copper sites

Cupriferous site		Voucher specimens collected	Total
Bona	16		0
Chabara	12	(b) 12; (e) 1; (g) 201; (n) 57; (o) ?; (r) 14; (w) ?; (aa) 34	319
Chilonge (near Tenke)*		(aa) 11	11
Chitamba	11		0
Dikulushi	69	(n) 1; (p) 9	10
Dikuluwe	2	(g) 353; (n) 24; (r) 20; (y) ?	397
Disele	35	(n) 3	3
Etoile (= Kalukuluku)	63	(a) ?; (c) ?; (e) 3; (f) ?; (g) 108; (h) 3; (k) 10; (l) 10; (m) ?; (n) 192;	365
		(o) ?; (r) 17; (s) ?; (t) ?; (u) ?; (w) ?; (x) ?; (z) ?; (aa) 22	
Fungurume	31	(e) 12; (g) 151; (n) 102; (o) ?	265
I	31	(g) 23	23
II	31	(g) 23	23
III	31	(p) 8	8
IV	31	(g) 1; (n) 37; (n) 50	88
V	31	(n) 44; (p) 59; (q) 9; (r) 42; (aa) 61	215
VI	31	(n) 30; (p) 5	35
"Grand Fungurume"	31		0
"Petit Fungurume"	31	(g) 39	39
Fungurume total	31	(e) 12; (g) 237; (n) 213; (p) 122; (q) 9; (r) 42; (aa) 61	696
Goma	30	(n) 5	5
Kabwelunono	23	(n) 2; (q) 17; (aa) 19	38
Kabwima	9		0
Kahumbwe	37	(n) 16; (w) ?	16
Kakanda	39		0
Kakavilondo	21	(g) 27; (q) 4;	31
Kakonge*		(g) 30	30
Kakontolwa	13		0
Kalabi	47	(i) 2	2
Kalongwe	1	(g) 186	186
Kalukundi	18	(g) 20; (n) 6	26
Kamatanda	48	(g) 173; (n) 27	200
Kambove	46	(g) 8; (n) 3; (o) ?; (u) ?; (x) ?	11
7 km W		(r) 5	5
Kamoto	7	(g) 6; (n) 18	24
Kamoya	45	(g) 228; (n) 15; (aa) 33	276
Kamwali	52	(g) 29	29
Kankeru	36	(e) 1; (n) 3	4
Kansuki	10		0
Karavia	64	(g) 7; (n) 26	33
Kasankaita	17		0
Kasombo	60	(d) ?; (e) 3; (n) 19;	22
Kasompi	19	(g) 152	152
Kasonta	56	(g) 133; (n) 61; (o) ?; (aa) 12	206
Kavifwafwaulu	25	(q) 30	30
Kazinyanga*		(y) ?	0
Kela	32	(e) 1; (n) 30	31
Kilamusembe	5	(n) 10	10
Kimpe	66		0
Kinsevere	54	(w) ?	0
Kipapila	65		0
Kipushi	59	(o) ?	0
Kwatebala	26	(n) 81; (q) 45	126

Likasi	50	(g) 34; (s) ?; (u) ?	34
Lufomboshi	34		0
Luishia	51	(g) 10; (j) 1; (n) 14; (aa) 17	42
Luiswishi	61	(g) 212; (n) 158; (o) ?; (r) 24; (aa) 23; (t) ?; (u) ?	417
Luita	38	(e) 9; (n) 46; (aa) 13	68
Lukuni	55	(n) 34	34
Lupoto	57	(d) ?; (e) 1; (g) 18; (n) 49; (x) ?; (aa) 13	81
Mabaya	67	(o) ?	0
Mambilima	28	(q) 13; (y) ?	13
Mashamba	4	(n) 25	25
Mashitu*		(g) 16	16
Menda	20	(e) 2; (g) 84	86
Mindingi	40b	(g) 109; (aa) 4	113
Mirungwe	40a	(e) 1; (n) 55; (aa) 12	68
Mitonte	41	(g) 67	67
Mupapala	33	(n) 5	5
Mupine	3	(g) 94	94
Musoshi	68		0
Mutoshi (ex-Ruwe)	6	(w) ?; (aa) 3	3
Mwadikomba	27	(q) 6	6
Mwana Mumba**		(n) 10	10
Niamumenda	58	(g) 104	104
Ngoma*		(n) 32	32
Pungulume	15		0
Ruashi	62	(g) 103; (n) 18; (s) ?; (u) ?; (v) ?; (x) ?	121
Safwe	14		0
Shimbidi	24	(q) 17	17
Shinkolobwe	44	(e) 12; (n) 68; (o) ?; (aa) 10	80
Milestone XIII	44	(r) 8	8
Principal	44		0
Signal	44	(r) 9	9
Shinkolobwe Total	44	(e) 12; (n) 68; (o) ?; (r) 17; (aa) 10	117
Shituru	49	(n) 10; (aa) 5	15
Sokoroshe	53	(n) 9	9
Swambo	42	(e) 2; (g) 112; (n) 31; (aa) 10	155
Tantara	43	(g) 8; (n) 10	18
Tenke	22	(e) 1; (g) 87	88
Tilwezembe	8	(g) 112; (n) 36; (r) 10; (aa) 6	164
Zikule	29	(q) 5	5
			5.301
(*) site not appearing on Figure 2			
(**) polluted sites			

Collectors:

(a) Bamps P.; (b) Bamps P. & Malaisse F.; (c) Bercovitz I.; (d) Bodenghien A.; (e) Bodenghien A. & Malaisse F.; (f) Breyne H.; (g) Duvigneaud P. (including "Duvigneaud & Timerman"); (h) Evrard C.; (i) Hoffmann E.; (j) Kisimba M.; (k) Kisimba & Muzinga Y.; (l) Léonard J.; (m) Lisowski S.; (n) Malaisse F.; (o) Malaisse F. & Goetghebeur P.; (p) Malaisse F. & Grégoire J.; (q) Malaisse F., Kisimba K. & Musinga Y.; (r) Malaisse F. & Robbrecht E.; (s) Ndjele; (t) Quarré P.; (u) Robyns W.; (v) RR PP Salésiens; (w) Schaijes M; (x) Schmitz A.; (y) Shewry P.R., Woolhouse H.W. & Thompson K.; (z) Symoens J.J., De Bilde J. & Schwind F.; (aa) TROPMETEX.

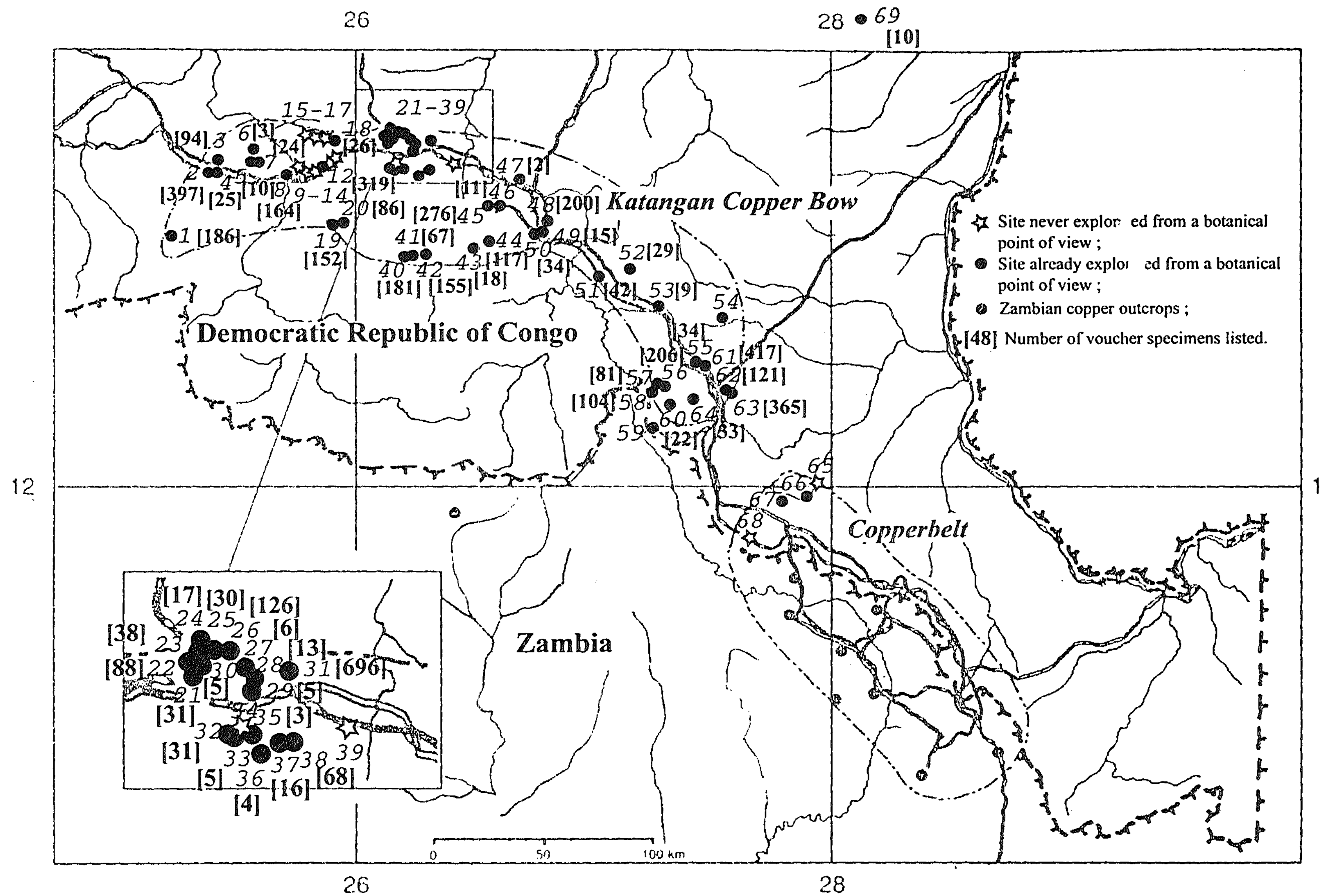


Fig.2. - Botanical prospecting and records on Katangan copper sites

Fig. 2. (on opposite page) List of the site already explored

1 - Kalongwe
2 - Dikuluwe
3 - Mupine
4 - Mashamba
5 - Kilamusembe
6 - Mutoshi (ex-Ruwe)
7 - Kamoto
8 - Tilwezembe
9 - Kabwima
10 - Kansuki
11 - Chitamba
12 - Chabara
13 - Kakontolwa
14 - Safwe
15 - Pungulume
16 - Bona
17 - Kasankaita
18 - Kalukundi
19 - Kasompi
20 - Menda
21 - Kakavilondo
22 - Tenke
23 - Kabwelunono
24 - Shimbidi
25 - Kavifwafwaulu
26 - Kwatebala
27 - Mwadikomba
28 - Mambilima
29 - Zikule
30 - Goma
31 - Fungurume
32 - Kela
33 - Mupapala
34 - Lufomboshi
35 - Disele
36 - Kankeru
37 - Kahumbwe
38 - Luita
39 - Kakanda
40a, 40b - Mirungwe, Mindingi
41 - Mitonte
42 - Swambo
43 - Tantara
44 - Shinkolobwe (Principal, Signal, Milestone XIII)
45 - Kamoya
46 - Kambove
47 - Kalabi
48 - Kamatanda
49 - Shituru
50 - Likasi
51 - Luishia
52 - Kamwali
53 - Sokoroshe I
54 - Kinsevere
55 - Lukuni
56 - Kasonta
57 - Lupoto
58 - Niamumenda
59 - Kipushi
60 - Kasombo
61 - Luiswishi
62 - Ruashi
63 - Etoile (Kalukuluku)
64 - Karavia
65 - Kipapila
66 - Kimpe
67 - Mabaya
68 - Musoshi
69 – Dikulushi

Even if a further detailed study is under way regarding the various collectors, we are already able to take provisional data into account. A second difficulty arises when collecting vegetation units are concerned; the definition and limits of copper influenced environment being differently regarded according to the botanists concerned. For Katanga, this is fortunately mainly the case for the earlier collector's labels. Indeed, at the opposite of what has occurred in Zimbabwe, Duvigneaud's vegetation units' denomination has been followed up by most of the later collectors, so that there exists generally no doubt regarding the relationship between plants and copper anomalies. Tab.I and Fig.2 quote values concerning the global amount of vouchers collected on each site, values given being by default.

Clearly it appears that some outcrops have been very heavily prospected from a botanical point of view (Fungurume, ...) while others are still unknown (Kasankaita, ...). Nevertheless, a site is well prospected only if it has been visited at the five different seasons.

Tab.I lets us know that more than 5,300 specimens have been recorded on the Katangan copper sites. Of course this number has to be taken by default.

THE COPPER FLORA: RICHNESS, ENDEMISM, PHYTOGEOCHEMICAL AND EVOLUTIONARY PATTERNS

RESULTS

After having made the point on the copper flora, endemics and hyperaccumulators, we will analyse the Katangan copper flora from an evolutionary point of view. Several evolution systems of Magnoliophyta's family have been suggested during the three last decades. We will use the Stebbins' (STEBBINS 1974).

Flora

The present study deals exclusively with Pteridophyta and Magnoliophyta. According to our survey, some 540 taxa occurs, at least, on Katanga copper outcrops. The relative importance of the various orders and families to which they belong has been established (Tab.II). The evolutionary aspect of this flora, according to STEBBINS' representation, is given on Fig.3.

Endemism

If some ruderal plants are known from several ecosystem, some cuprophytes are literally linked with the presence of abnormal copper amounts in the soil. Today, we recognise 35 Katangan copper outcrops endemics (Tab.III). Some of them are known from only two or one sites. Among these 35 endemics, six have today disappeared and exist only as voucher specimens. Five of them were known only from the Dikuluwe site, totally exploited and destroyed today. The evolutionary representation of the endemics is given on Fig.4.

Copper hyperaccumulators

BROOKS et al. (1977) define the terms of "copper hyperaccumalator" for a plant for which the dry matter of the analysed part is superior to 1,000 $\mu g.g^{-1}$. Today, 25 Katangan copper hyperaccumulators are quoted in the literature (BROOKS et al. 1978, MALAISSE et al. 1978, MORRISON et al. 1979). They are listed with their respective copper amounts accumulated in Tab. IV and their evolutionary representation is given on Fig.5.

DISCUSSION

With the exception of Hamamelidae (in the subclass of Magnoliopsida) and of Arecidae and Alismatidae (in the subclass of Liliopsida), all the superorders of the Magniliophyta class are represented on the Katangan copper outcrops.

Tab.II. - Importance of the different orders and families
Ng: number of genus; Nt: number of taxa

Class	**Subclass**	**Superorder**	**Order**	**Family**	**Ng**	**Nt**
Pterido-phyta	Sphenopsida		Equisetales	Equisetaceae	**1**	**1**
	Lycopsida		Selaginellales	Selaginellaceae	**1**	**2**
	Pteropsida		Ophioglossales	Ophioglossaceae	**1**	**2**
			Filicales	Actiniopteridaceae	1	3
				Adiantaceae	4	7
				Aspidiaceae	2	3
				Aspleniaceae	1	1
				Athyriaceae	1	1
				Cyatheaceae	1	1
				Davalliaceae	2	2
				Pteridaceae	3	4
				Schizeaceae	3	3
				Sinopteridaceae	1	4
					19	**29**
Magniolio-phyta	Magnioliopsida	Magnoliidae	Magnioliales	Annonaceae	**1**	**2**
			Ranunculales	Ranunculaceae	2	2
				Menispermaceae	1	1
					3	**3**
		Caryophyllidae	Caryophyllales	Caryophyllaceae	2	3
				Amaranthaceae	3	4
					5	**7**
			Polygonales	Polygonaceae	**1**	**1**
		Dilleniidae	Theales	Dipterocarpaceae	1	1
				Hypericaceae	1	1
					2	**2**
			Malvales	Tiliaceae	1	4
				Malvaceae	1	1
					2	**5**
			Urticales	Moraceae	**1**	**2**
			Violales	Passifloraceae	1	1
				Begoniaceae	1	1
				Cucurbitaceae	2	2
					4	**4**
			Capparales	Capparaceae	**1**	**1**
			Ebenales	Ebenaceae	**1**	**1**
		Rosidae	Rosales	Crassulaceae	1	1
				Chrysobalanaceae	1	1
					2	**2**
			Fabales	Mimosaceae	3	4
				Caesalpiniaceae	3	3
				Fabaceae	17	39
					23	**46**
			Myrtales	Thymeleaceae	1	3
				Melastomataceae	3	4
				Combretaceae	1	5
					5	**12**
			Proteales	Proteaceae	**2**	**3**
			Santalales	Santalaceae	1	2
				Olacaceae	1	1
				Loranthaceae	1	1
					3	**4**

Class	Subclass	Superorder	Order	Family	Ng	Nt
			Euphorbiales	Euphorbiaceae	7	14
				Hymenocardiaceae	1	1
					8	**15**
			Rhamnales	Vitaceae	**1**	**1**
			Sapindales	Burseraceae	1	1
				Anacardiaceae	1	1
					2	**2**
			Geraniales	Oxalidaceae	1	2
				Basalminaceae	1	1
					2	**3**
			Polygalales	Malpighiaceae	1	1
				Polygalaceae	2	9
					3	**10**
			Apiales	Apiacee	**5**	**6**
		Asteridae	Gentianales	Loganiaceae	1	1
				Gentianaceae	4	7
				Apocynaceae	2	2
				Asclepiadaceae	1	1
					8	**11**
			Polemoniales	Solanaceae	1	1
				Convolvulaceae	2	17
				Boraginaceae	1	1
					4	**19**
			Lamiales	Verbenaceae	2	5
				Lamiaceae	5	29
					7	**36**
			Scrophulariales	Scrophulariaceae	6	39
				Gesneriaceae	1	1
				Bignoniaceae	1	1
				Acanthaceae	11	17
					19	**58**
			Campanulales	Campanulaceae	1	4
				Cypheaceae	1	1
				Lobeliaceae	1	2
					3	**7**
			Rubiales	Rubiaceae	**12**	**17**
			Dipsacales	Dipsacaceae	**1**	**1**
			Asterales	Asteraceae	**39**	**104**
	Liliopsida	Commelinidae	Commelinales	Xyridaceae	1	1
				Commelinaceae	2	4
					3	**5**
			Poales	Poaceae	**30**	**55**
			Cyperales	Cyperaceae	**7**	**19**
		Liliidae	Liliales	Iridaceae	3	13
				Liliaceae	4	6
				Amaryllidaceae	1	1
				Velloziaceae	1	3
				Smilacaceae	1	1
					10	**24**
			Orchidales	Orchidaceae	**5**	**19**
					246	**540**

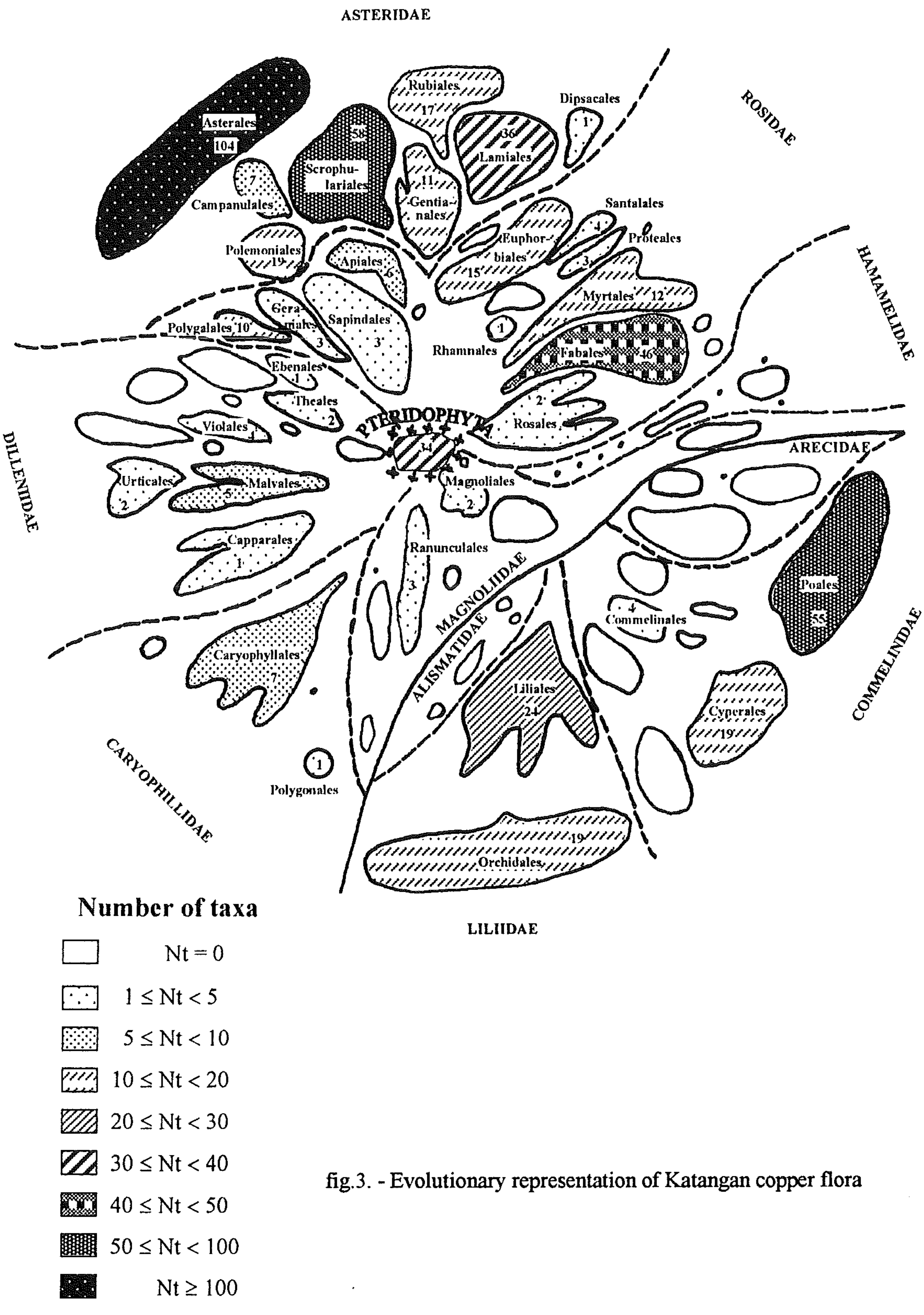


fig.3. - Evolutionary representation of Katangan copper flora

Tab.III. - Katangan copper endemic

Famille	Taxon	Number of outcrops where the taxon can be observed
Acanthaceae	*Justicia metallorum*	3
Actiniopteridaceae	*Actiniopteris kornasii*	2
Adiantaceae	*Pellaea aff. pectiniformis sp. nov.*	1
0Amaranthaceae	*Pandiaka carsoni copper ecotype*	3
Asteraceae	*Vernonia duvigneaudii*	1
	Vernonia ledocteana	†
Campanulaceae	*Wahlenbergia ericoidella*	2
	Wahlenbergia malaissei	1
Caryophyllaceae	*Silene burchelli var. angustifolia copper ecotype*	†
	Silene cobalticola	1
Commelinaceae	*Commelina zigzag*	5
	Cyanotis cupricola	2
Cyperaceae	*Ascolepis metallorum*	9
	Bulbostylis cupricola	21
	Bulbostylis fusiformis	2
	Bulbostylis pseudoperennis	16
	Cyperus kibweanus	1
Euphorbiaceae	*Acalypha cupricola*	10
	Monadenium cupricola	2
Fabaceae	*Crotalaria cobalticola*	11
	Crotalaria peschiana	3
	Vigna dolomitica	1
Gentianaceae	*Faroa chalcophila*	2
	Faroa malaissei	2
Gesneriaceae	*Streptocarpus rhodesianus var. perlanata*	†
Lamiaceae	*Becium grandiflorum var. ericoides biotypus monocotyleoides*	3
	Becium grandiflorum var. metallorum biotypus peschianum	1
	Haumaniastrum robertii	14
Melastomataceae	*Dissotis derriksiana*	†
Passifloraceae	*Basananthe cupricola*	1
Poaceae	*Eragrostis dikuluwensis*	†
Santalaceae	*Thesium pawlowskianum*	2
Scrophulariaceae	*Crepidorhopalon perennis*	2
	Hartliella cupricola	1
Sinopteridiaceae	*Cheilanthes aff. perlanata sp. nov.*	1

As far as the entirety of the Katangan copper flora is concerned, a general trend arises namely the importance of advanced families. This is clearly illustrated on Figure 3. Regarding superorders, Asteridae are in top position, well before Rosidae and Commelinidae. The order of Asterales is really well represented with more than 100 taxa, followed by Scrophulariales and Poales with more than 50 taxa each. Fabales and Lamiales appear respectively in 4th and 5th positions.

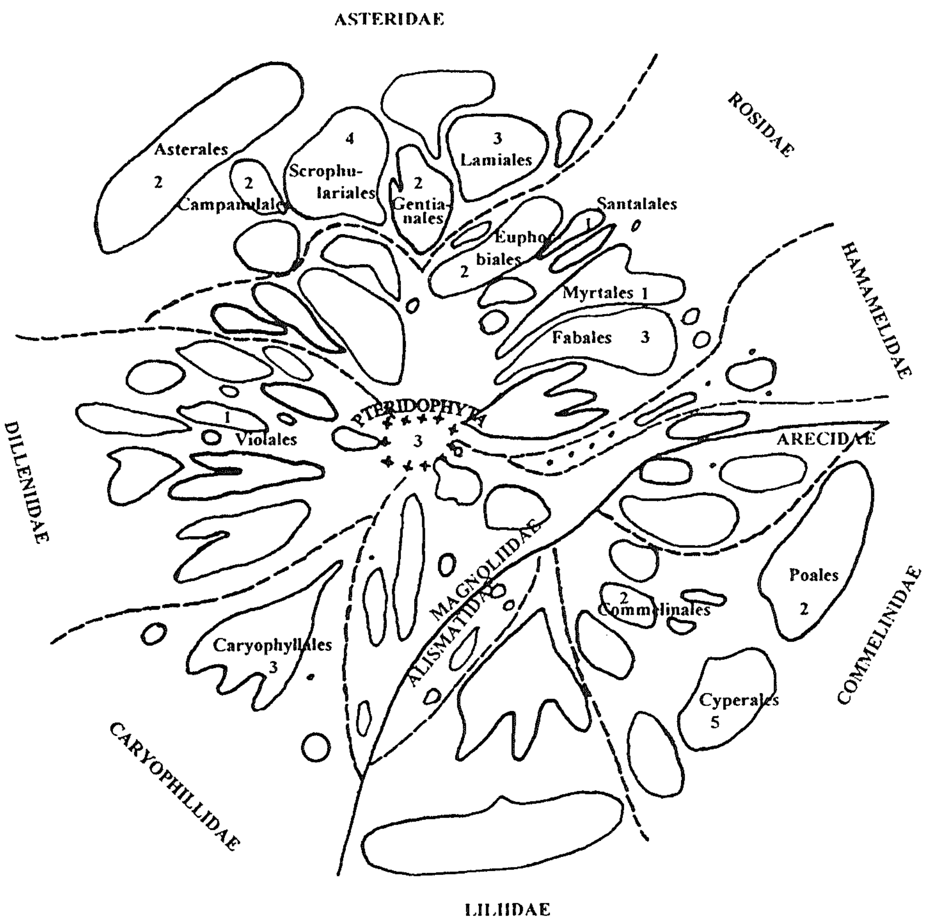


Fig.4. - Evolutionary representation of Katangan copper endemics

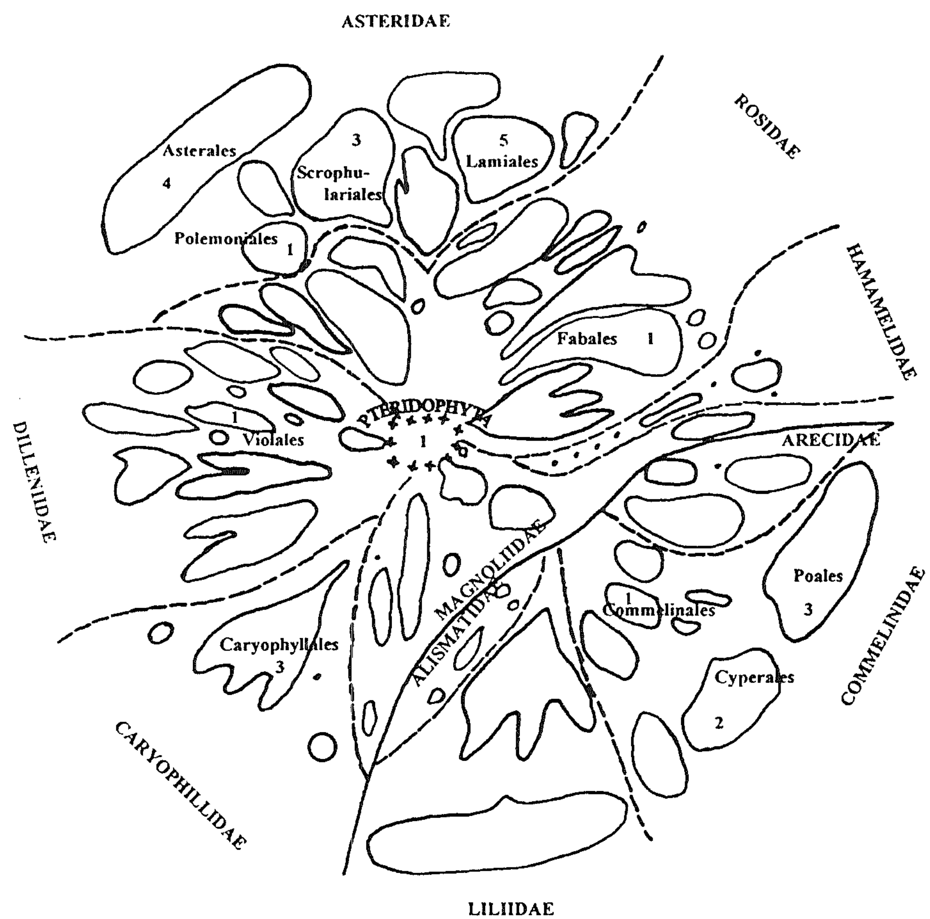


Fig.5. - Evolutionary representation of Katangan copper hyperaccumulators

Tab.IV. - Katangan copper hyperaccumulators

Family	Taxon	Copper ($\mu g.g^{-1}$)	References
Actiniopteridaceae	*Actiniopteris kornasii*	3,535	(7)
Amaranthaceae	*Celosia trigyna*	2,051	(7)
	Pandiaka carsonii (copper ecotype)	6,260	(3)
Asteraceae	*Anisopappus chinensis* ssp. *chinensis*	1,065	(7)
	Anisopappus davyi	3,504	(8)
	Gutenbergia pubescens	5,095	(7)
	Vernonia petersii	1,555	(5)
Caryophyllaceae	*Silene cobalticola*	1,660	(1)
Commelinaceae	*Commelina zigzag*	1,210	(3)
Convolvulaceae	*Ipomoea linosepala* ssp. *alpina*	12,300	(3)
Cyperaceae	*Ascolepis metallorum*	1,200	(1)
	Bulbostylis pseudopernnis	7,783	(4)
Fabaceae	*Vigna dolomitica*	3,000	(2)
Lamiaceae	*Aeollanthus subacaulis* var. *linearis*	3,920	(2)
	Becium grandiflorum var. *vanderystii*	1,135	(7)
	Haumaniastrum katangense	8,356	(5)
	Haumaniastrum robertii	2,070	(1)
	Haumaniastrum rosulatum	1,089	(7)
Poaceae	*Eragrostis racemosa*	2,800	(2)
	Rendlia altera	1,560	(6)
	Sporobolus congoensis	1,671	(8)
Scrophulariaceae	*Buchnera henriquesii*	3,250	(4)
	Crepidorhopalon perennis	9,322	(2)
	Striga hermontheca	1,105	(7)
Tiliaceae	*Triumfetta digitata*	1,060	(4)

(1) : [DUVIGNEAUD & DENAEYER-DE SMET 1963] ;
(2) : [MALAISSE & GREGOIRE 1978] ;
(3) : [MALAISSE *et al.* 1979] ;
(4) : [BROOKS *et al.* 1980] ;
(5) : [BROOKS *et al.* 1982] ;
(6) : [BROOKS & MALAISSE 1985] ;
(7) : [BROOKS *et al.* 1987] ;
(8) : [MALAISSE *et al.* 1994].

Even if Pteridophyta is to be regarded as a primitive taxon, a relative richness of ferns and fern allies may be noted with 34 plants. This results from the xerophytic conditions of the rocky copper rich slopes occurring on several hills, a niche for which several ferns present preferences.

Regarding the evolutionary pattern of the endemic taxa, they are well represented within the Cyperales (5), the Scrophulariales (4) and the Lamiales (4). It is quite interesting to note that from the 19 Cyperales observed on copper outcrops in Katanga, 5 are endemic to these sites as, on the other way, from the 104 Asterales growing on these sites, only two are endemic. Poaceae and Cyperaceae, both of importance in these herbaceous vegetations, show some differences. Whilst endemic species have to be found in some genera of Cyperaceae (namely *Ascomepsis*

Bulbostylis), the grasses observed are most characterised by a wide ecology, including man made heavy metal polluted sites.

At the family level, Cyperaceae is the most represented with 5 endemic taxa, before Lamiaceae (4), Euphorbiaceae (3), Fabaceae (3) and Gentianaceae (3). At the genus level, it is interesting to notice that 3 *Bulbostylis* and 3 *Becium* are concerned (Tab. III).

If endemic taxa are mostly to be found in advanced families, nevertheless, the existence of three copper endemic ferns is of interest; each of them, being observed on one or two copper outcrops, according to our present knowledge.

Moreover, a lot of endemics belongs to genera with their diversity centre located either in the Katangan-Zambian domain as defined by MALAISSE (1997), *Crepidorhopalon* for instance, or at least in the Zambezian regional centre of endemism, as defined by WHITE (1983), *Crotalaria* namely. The best example is given by the genus *Hartliella*, which distribution is restricted to High Katanga and of which two of the four species occur on copper outcrops, *Hartliella cupricola* being restricted to Kahungwe copper hill. Lastly, if the genus *Monadenium* shows a maximum of diversity in the Masai regional centre of endemism, dwarf hysteranthous habit, to which belongs *Monadenium cupricola*, is mainly restricted to the Zambezian centre (MALAISSE & LECRON 1990, MALAISSE *et al.* 1995).

Regarding the evolutionary patterns of the copper hyperaccumulator taxa, it should be noticed, first of all, that among the 25 copper hyperaccumulator taxa recorded, 13 are from Asteridae superorder, while 6 are from the Commelinidae. The comparison of hyperaccumulators versus total copper flora rates for the Asteridae and Commelinidae superorder shows there some analogies with respectively 253/13 and 79/6.

In conclusion, the copper flora of Katanga is tremendous from several phytogeographical aspects. Indeed, it shows an undeniable diversity (about 540 taxa), with an important representation of the advanced families (according to Stebbins' system), a relatively high endemism (6.5 %) belonging mainly to genera with a Zambezian regional centre of endemism. Hyperaccumulators have mainly to be found in Asteridae and Commelinidae superorders.

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