Korean Jour. Botany
Vol. 20, No. 1, 45—52 (1977)

Physiological and Ecological Studies of the Vegetation on Ore Deposits

1. Zinc Flora and Indicator Plants on the 2nd Yunwha Mine

Chang, Nam Kee and Chang Soo Mok
(Department of Biology Education, College of Education, Seoul National University, Seoul)

金屬鑛體上에 나타나는 植物에 관한 生理生態學的 研究

1. 아연광지대의 指標種과 植生

張 楠 基·睦 昌 洙
(서울大學校 師範大學 生物敎育科)

ABSTRACT

During the period of 1975—76, a survey was carried out to find out zinc indicators in the natural vegetation in Korea. The symptoms of chlorosis were observed in flowering plants in the areas of zinc outcrop of Wolgok-A, Seokgok-9, and Sowolgok. Although 28 species were found to be chlorotic, the total quantity of chlorotic foliage observed was small. Reasons for chlorosis in the areas of zinc ore deposits is considered as effects of zinc, lead, copper and calcium ions.

Sedum sp. and *Dianthus sinensis* were confined to soil containing more than exchangeable zinc of 30 ppm and to accumulation in the plants contained at least 1,300—14,000 ppm of zinc. Therefore *Sedum* sp. and *Dianthus sinensis* might be used as zinc indicators in Korea.

INTRODUCTION

Plant communities growing over soils high in copper, lead or zinc have a certain similarity with serpentine floras: plant growth is retarded, broadleaf plants are absent, and endemic forms are to be found (Schwickerath, 1931; Robyns, 1932; Baumeister, 1954; Schwanitz and Hahn, 1954a).

The zinc floras are found in Western Germany and Belgium where the soils are rich in zinc and do not contain inordinate amounts of copper or lead. Early miners were guided to ore deposits by indicators of the zinc flora such as *Viola calaminaria* (Brooks, 1972). The capacity of zinc floras to accumulate zinc is quite remarkable. Linstow (1929) reports that *Thlaspi calaminare* of members of the zinc flora contains ten times as much of this element in the leaves as in the roots.

It is of interest to know how the zinc flora are found in Korea and what effect, if any, of indicators have in determining the flora over soils high in zinc. A survey on a zinc mine in Korea carried out during 1975—76.

MATERIALS AND METHODS

1. Survey method

A care was taken to distinguish chlorosis from symptoms of fungal, virus and insect attack. Records were included only where chlorosis was pronounced and occurred with the greatest severity in the youngest foliage. In 1976 observations were restricted to areas of the zinc ore deposits of Korea and zinc ore dales of the 2nd Yunwha Mine were examined in greater detail and lists of chlorotic species were obtained.

Moreover, the survey was extended to enclude the vegetation in the areas of zinc outcrop and found out indicator plants.

The position of the sites at which lists of chlorotic species were collected is shown in Fig. 1.

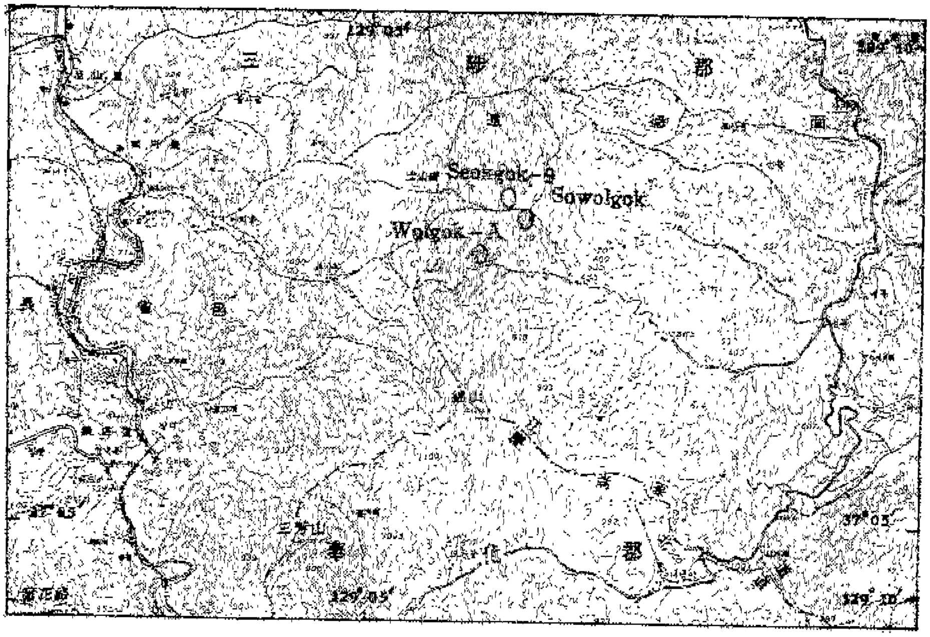

Fig. 1. Map showing the 2nd Yunwha Mine.

Table 1. Chemical analyses of zinc ore in the 2nd Yunwha Mine

Components	Contents, %	Components	Contents, %
Pb	0.35	As	0.23
Zn	4.35	Bi	0.008
Cu	0.12	Cd	0.051
Fe	8.55	Sb	0.004
Mn	1.08	WO_3	trace
SiO_2	60.89	$PbSO_4$-Pb	0.005
CaO	7.38	$PbCO_3$-Pb	0.008
MgO	0.47	SG	3.409
Al_2O_3	2.36	Au	0.1 g/T
S	6.00	Ag	20 g/T

2. Chemical compositions of zinc ore

Chemical compositions of zinc ore in the 2nd Yunwha Mine were given in Table 1. The contents of zinc, lead and copper in this ore are 4.35, 0.36 and 0.12%, respectively.

3. Chemical analyses of plants and soils

The contents of chlorophyll and carotenoid in the normal and chlorotic fresh leaves of plants in the areas of the zinc mine were determined by spectrophotometry.

Plant samples were collected from sites of the zinc.

The material was bulked and thus only one collection from each sites was analysed. The materials were rinsed in distilled water. Flowers, leaves, dead leaves, stems and roots were separated from the plants and oven-dried at 105°C

These materials were ashed in a mixture of nitric and perchloric acids. The analyses of P, K and Na, and of Ca, Mg and Zn carried out by spectrophotometry, flame photometry, and atomic absorption spectrophotometry, respectively. The nitrogen content of the materials was determined by the micro-Kjeldahl method.

Soils were sampled in duplicate from areas about 1m square, which seemed uniform and typical for the site. The samples were taken A_1 horizon from four places within the square. Where there was a superficial layer of stones or plants and roots these were removed before sampling. All analyses were carried out in duplicate on an air-dried fraction of the sample and on a fraction that had passed through a standard 2mm sieve.

Soil pH was determined in a 1 : 2.5 soil/distilled water mixture. Total nitrogen in soils was determined by the micro-Kjeldahl method. Exchangeable cation and hydrogen were analysed by the methods of Brown (1943). Exchangeable K, Na, Ca, Mg, and Zn are extracted by 1 N ammonium acetate solution of pH 7 and determined by flame photometry and atomic absorption spectrophotometry.

Table 2. A comparison of the incidence of chlorosis in areas of the zinc mine in three different dales

Species	Areas		
	Wolgok-A	Seokgok-9	Sowolgok
Arlemisia annua	+	−	+
Artemisia asiatica	−	−	+
Arundinella hirta	−	+	−
Benzoin obtusilobum	+	+	+
Bidens biternata	−	−	+
Callicarpa japonica	+	−	−
Carpinus laxiflora	+	−	−
Castanea crenata	−	−	+
Clematss apiifolia	+	−	−
Commelina communis	+	−	−
Duretia tricuspis	−	−	+
Humulus japonicus	−	+	−
Imperata cylindrica	−	+	−
Indigofera kirilowi	−	−	+
Juglans mandsurica	+	−	−
Lespedeza crytobotrya	+	−	−
Lespedeza Maximowiczii	+	−	−
Ligusirum ibota var. *angustifolium*	−	−	+
Mentha sacharinensis	−	+	+
Miscanthus sinensis var. *purpurascens*	−	+	+
Persicarla hydropiper	−	−	+
Persicaria perfoliata	−	−	+
Quercus mongolica	+	−	−
Rubus crataegifolius	−	+	−
Securinega subfruticosa	+	−	−
Spiraea prunifolia var. *simpliciflora*	+	−	−
Stephanandra incisa	+	−	−
Weigela florida	+	−	+

Photo. 1~5. Explanations of photographs.

1. Chlorosis in *Juglans mandsurica* from vegetation in Wolgok-A,
2. Chlorosis in the young foliage of *Spiraea prunifolia* var. *simpliciflora* on soils in Seokgok-9.
3. Chlorosis in shoots of *Lespedeza Maximowiczii* growing on soils in an area of the 2nd Yunwha Mine.
4. A plant of *Miscanthus sinensis var. purpurascens* with chlorosis on soils in Seokgok-9.
5. Vegetation on soils of zinc outcrop in Seokgok-9.

Available phosphorus is extracted with Truog's reagent and analysed by spectrophotometry.

RESULTS AND DISCUSSION

1. A feature of vegetation

Chlorotic plants were frequently observed in the vegetation of the area of the 2nd Yunwha Mine during the period from May to September.

The proportion of foliage affected was small, although locally chlorosis was severe. Between 14 and 18 July, records of chlorosis were collected from three dales (Table 2).

Chlorotic symptoms in Wolgok-A were 14 species of flowering plants. Chlorotic individuals of 7 species were observed in Seokgok-9 during this survey. In Sowolgok chlorosis was especially extensive and severe in 13 species. Chlorotic individuals of 28 species were shown in the areas of the 2nd Yunwha Mine. According to Chung (1965), exceeding zinc ion showed yellow color of leaf tips of *Digitaria sanguinalis* var. *cilialis* and cases of lead and copper occurred chlorotic symptoms with reddish spots of the leaves of *Chenopodium album* var. *centrorubrum* and *Echinochloa Crusgalli*. Grime and Hutchinson (1967) reported that lime-chlorosis is clearly of widespread occurrence in England. Since there was zinc ore within lime-stone in the areas of the 2nd Yunwha Mine, the calcium levels in soils of those area were very high.

Moreover, as shown in Table 1, the contents of zinc, lead, copper and calcium in the zinc ore are 4.35, 0.36, 0.12 and 7.38%, respectively. Soils in the areas of the zinc outcrop contained about 10 times as much exchangeable zinc levels as the control site (Table 3). It is also apparent that the observations of chlorotic sign are consistent with results obtained by Chung (1965), and Grime and Hutchinson (1967). Therefore, it seems possible that chlorosis in these area is pronounced and occurred by the effects of zinc, lead, copper and calcium.

2. Chlorosis

Chlorosis of the several herbaceous species including *Miscanthus sinensis* var. *purpurascens* (Phot. 4) was often apparent in the main shoots remained green. The trees and shrubs such as

Table 3. Chemical analyses of soil in the area of zinc outcrop and control area

Components	Zinc ore areas		Control areas	
	Wolgok-A	Seokgok-9	Danyang	Kwangsi
Soil pH	6.85	6.80	6.90	6.00
Exchangeable P (meg/100g)	11.0	9.9	4.8	2.1
Exchangeable cation(〃)	14.08	14.08	12.98	3.08
Total nitrogen (%)	0.308	0.952	0.406	0.336
Available P (ppm)	0.25	0.69	1.99	0.84
Exchangeable K (ppm)	178.9	1795.5	176.0	121.2
Exchangeable Ca (ppm)	1170	4680	4264	258
Exchangeable Mg(ppm)	241.8	171.0	210.1	840.0
Exchangeable Na(ppm)	102.2	212.3	125.8	86.5
Exchangeable Zn(ppm)	30.8	33.8	3.0	2.6

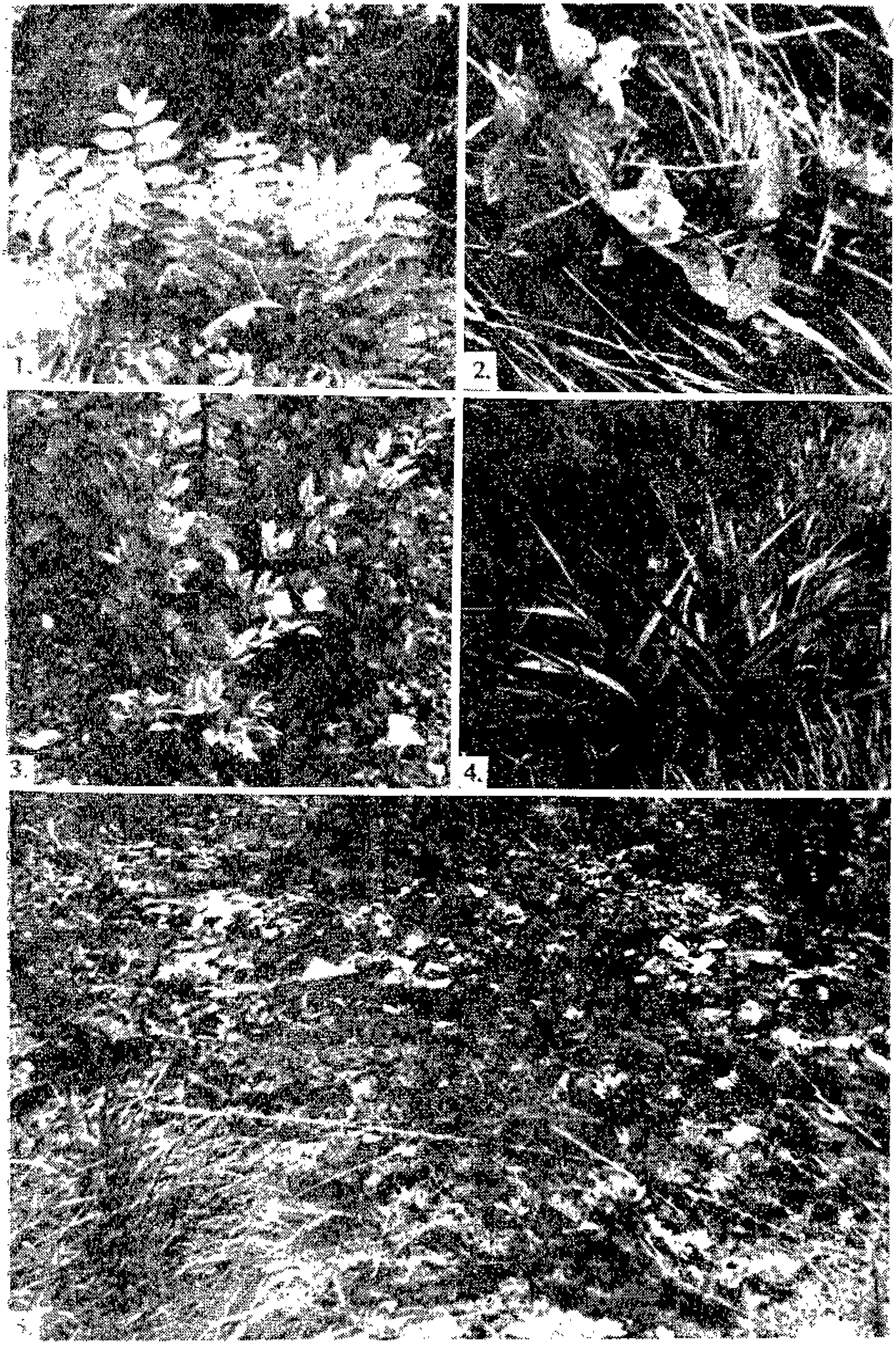
1.
2.
3.
4.

Table 4. The comparison of the amount of chlorophyll and carotenoid in the normal and chlorotic fresh leaves of plants in the area of zinc mine

Species		Chlorophyll a (mg/l)	Chlorophyll b (mg/l)	Chlorophyll a / Chlorophyll b	Total chlorophyll (mg/l)	Total carotenoid (mg/l)
Wolgok-A						
Juglans mandsurica	Normal	10.472	7.117	1.5	17.576	1.40
	Chlorosis	5.137	3.586	1.5	8.717	1.20
Quercus mongolica	Normal	9.328	6.398	1.5	15.714	1.62
	Chlorosis	5.045	3.438	1.5	8.478	1.32
Benzoin obtusilobum	Normal	9.351	5.870	1.6	15.210	2.17
	Chlorosis	3.404	2.860	1.2	6.260	1.48
Miscanthus sineesis var. *purpurascens*	Normal	7.591	6.200	1.3	13.760	2.32
	Chlorosis	4.397	2.579	1.7	6.972	1.99
Lespedeza maximowiczii	Normal	8.556	6.095	1.4	14.640	0.98
	Chlorosis	6.413	3.573	1.8	9.979	0.73
Seokgok-9						
M. sinensis var. *purpurascens*	Normal	7.069	4.256	1.7	11.317	3.02
	Chlorosis	2.687	1.325	2.1	4.010	2.94
Artemisia annua	Normal	7.808	5.263	1.5	13.063	2.47
	Chlorosis	4.404	2.403	1.9	6.804	2.36
Indigofera kirilowi	Normal	5.908	3.889	1.6	9.791	1.96
	Chlorosis	3.061	1.740	1.8	4.799	1.65
Benzoin obtusilobum	Normal	11.915	7.751	1.6	9.652	2.54
	Chlorosis	6.258	4.833	1.3	11.084	1.60

Juglans mandsurica (Phot. 1), *Spiraea prunifolia* var. *simpliciflora* (Phot. 2), and *Lespedeza maximowiczii* (Phot. 3) were subject to severe chlorosis.

Chlorosis was often distributed asymmetrically in the canopy of a shrub or a tree so that only one side or only certain branches were affected. The ecological aspect of tree chlorosis was frequently observed in a mosaic pattern of yellow-green and green.

The comparison of the contents of chlorophyll and carotenoid in the normal and chlorotic foliages of several plants in the areas of the zinc mine is given by Table 4.

The amount of chlorophyll a and b in the chlorotic leaves was about half in the normal. Carotenoid levels of chlorotic plants were lower than normal leaves. It suggests that chlorosis shows decrease of chlorophyll and carotenoid contents in plant leaves.

3. Indicators to the zinc ore deposits

Most of vegetation of the core areas of the zinc outcrop falls into two types of *Sedum* sp., and *Sedum* sp.-*Dianthus sinensis* communities (Photo. 5). All the sites have areas with less than 10% plant cover. These are quite distinct and are dealt with separately. A number of plants have been classified as zinc indicators but these species are confined mainly to Europe (Brooks, 1972). Dorn (1937) in his well known, though somewhat unselective, listing of indicators has also included a number of poorly documented species from Brazil. The same author has included *Amorpha canescens* as a zinc indicator from the United States, altho-

Table 5. Inorganic components of *Sedum* sp. and *Dianthus sinensis*

Speices		N (%)	P (ppm)	K (%)	Ca (ppm)	Mg (ppm)	Na (ppm)	Zn (ppm)
Zinc ore area								
Sedum sp.	(DL)	0.84	123	2.05	4675	163	1651	14125
Sedum sp.	(L)	1.37	247	3.08	4950	155	1180	6875
Sedum sp.	(S)	1.79	714	4.40	3100	160	1887	3450
Sedum sp.	(R)	1.51	136	1.91	1800	138	1337	10375
Dianthus sinensis	(F)	1.93	1130	3.91	900	95	708	775
Dianthus sinensis	(L)	2.31	504	2.93	1350	108	629	2000
Dianthus sinensis	(S)	1.47	440	3.23	500	25	1730	1325
Dianthus sinensis	(R)	1.26	121	1.81	375	48	1101	3500
Control area								
Dianthus sinensis	(F)	1.65	536	2.49	525	295	550	35
Dianthus sinensis	(L)	1.23	470	2.83	1125	480	354	39
Dianthus sinensis	(S)	0.84	372	2.25	825	308	668	37
Dianthus sinensis	(R)	0.84	107	1.86	250	220	590	42

*DL; dead leaves, L; leaves, S; stems, R; roots, F; flowers.

ugh according to Cannon (1960b) it does not grow on mineralized ground. Cole et al.(1968) reported on the association of *Gomphrena canescens*, *Polycarpaea synandra* var. *gracilis*, and *Tephrosia polyzyga* with lead and zinc mineralization in the Bulman-Waimuna Springs area of Northern Territory, Australia.

Inorganic components of above and under ground parts of *Sedum* sp. and *Dianthus sinensis* growing on soils of zinc ore deposits were presented in Table 5. Accumulation of zinc by dead leaves, stems and roots of *Sedum* sp. occupied 14, 125, 6,875, 3,450, and 10,375 ppm/D.M., respectively. As shown in Table 5, *Dianthus sinensis* accumulated zinc of 775—3,500 ppm/D.M. from 30 ppm. of exchangeable zinc in soils of zinc outcrop. This amount of zinc contains 20—80 times as much of this element in the plant on control area. Although none of *Gomphrena canescens* and *Tephrosia polyzyga* officially classified as an indicator, Cole et al. (1968) noted that the former was confined to soils containing more than 5,000 ppm zinc and the latter was confined to substrates containing at least 1,000 ppm zinc. Therefore, according to the results of Tables 3 and 5, the author has classified *Sedum* sp. and *Dianthus sinensis* as zinc indicators on zinc ore deposits in Korea.

要 約

아연광 露頭에 生育하고 있는 植物의 生理 生態學的 特徵을 알고 있으면 이것을 利用하여 아연광의 탐사를 수행할 수 있으므로, 강원도 삼척군 원덕면 제 2 연화 광산지역에서 1975~76년에 걸쳐 아연광에 대한 지표종과 식피의 변화를 연구하였다. 월곡—A, 석곡—9, 소월곡지역에서 chlorosis가 일어난 식물이 28종 조사되었으며, chlorosis는 잎에 부분적으로 나타났다. 아연광지역에서 chlorosis가 일어난 것은 과잉의 아연, 납, 구리와 칼슘이온의 영향이라고 본다. 아연꽃(*Sedum* sp.)과 패랭이꽃(*Dianthus sinensis*)은 토양의 치환성 아연함량 30 ppm 보다도 훨씬 많은 1,300~14,000 ppm의 아연을 축적하고 있었다. 따라서 아연꽃(*Sedum* sp.)과 패랭이꽃(*Dianthus sinensis*)을 한국에서의 아연광에 대한 指標種으로 보고한다.

REFERENCES

Baumeister, W. 1954. The influence of zinc in *Silene inflata* Smith. *Ber. Dt. Bot. Gesell.* 67 : 25—213.

Brooks, R.R. 972. Geobotany and biogeochemistry in mineral exploration. New York, Harper & Row Co.

Brown, I.C. 1943. A rapid method of determining exchangeable hydrogen and total exchangeable bases in soil. *Soil Sci.* 56 : 353—357.

Cannon, H.L. 1960. Botanical prospecting for ore deposits. *Science* 132 : 591—598.

Chung, H.K. 1965. A study on the influence of exceeding metallic ions to the symptomatic plants. *J. Korean Ist. Mining* 2 : 176—179.

Cole, M.M., D.M.J. Provan, and J.S. Tooms. 1968 Geobotany, biogeochemistry, and geochemistry in the Bulman-Waimuna Springs area, Northern Territoy, Australia. *Inst. Mining Metallurgy Trans. Sec.* B p.81—104.

Dorn, P. 1937. Plants as a guide to mineral deposits. *Biologe* 6 : 11—13.

Grime, J.P. and T.C. Hutchinson. 1937. The incidence of lime-chlorosis in the natural vegetation of England. *J. Ecology* 55 : 557—566.

Linstow, O. Von. 1929. Plant indicators of soil. *Berlin Preuss. Geol. Landesanstalt.* p. 246.

Robyns, W. 1932. Vegetation and flora of the copper belts of Upper Katanga. *Naturw. Tijdschr.* 14 : 101—106.

Schwanitz, F. and H. Hahn. 1954a. Genetic-developme-nt-physiological investigations on galmei plants. *Zeitscher. Bot.* 42 : 179—190.

Schwickerath, M. 1931. *Viola calaminariae* in zinc soils near Aachen. *Beitr. Nat. Denkm. Pflege.* 14 : 463—503.

(Received February 11, 1977)