Reasons of leaves withering in tropical plants cultivated under greenhouse conditions

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Abstract

In order to determine the reasons of necrosis of exotic plants leaves cultivated in greenhouses plants belonging to ten following species were examined: *Ceratozamia mexicana* Brongn., *Stangeria eriopus* ⟨Kunze⟩ Nash ⟨Cycadaceae⟩, *Eriobotrya japonica* Lindl. ⟨Rosaceae⟩, *Camellia japonica* L. ⟨Theaceae⟩, *Phoenix roebeleni* O'Brien ⟨Palmae⟩, *Sequoia sempervirens* Endl. ⟨Taxodiaceae⟩, *Calathea bachelmiana* Morr. ⟨Marantaceae⟩, *Cordyline terminalis* Kunth ⟨Agavaceae⟩, *Spathiphyllum wallisii* Reg. and *Anthurium magnificum* Lind. ⟨Araceae⟩. Chemical analysis were performed in soil samples in which these plants grow, in samples of tap-water applied for watering and in samples of decaying and healthy leaves. In order to examine the process of withdrawal of mineral components from necrotic leaves, both: necrotic and green parts of decaying leaves were subjected to examination. On the basis of the research it was concluded, that — in spite of generally low level of salinity of the water used for watering — some ions content, particularly that of Cl^- , was unfavourable to plants. Unfavourable ionic composition was discovered in water extracts derived from some of the breeding-ground soils. A comparison of healthy and decaying, necrotic leaves chemism proves that Cl^- assimilated by the plants from the breeding-grounds and accumulated in leaves, affects them toxically.

INTRODUCTION

Survival of exotic intertropical plants collection in our climate is feasible only under greenhouse conditions, still, the greenhouse as a safeguard system does not guarantee maintenance of the same biotope parametres to which the plants adopted themselves in natural environment.

While such factors as air temperature, air and soil humidities can be regulated and maintained on comparatively balanced levels, much more difficult problem lies in reconstruction and preservation of appropriate soil conditions, first of all a concentration of particular ions in soil solution. It is known from practice that greenhouse soil undergoes salinity as a result of fertilizers application. Water used for watering can be the other possible source of soluble salts.

A typical symptom of physiological disorders being found in several exotic plants of Warsaw University Botanical Garden's greenhouses is leaf withering and browning advancing gradually from tops to edges of leaf blades. The identical character of leaf changes for several types of taxonomically distant plants suggested reasons should be sought among abiotical factors. Therefore detailed experiments were undertaken on chemism of healthy and withering leaves, the water used for watering and soil applied in the plants cultivation. The results of the experiments and arising conclusions are presented in this paper.

MATERIALS AND METHODS

In samples of water taken from two greenhouse reservoirs the followings were determined: Ca^{++} , K^+ and Na^+ contents — by flame spectrophotometrical method; Mg^{++} — by atomic absorption method; NH_4^+ — colorimetrically, applying phenol reagent; SO_4^{--} — nephelometrically; H_2PO_4^- — colorimetrically, according to Jackson method; HCO_3^- — acidometrically, with 0.02n H_2SO_4 in presence of methyl orange; Cl^- — argentometrically, with 0.01n AgNO_3 in presence of 10% KCrO_4 .

Soluble salts were extracted from soil samples by the redistilled water, maintaining dry soil: water ratio as 1:5 and 1 hour shaking time of a rotary stirrer. Clear filtrates, in which concentrations of Ca^{++} , Mg^{++} , K^+ , Na^+ , SO_4^{--} , HCO_3^- , Cl^- ions were estimated by the above mentioned methods, were obtained by separation of solutions from a solid soil phase using porcelain funnels with paper filter installed in a system of subpressure sunction flasks.

Leaf samples for the experiments were collected in two terms from such plants whose younger leaves were healthy while older ones were showing pathological changes. In the samples taken on March 22, 1977 mineral components content was estimated both: for the whole of homogenized healthy leaves and for withered ones, while in April 15, 1978 samples only necrotic leaves were tested and mineral components contents separately determined for decayed leaf parts and green, still alive parts. Content of Ca^{++} , Mg^{++} , K^+ , Na^+ , SO_4^{--} and H_2PO_4^- in leaves was being determined after their incineration at 530°C and dissolution of ashes in 10% HCL . However in order to determine the Cl^- content by Hosband/Golden method leaf samples were incinerated with CaO addition at the same temperature, then their ashes dissolved in 1:3 diluted HNO_3 .

RESULTS

Chemism of water applied for watering

The only source of water available to the Botanical Garden greenhouses is Warsaw urban waterworks supply system drawing water from Vistula River. According to previous studies (Czerwiński et al., 1976; Czerwiński and Pracz, 1976) Vistula's water in the vicinity of Warsaw shows higher than normal quantities of magnesium, sodium and chloride.

The water treatment for municipal use is based, among some other things, on chlorination i.e. on its additional enrichment with Cl^- ions (Table 1).

Table 1
Content of soluble salt ions in water of greenhouse reservoirs

Ions	Content in 1 dm ³ of water			
	Reservoir I		Reservoir II	
	mg	meq	mg	meq
Ca^{++}	56.80	2.83	74.40	3.71
Mg^{++}	2.07	0.17	2.07	0.17
K^+	6.00	0.15	5.40	0.14
Na^+	34.80	1.51	39.20	1.70
NH_4^+	0.79	0.44	0.45	0.025
SO_4^{--}	1.07	0.022	1.19	0.025
H_2PO_4^-	0.05	5.15×10^{-4}	0.018	1.86×10^{-4}
HCO_3^-	172.00	2.81	249.50	4.09
Cl^-	34.40	2.66	112.30	3.17
NO_3^-	2.32	0.037	0.12	1.93×10^{-3}
Sum	370.30	—	484.65	—
pH	7.6	—	7.5	—

The total quantity of dissolved salts observed in the greenhouse reservoirs, amounting to 370.3-484.85 mg/dm³ (Table 1), is admittedly far less than critical limit value, but the ionic composition of these salts is unfavourable from the point of view of their influence on plants. Taking into consideration an equivalential concentration of the particular ions, the following decreasing sequence arrangement can be obtained: $\text{Ca}^{++} \simeq \text{HCO}_3^- \simeq \text{Cl}^- > \text{Na}^+ > \text{Mg}^{++} \simeq \text{K}^+ > \text{NH}_4^+ \simeq \text{NO}_3^- > \text{SO}_4^{--} > \text{H}_2\text{PO}_4^-$. Thus, apart from Ca^{++} and HCO_3^- ions, Cl^- and

Na^+ are dominating in that water. Such state is subject to certain changes already in the greenhouse soil, as a result of a replacement reaction between so called soil solution differentiated by tap water and soil sorption complex. Fertilizers application can result in increase of concentration of such ions as K^+ , NH_4^+ , Cl^- , H_2PO_4^- and NO_3^- . Such an increasing quantity of Cl^- anions in the soil solution creates a possibility of an increasing accumulation of that element in overground parts of the plants. Assuming that if an average transpiration coefficient equals to 500, and that the chloride ion is totally absorbed, than the plant could potentially gather – when the content amounts to 94.4-112.3 mg/cm^3 of water (Table 1) – 47.2-56.15g, or 4.72-5.61% of chloride for each kilogramme of tissue dry mass.

Pathological symptoms of plants and chemism of their leaves and greenhouse soil

Ceratozamia mexicana Brongn. of *Cycadaceae* family occurs in natural humid biotopes of south-eastern Mexico. Under tropical greenhouse conditions leaves of that plant wither gradually starting from their tops. Decayed leaf parts were brown. Soil in the pots contained soluble salts in shape of sulphates, dicarbons and chlorides, 136.5 $\text{mg}/100\text{g}$ of soil (Table 2). Chloride quantity at the rate of 19 $\text{mg}/100\text{g}$ of soil is already harmful for many species (Czerwiński, 1978).

Young, healthy leaves contained relatively small quantity of ash ingredients, among which potassium equivalently predominated (Fig. 1). Low quantity of chloride in healthy leaves at the rate of 1.97 $\text{meq}/100\text{g}$ of dry mass (0.07%), as compared with the high concentration of Cl^- in soil solutions, testifies to minimal absorption of Cl^- from breeding-ground. In the course of growth however chloride quantity in older leaves increases causing occurrence of decay of leaf tops and edges. *Ceratozamia mexicana* proved to be a plant very sensitive to chlorine because even at 10.99 $\text{meq}/100\text{g}$ of dry mass (0.39%) concentration of leaves were already necrotic to a considerable extend (Table 3; Fig. 1). Therefore the critical value at which the first symptoms of chloride poisoning appear is much lower.

It is not only the quality of chlorine which increases in decaying leaves but also proportions of other ions is being changed (Tables 3, 4; Fig. 1). Thus content of calcium increases, what is a normal symptom as time passes and leaves get older, and also amount of potassium decreases almost half way down, because it can be withdrawn from decaying older leaves and transported into the younger once. The migration of particular components occurs not only between older and younger leaves but also within the decaying leaves themselves (Table 4). From the decayed brown zone mostly calcium and magnesium is withdrawn and at the same time sodium, chlorine and SO_4^{--} content increases there. The obtained results point out that *Ceratozamia mexicana* is very sensitive to changes in

Table 2

Content of soluble salt ions and pH in soils from greenhouse

Plant	In 100 g of dry soil	Ions							pH		
		Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺⁻	SO ₄ [—]	HCO ₃ [—]	Cl [—]	Sum	In H ₂ O	In KCl
<i>Ceratozamia</i>	mg	16.60	3.90	5.00	18.60	40.40	33.00	19.00	136.50	7.4	—
<i>mexicana</i>	meq	0.82	0.32	0.12	0.80	0.84	0.54	0.53			
<i>Eriobotrya</i>	mg	6.30	1.83	7.20	6.20	28.10	29.00	0.90	79.53	7.3	6.9
<i>japonica</i>	meq	0.31	0.15	0.18	0.26	0.58	0.47	0.02			
<i>Camellia</i>	mg	5.40	1.98	5.70	7.60	16.30	53.40	6.20	96.58	7.3	7.0
<i>japonica</i>	meq	0.24	0.16	0.14	0.33	0.33	0.87	0.17			
<i>Phoenix</i>	mg	10.40	2.75	10.00	10.00	36.50	38.10	2.70	110.45	7.2	7.0
<i>roebeleni</i>	meq	0.51	0.22	0.25	0.43	0.76	0.62	0.07			
<i>Stangeria</i>	mg	4.90	1.58	4.80	6.50	24.20	77.80	9.80	124.68	7.2	7.0
<i>eriopus</i>	meq	0.24	0.12	0.12	0.28	0.50	1.27	0.27			
<i>Sequoia</i>	mg	4.40	1.36	3.00	5.50	22.00	25.90	trace	62.16	7.3	6.9
<i>sempervirens</i>	meq	0.21	0.11	0.07	0.23	0.45	0.42	—			
<i>Calathea</i>	mg	23.40	8.68	46.20	21.20	83.30	32.00	22.20	236.98	6.7	6.6
<i>bachemiana</i>	meq	1.16	0.71	1.18	0.92	1.73	0.52	0.62			
<i>Cordylina</i>	mg	7.00	1.79	17.80	7.60	32.60	59.50	4.40	130.69	7.6	7.2
<i>terminalis</i>	meq	0.34	0.14	0.45	0.33	0.67	0.97	0.12			
<i>Anthurium</i>	mg	5.20	1.48	6.40	7.20	19.10	22.90	trace	62.28	6.9	6.4
<i>magnificum</i>	meq	0.25	0.12	0.16	0.31	0.39	0.37				

Table 3
Content of elements in healthy leaves — 0 and in necrotic — 1

Plant	State of leaves	Per cent in dry matter							Ratio (Ca+Mg+K+Na):Cl in meq
		Ca	Mg	K	Na	S	Cl	Sum	
<i>Ceratozamia mexicana</i>	0	0.29	0.09	0.87	0.10	0.13	0.07	1.55	12.5
	1	2.03	0.18	0.38	0.28	0.13	0.39	3.39	2.8
<i>Eriobotrya japonica</i>	0	1.19	0.20	2.13	0.18	0.03	0.18	3.73	27.2
	1	2.13	0.19	1.25	0.54	0.13	0.43	4.67	14.6
<i>Camellia japonica</i>	0	1.46	0.35	1.40	0.40	0.38	0.21	4.20	26.2
	1	1.32	0.38	1.37	0.51	0.44	0.43	4.45	12.7
<i>Phoenix roebeleni</i>	0	0.59	0.16	1.18	0.17	0.31	0.16	2.57	17.8
	1	1.09	0.25	0.55	0.42	0.29	0.57	3.17	6.7
<i>Stangeria eriopus</i>	0	0.41	0.19	1.55	0.88	0.15	0.98	4.16	7.4
	1	1.57	0.31	0.79	1.47	0.22	1.60	5.96	4.2
<i>Sequoia sempervirens</i>	0	1.27	0.16	1.57	0.53	0.17	1.51	5.21	3.3
	1	1.78	0.25	1.64	0.77	0.28	1.99	6.71	3.3
<i>Calathea bacheliana</i>	0	0.66	0.28	1.14	0.36	0.20	1.63	4.27	2.2
	1	1.02	0.38	2.90	0.80	0.30	2.41	7.81	2.8
<i>Spathiphyllum wallisii</i>	0	1.32	0.35	4.50	0.42	0.15	2.84	9.54	3.0
	1	3.55	0.49	1.67	1.23	0.23	3.76	10.93	2.9
<i>Cordyline terminalis</i>	0	1.60	0.10	2.94	1.54	0.32	3.12	9.62	2.6
	1	1.59	0.20	2.90	1.90	0.28	3.66	10.53	2.4
<i>Anthurium magnificum</i>	0	2.40	0.39	4.02	0.16	0.22	3.16	10.35	2.9
	1	2.05	0.31	3.91	0.28	0.25	3.58	10.38	2.4

quantitative proportion of particular ions in soil solution and in leaves; in case if the concentration of Cl^- in soil solutions is higher, it draws more of it than needed. That leads to decrease of kation sum to chlorine ratio, from 12.5 for healthy leaves to 2.8 for decaying ones (Table 3). Such reaction of that plant is analogical to a reaction to chloride by *Aesculus hippocastanum* growing under urban conditions in Poland; even slight only contamination of an urban lawn soil by chlorine compounds and increase in Cl^- quantity in leaves from 0.03% to 0.28% results in edge necrosis and gradual shriveling of leaves during vegetation season (Czerwiński, 1978).

The cultivation of the *Ceratozamia* under greenhouse conditions is feasible in cases when water minimal Cl^- contents is available. Use of chlorine containing fertilizers should be avoided too.

Eriobotrya japonica Lindl. of *Rosaceae* family, allied to apple-tree, comes from Central China but is being also cultivated in Japan, India, Mediterranean countries, Crimea, trans-Caucasian country, southern states of the U.S.A. and in

Fig. 1. Content of ions in: a — healthy leaves, b — necrotic leaves, 1 — *Ceratozamia mexicana*, 2 — *Eriobotrya japonica*, 3 — *Camellia japonica*, 4 — *Phoenix roebeleni*, 5 — *Stangeria eriopus*, 6 — *Sequoia sempervirens*, 7 — *Callathea bachemiana*, 8 — *Spathiphyllum wallisii*, 9 — *Cordyline terminalis*, 10 — *Anthurium magnificum*

Chile. The tree, able to reach 8 m of height, is resistant to negative temperatures till -15°C (Pieniążek and Pieniążek, 1964; Podbielkowski, 1974).

Leaves of *Eriobotrya japonica* cultivated in pots in cool greenhouses are subject to withering, process of which begins also in the top parts and advances gradually to cover more and more of the blade surface. Shrivelled parts of leaves are tawny in colour while maintaining turgor alive parts of them, are green. Soil in the pots contained 79.53 mg/100 g of soil of soluble salts, mostly in shape of sulphates and bicarbonate components. Quantity of chlorine was minimal amounting to 0.9 mg/100 g only (Table 2). So the total quantity of soluble salts and their ionic components was favourable from the point of view of the needs of

Table 4
Content of ions in separated parts of necrotic leaves

Plant	Part of leaf	meq in dry matter							Ratio: (Ca+Mg+K+ +Na): Cl in meq
		Ca ⁺⁺	Mg ⁺⁺	K ⁺	Na ⁺	SO ₄ ⁻⁻⁻	H ₂ PO ₄	Cl ⁻	
<i>Ceratozamia</i>	green	101.8	12.3	4.4	6.6	8.9	1.1	7.0	17.9
<i>mexicana</i>	brown	80.8	7.2	3.6	17.7	13.7	1.5	15.0	7.3
<i>Eriobotrya</i>	green	56.8	5.7	33.6	10.9	10.3	1.3	6.5	16.5
<i>japonica</i>	brown	12.5	21.0	2.1	5.9	3.3	1.5	7.5	5.5
<i>Camellia</i>	green	49.4	11.8	27.6	14.3	13.7	1.2	10.5	9.8
<i>japonica</i>	brown	26.9	12.8	11.3	5.5	10.3	2.0	12.0	4.7
<i>Poenix</i>	green	53.9	21.0	14.6	6.3	18.9	1.2	9.0	10.6
<i>roebeleni</i>	dark brown	48.4	21.5	8.7	21.4	23.4	2.6	28.5	3.5
<i>Stangeria</i>	green	65.4	20.6	22.2	30.0	10.3	1.5	32.5	4.2
<i>eriopus</i>	yellow	52.3	24.2	22.2	31.2	11.2	1.9	42.4	3.1
	dark brown	64.9	29.3	20.5	30.8	17.2	2.7	48.4	3.0
<i>Sequoia</i>	green	79.8	28.3	32.7	21.7	13.0	1.5	61.9	2.6
<i>sempervirens</i>	brown	124.7	17.5	15.6	19.1	29.4	2.7	28.5	6.2
<i>Calathea</i>	green	56.1	24.7	53.6	14.4	16.4	2.5	54.6	2.7
<i>bachemiana</i>	brown	50.9	21.0	18.9	25.2	20.3	4.4	27.5	4.2
<i>Cordyline</i>	green	106.8	17.5	51.8	32.6	24.4	2.8	116.1	1.8
<i>terminalis</i>	brown	25.4	4.6	8.1	13.2	4.2	3.0	87.6	0.6
<i>Anthurium</i>	green	107.8	24.7	51.1	6.5	11.2	1.4	75.1	2.5
<i>magnificum</i>	brown	118.8	25.2	34.4	16.5	22.5	2.1	75.1	2.6

the plants belonging to glycophytes group. In spite of low concentration of Cl^- in the soil solutions, chlorine content of decaying leaves of *Eriobotrya japonica* amounted to 0.43% and was almost 2.5 times greater than that of the healthy leaves. The shriveling leaves contained higher quantity of sodium as well (Table 3); from the decayed brown zone potassium and sodium were very intensively withdrawn and also, but less intensively, sodium and SO_4^{--} ion (Table 4).

Camellia japonica L. of *Theaceae* family vegetates under natural conditions in evergreen deciduous forest growing along Japan Sea coast in southern part of Honsiu Island, at the altitudes from 100 to 1200 m above sea level, and also on the same island along Pacific Ocean coast, on Kiusiu and Riukiu Islands and also beyond Japan — along southern and north-western coast of Korean Peninsula. *Camellia japonica* is a little tree of temperate and humid zone of temperatures ranging from 0°C in winter to 35°C in summer time (Takasi Tuya ma, 1968). Trees cultivated in pots in cool greenhouses had their leaves overcoloured with yellow and white-yellow spots while their tops and edges showing brown and shriveling. The soil in pots contained 96.58 mg/100 g of soluble salts having equivalently in their kation part majority of sodium and further — in diminishing order of quantities — Ca^{++} , Mg^{++} , K^+ (Table 2). In their anion part, Cl^- concentration amounting to 6.2 mg/100 g of soil was equivalently the lowest.

As oposed to the above described two species contents of calcium, magnesium and potassium both; in healthy and in decaying leaves of the *Camellia* are almost the same (Table 3). Among the remaining ash components, the pathologically changed leaves contained some more sodium and sulphur but the amount of chlorine (0.43%) was doubled (Table 3). Calcium, potassium and sodium in partly decayed leaves was withdrawn from the decayed brown zones to a considerable extend (Table 4).

Phoenix roebeleni O'Brien of *Palmae* family is a plant of evergreen equatorial forests of South-East Asia. It exist in a zone of annual precipitation about 3000 mm, from Assam till South Vietnam, in areas lying at 600-800 m above sea level. Leaves of *Phoenix roebeleni* cultivated in soil in tropical greenhouses shrivel due to necrosis which gradually progresses from tops. Decayed leaf parts show dark-brown colour and they are marked off from the unchanged green parts by yellow-orange passing zone. The tropical greenhouse soil contained 110.45 mg/100 g of soluble salts (Table 2) with calcium components predominant, a little less of sodium components and equivalently nearly the same but almost half of the amount of potassium and magnesium components than that of calcium and sodium. The soluble salts appeared mostly in shape of sulphates and bicarbonates and only an insignificant part of them as chlorides (Table 2). In spite of apparently favourable soil condition the necrotic leaves of *Phoenix roebeleni* contained more calcium, magnesium, sodium and chlorine and less potassium than the healthy ones (Table 3; Fig. 1). The shriveling leaves contained 0.57% of Cl^- and were characterized by threefold lower metal kations to chlorine ions

ratio <Table 3>. In the decayed brown part significant accumulation of Cl^- , Na^+ , SO_4^{--} and H_2PO_4^- took place and – at the same time – a slight withdrawal of Ca^{++} and a little more intensive that of K^+ were observed <Table 4>.

Stangeria eriopus <Kunze> Nash of *Cycadaceae* family exist in savannah areas of South-East Africa. Pathological changes, noticed in plants cultivated in pots in tropical greenhouse, manifest themselves by partial shriveling of leaves starting in top parts of the plants. Decayed fragments of leaf blades grow yellow, in places dark-brown.

In comparison to all formerly described species, healthy leaves of this plant contained considerably more chlorine and sodium. Pathological changes, such as a yellowing of leaves, took place when the quantity of Cl^- in dry mass of leaves exceeded 1% <Table 3>. The *Stangeria eriopus*' leaves chemism differs from that of previously described four species. Only potassium is being withdrawn from pathologically changed leaves however higher amount of calcium, magnesium and sodium – in comparison with healthy leaves – points out further accumulation of these components. Partition of a leaf into a decayed and an alive zones is not associated with translocation of calcium, potassium and sodium, whereas yellow and brown fragments contain more of Mg^{++} , SO_4^{--} , $\text{H}_2\text{PO}_4^{--}$ and Cl^- than green fragments do. The *Stangeria eriopus* more intensive absorption of chlorine from breeding-ground causes smaller that for the four species sum of metal kations to Cl^- ratio <Table 3, 4>.

Sequoia sempervirens Endl. of *Taxodiaceae* family is one of the dominant species of conifers in Pacific Ocean coastal region of North America. It occurs at the foot of Sierra Nevada, to the north and south of San Francisco and from Monterey Lay to northern California's borders, up till approximately 42°NN .

In *Sequoia sempervirens* cultivated in Botanical Garden in pots, in cool greenhouses, a symptom of necrosis occurs in the shape of tawning and shriveling of needles. Soil in the pots contained, in to 100 g of dry mass, 62.16 mg of soluble salts, mostly sulphates and bicarbonates of sodium and potassium <Table 2>. The *Sequoia* belongs also to a group of plants assimilating considerable chlorine quantities taken from the soil <Table 3>. Healthy needles contained 1.51/ of Cl^- while quantity of the same component in tawning needles approached 2%.

Sequoia sempervirens is a long-lived tree reaching 50-80 m of height, begining its decay in an age of about 500 years. It grows in warm and humid climate with annual precipitation over 2000 mm. Winter season is a more humid season there while more dry summer is characterized by frequent fogs <Podbielkowski, 1974; Walter, 1968>.

All the mineral elements absorbed from soil are quite lastingly accumulated in tissues and are not subject to withdrawal from needles turned brown <Table 3>. However translocation of mineral components takes place in partly decayed needles where chlorine, potassium, magnesium and sodium undergo a transfer from brown to green zone <Table 4>. Inclination to absorption and accumula-

tion of a greater amount of chlorine determines very low ratio of Ca^{++} , Mg^{++} , Na^+ , K^+ kations sum — to Cl^- <Table 3> both: in green and decayed leaves. A lower value of that ratio in green fragments of the needles turned brown <Table 4>, what is due to withdrawal of chlorine from the decaying zone, is a characteristic feature of the plant in comparison with other species.

Calathea bachemiana Morr. of *Marantaceae* family is a perennial plant from undergrowth of equatorial forests of Brasil. It grows on laterite soils under the following conditions: annual mean temperature 25-28°C; annual precipitation 2000-4000 mm; high air humidity level <Pareys Blumengärtnerei, 1958; Podbielkowski, 1974>.

The *Calathea bachemiana* cultivated in the tropical greenhouse of Botanical Garden shows gradually progressing phenomena of browning and shriveling of leaf blades as a reaction to chloride. The soil in which the *Calathea* grows contained the highest quantity of soluble salts amounting to 236.98 mg/100 g of soil, with their ionic composition unfavourable to glycophytes, because apart from sulphurs and bicarbonates a considerable quantity of chlorides was present too <Table 2>. The highest salinity degree comes as a result of the sum of the mineral components carried into the ground with water — on one side, and total demand of the plant — on the other. In healthy top leaves an equivalential content of bivalent Ca^{++} and Mg^{++} kations and monovalent K^+ and Na^+ kations was very much alike, while in older decaying leaves considerable predominance of monovalent over bivalent ones was noted <Fig. 1>.

The *Calathea bachemiana* assimilates from soil a considerable quantity of chlorine as well and unfavourably reacts to chlorine content of 2% approx. in conversion to dry mass <Table 3>.

All the mineral components together with very active potassium are more strongly assimilated in tissues, so do not undergo translocation from decayed to young, healthy leaves <Table 3>. In leaves necrotically changed, from their shriveling brown zone considerable amounts of potassium and chlorine as well as low quantities of calcium and magnesium are withdrawn <Table 4>.

In appropriate proportions of particular mineral components both in still healthy and in decayed leaves, is expressed by very small values of kation sum to chlorine ratio <Tables 3, 4>.

Spathiphyllum wallisii Reg. of *Araceae* family is a perennial plant growing in humid tropical zones of Columbia. Leaves of *Spathiphyllum wallisii* cultivated in tropical greenhouse show decay on edges and in their top parts, taking on dark tawny colour there. The decayed parts of the leaves are separated from the green area by transient yellow-orange zone.

The *Spathiphyllum wallisii* belongs to a group of plants assimilating from soil a very large quantity of mineral components, the sum of which makes about 10% of leaf dry mass <Table 3>. For the healthy leaves potassium and chloride predominated both: in percentage and equivalently <Table 3; Fig. 1>. In the

leaves which were suffering from necrosis, quantity of calcium and sodium was increased by a number of times and their chlorine content rose too, while amount of potassium decreased. An intensive accumulation of chlorides from the soil is accompanied by higher resistance of the plant to their toxic effect. The leaves containing 2.84% Cl^- were having still normal appearance with no visible pathological changes. Leaf blades edges decay was ascertained when quantity of chlorine amounted to 3.76% (Table 3). In both: healthy and decaying leaves, the equivalential ratio of metal kations sum to $-\text{Cl}^-$ was a very low one and amounted to 3 and 2.9 respectively (Table 3).

Cordyline terminalis Kunth of *Agavaceae* family is a shrub from inter- and circumtropical zones. It appears starting from Eastern Himalayas, through China, Indochina Peninsula, Malay Archipelago till Melanesia, Polinesia, North Australia and New Zeland (Pareys Blumengärtner, 1958). The plant requires higher humidity, good shadowing and temperatures 20-25°C in summer and 18-20°C in winter time.

In the plants cultivated in pots in a palm-house gradual decay of leaves occurs, progressing from their top part. A colour of the decayed parts is brown with pinky tint.

The soil in the pots with total salinity 130.69 mg/100 g of soil contained the most of soluble potassium compounds, then equivalent quantities of calcium and sodium and considerably less of magnesium compounds (Table 2). Quantity of Cl^- was relatively low, amounting only to 4.4 mg/100 g of breeding-ground.

The *Cordyline terminalis* belongs also to the group of plants accumulating a lot of ash components in their leaves, out of which there is the most of chlorine, then equivalently nearing quantities of potassium, calcium and sodium (Fig. 1). Its characteristic feature, similarly as that of *Camellia japonica*, is identical content of some components in healthy and decaying leaves, what mostly relates to calcium and potassium (Table 3). On the other hand, quantities of sodium, chlorine and magnesium in decaying leaves increase. Within the pathologically changed leaves intensive translocation of particular ions is taking place (Table 4). With the exception of H_2PO_4^- , all ions are being withdrawn from brown zone, but Cl^- 's degree of withdrawal is lower than that of metal kations. Sum of the metal kations to $-\text{Cl}^-$ ratio in decayed parts of leaves is in the magnitude range of 0.6. (Table 4), and testifies to total unsettlement of ionic balance. The limit value, with which chlorine begins to produce a toxic effect on *Cordyline terminalis*, lies over 3.12%, if converted into dry mass of leaves (Table 3).

Anthurium magnificum Lind. of *Araceae* family is a perennial plant of humid tropical zone of Columbia.

Leaves of the *Anthurium magnificum* cultivated in pots of the tropical greenhouses undergo decay progressing gradually from its top parts. There is a transitional zone of orange colour between decayed, brown part of leaf blade and its green part. The soil in the pots contained 62.28 mg/100 g of soluble salts

〈Table 2〉. Because of just vestigial amount of Cl^- , the soluble compounds were almost solely represented in a shape of sulphures and bicarbonates.

The *Anthurium* absorbs from soil a relatively large quantity of ash components 〈Table 3〉. Proportionally, in dry mass of healthy leaves, there is the most of potassium, then of chlorine and calcium, but equivalently proportions of these three components are close to each other 〈Fig. 1〉. From the wholly pathologically changed leaves only small quantities of calcium, magnesium and potassium are withdrawn 〈Table 3〉 and from brown zones of these leaves only potassium is subject to migration 〈Table 4〉. The intensive absorption and accumulation of large chlorine quantities in leaves affects equivalent ratio of kations sum — to Cl^- , which insignificantly differing for healthy and decaying leaves amounts to about 2.5 〈Tables 3, 4〉.

Reaction to chlorine in a shape of gradual decay of *Anthurium* leaves, similarly as for *Cordyline terminalis*, takes place after surpassing the limit value of over 3% Cl^- — in conversion to dry leaf mass 〈Table 3〉.

DISCUSSION AND CONCLUSIONS

The all investigated plants originate from humid zones or areas where rainy season is characteristic "savannah", with soils containing inconsiderable quantity of soluble salts, particularly only trace quantities of SO_4^{--} and Cl^- ions.

During last years many plants of glycophite group were examined and their high sensitivity to chlorine was determined in cases, when that ion concentrations was increasing in soil solution showing values higher than these which were met in natural conditions 〈Czerwiński, 1978; Holmes, 1961; Holmes and Baker, 1966; Stroganov, 1970〉. It was experimentally proved, that chlorine becomes toxic, when its quantity in overland portion of a plant is higher than specified critical value. The study results revealed that plant's ability to active absorption of chlorine ions and accumulation of them in roots, against concentration gradient 〈Wenkateswarille et al., 1965〉. Against a trace quantity of chlorine to be found in soil solutions of moderately humid and humid climatic zones, this attribute is indispensable due to essential function, which chlorine ions fulfil in a biochemical metamorphosis. In the of the active mechanism of chlorine assimilation and lack of regulation depending on Cl^- concentration in cases of increasing strength, chlorine accumulation rate of overground portion of plants is a function of time, and concentration of Cl^- ions in the soil solutions.

Demand for chlorine in case of plants of glycophites group is very low and sufficient even if its content in the plants tissues is of a hundredth of a percent rate. In cases when quantity of chlorine of overground portions of a plant gradually increases it begins to be toxic after exceeding a specified limit value. It was found, that the limit value is different for particular plant species and so, for example, for *Aesculus hippocastanum* externally visible pathological change occurs as early as

when Cl^- quantity in dry mass of leaf exceeds 0.28% and for *Acer platanoides* and *Fraxinus excelsior* 0.7-0.8%, while for and orange-tree 1.5% and for an almond-tree 1.8%-3.1% (Czerwiński, 1978; Holmes and Baker, 1966).

Symptoms of poisoning by excessive quantity of Cl^- in tissues are very typical. In leafy plants, tops and edges of leaf blade begin to shrivel, while remaining part of leaf remains unchanged (Czerwiński, 1978). The decayed area increases as time passes and in cases of high sensitivity of a plant or rapid accumulation of chlorine covers the whole of the leaf.

Therefore typical symptom of poisoning by chlorine, confirmed by analysis results, occurred in all examined plant species cultivated in greenhouses of U. W. Botanical Garden.

Taking under consideration quantities of chlorine in leaves for which the characteristic necrosis of edges occurred, all examined plants could be divided into three following groups:

1. The very sensitive plants — with low chlorine limit value, for which pathological changes are visible already with Cl^- quantity below 0.6% of dry mass of leaves. Here belong: *Ceratozamia mexicana*, *Eriobotrya japonica*, *Camellia japonica* and *Phoenix roebeleni*.

2. Medium-sensitive plants — in which pathological changes occur when chlorine lies in the range from 1.6 to 2.41% of dry mass of leaves. Here belong: *Stangeria eriopus*, *Sequoia sempervirens* and *Calathea bachemiana*.

3. Little-sensitive plants in which decaying of leaves takes place, when chlorine content exceeds 3.6% of dry mass of leaves. Here belong: *Spathiphyllum wallisii*, *Cordyline terminalis* and *Anthurium magnificum*.

The constant source of chlorine in the greenhouses soil in case of Botanical Garden is undoubtedly the tap-water applied for plants watering, which in spite of the fact that is being stored in open reservoirs, does not loose chlorine ions. A temporary concentration of Cl^- in soil solution increases is also as a result of mineral fertilizers use, particularly of potassium salt.

The chlorine originating from fertilizers can be easily avoided if bicomponent fertilizers such as potassium nitrate and potassium phosphate are applied. The much more difficult problem in urban circumstances is to obtain water uncontaminated with chlorine. In winter time, use of large doses of NaCl for street snow removal causes not only local lawn soil pollution (Czerwiński, 1978) but also a considerable chlorination of surface waters as well as ground waters of the first water-bearing horizon. (Czerwiński et al., 1976; Czerwiński and Prac, 1976; Dobrzański et al., 1975). Therefore, an eventual decision to build a special borehole water intake for the Botanical Garden use, should be preceded by a preliminary underground-waters investigation. The possibility of an additional treatment of tap-water before applied for greenhouses use — by highly productive distilleries or ion exchangers should be taken into consideration.

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Przyczyny zasychania liści u roślin egzotycznych uprawianych w warunkach szklarniowych

Streszczenie

W celu stwierdzenia przyczyn nekrozy liści roślin egzotycznych uprawianych w szklarniach, badaniami objęto rośliny należące do 10 gatunków, a mianowicie: *Ceratozamia mexicana* Brongn., *Stangeria eriopus* (Kunze) Nash (Cycadaceae), *Eriobotrya japonica* Lindl. (Rosaceae), *Camellia japonica* L. (Theaceae), *Phoenix roebeleni* O'Brien (Palmae), *Sequoia sempervirens* Endl. (Taxodiaceae), *Calathea bachelmiana* Morr. (Marantaceae), *Cordyline terminalis* Kunth. (Agavaceae), *Spathiphyllum wallisii* Reg. i *Anthurium magnificum* Lind. (Araceae). Analizy chemiczne wykonano w próbkach ziemi, w których rosły w.w. rośliny, w próbkach wody wodociągowej używanej do podlewania oraz w próbkach liści zdrowych i liści zasychających. Dla zbadania procesu wycofywania składników mineralnych z liści objętych nekrozą, poddano analizom nekrotyczne i zielone części liści zasychających. W wyniku przeprowadzonych badań stwierdzono, że mimo ogólnie niskiego poziomu zasolenia wody używanej do podlewania, zawartość niektórych jonów, a szczególnie jonu Cl^- , była niekorzystna dla roślin. Niekorzystny skład jonowy stwierdzono również w ekstraktach wodnych niektórych podłoży ziemnych. Z porównania chemizmu liści zdrowych i liści nekrotycznie zasychających wynika, że Cl^- pobierany przez rośliny z podłoża i akumulowany w liściach, wpływa na nie toksycznie.