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Epiphytic lichen diversity in the urban area of Košice (E Slovakia) with some notes on its air quality

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Abstract: Lichen diversity in the City of Košice was studied investigating lichen diversity on 160 trees distributed over 32 sites. Its relationship to pollution sources (steel plant, thermal power station) were determined by calculating the IAP (Index of Atmospheric Purity). A total of 60 lichen species was found, 30 of which are endangered. The rare species *Parmelina quercina* is reported for the first time. The lichen diversity in the City of Košice is decreasing as we move closer to the sources of pollution and also in the southern part of the city. An intermediate level of diversity was identified in residential areas, parks and forest parks. The highest diversity was found in the recreational area at the forest edge, Bankov.

Keywords: lichen distribution, endangered species, eastern Slovakia, air pollution, Central Europe.

Introduction

Lichen diversity has been linked to air quality since 19th century (Nylander 1866; Grindon 1859; Hawksworth 1970). Today, it continues to provide a valuable insight into environment (Bargagli & Nimis 2002). As a slowly growing sesile symbiotic organisms without protective layer, great part of epiphytic lichens are highly sensitive to air pollution. This makes them suitable to be used as bioindicators of SO_x, NH_4 and NO_x pollutants (Koch et al. 2019). The variability of pollution tolerance among lichen species brings additional information about the condition of the environment. For instance, *Lecanora conizaeoides* (known as a strong acidophilic species) was widely spreading in Europe during the 20th century but now is declining (Hauck et al. 2011; Paoli et al. 2021 and references within).

The City of Košice is the second biggest city in Slovakia with population over 250,000. Air quality in the Košice area is heavily influenced by several metallurgical, engineering, mining, and power industrial plants that release into the air SO_x, NO_x, CO, and PM pollutants and are located mostly to the south of the city. Local sources of air pollution are traffic and local heating systems using solid fuel. The prevalent northern winds lead to the spreading of pollutants in the south (Pavolová et al. 2012).

The lichen biota of Košice and its surroundings has been investigated partially (Bačkor & Bodnárová 2002; Bačkor et al. 2003; Marcinčinová et al. 2020). Besides species common in urban areas, several additional sensitive species were occasionally reported, e. g. *Evernia prunastri*, *Parmelina tiliacea*, *Flavoparmelia caperata*, *Usnea hirta*, *Ramalina fastigiata* or *Bryoria* sp. More complex research was carried out in nearby territories, such as the Slovenské rudohorie Mts., the Volovské vrchy Mts., the Čierna hora Mts. and the Slanské vrchy Mts. (e. g., Suza 1949; Pišút & Liška 1985; Bačkor & Bodnárová 2002; Pišút 2002; Orthová 2003; Guttová et al. 2017a; Goga et al. 2018).

The main objective of the present study is to provide insight into the lichen biota of the City of Košice and to use lichen diversity to estimate its air quality.

Materials and Methods

The City of Košice lies in the Košice Basin in the wide valley of the Hornád River, bordered on the west by the foothills of the Slovenské rudohorie Mts. The city center is located at an altitude of 208 m a.s.l. The climate in Košice is humid continental Dfb as per Köppen-Geiger climate classification (Beck et al. 2018), average temperature of 19 °C in July and -3.5 °C in January. The average annual precipitation is 600-700 mm (Anonymous 2021).

There are several major pollution sources in the city area, as indicated in Fig. 1. The main sources of pollution are represented by nearby iron and steel plant southward from the centre and the coal heating power station located directly in the southern part of the city (both act as sources of emission of solid pollutants, SO_2 and NO_x) (Hančuľák et al. 2015).

Field work and data collection

The field survey was conducted during 2020-2021 period at 32 locations (Tab. 1). As a central point of the mapped area site 1 – Faculty of Science, Dean's Office was selected for its location in the city centre. Mapped sites are of two types: urban and peripheral. Parks or larger greenery consisting of at least of 20 trees were selected as urban sites. We omitted trees in close proximity to main roads to avoid direct influence by traffic pollution. The peripheral sites were recreational areas or tourist sightseeing sites. Non-native tree species were selected in parks where native species were not present. To estimate IAP values or distribution of oligotrophic and nitrophilous species we selected suitable native species.

At each site we randomly selected 5 trees, ideally both with acidic and sub-neutral bark pH. All selected trees were solitary, straight, preferably without moss and at least 40 cm in perimeter. At each tree all lichens growing up to 180 cm were recorded, including the base of the trunk along with their frequencies. Frequency (f) of each species was recorded according according to Guttová et al. (2013) as follows: 1 – a species is rare, 1-3 thalli overall; 3 – a species is infrequent and has medium degree of coverage; 5 – a species is very frequent with a high degree of coverage. To each species ecological index of the species (Q) was calculated. Q present the mean number of accompanying species on the tree. We calculated the IAP (The index of atmospheric purity) using equation (1) following LeBlanc & Sloover (1970):

$$\mathrm{IAP} = \sum_{n}^{1} \frac{\mathrm{Q}*\mathrm{f}}{10} \qquad (1)$$

where Q = ecological index of the species, f = frequency of occurrence of the species on the substrate.

The GPS coordinates in WGS-84 system of the centres of locations were later determined using mapy.cz website. The heatmap used in Fig. 1 was created in Microsoft Power BI as a simple visualization of number of spiecies present at each location. The collected specimens are stored at the herbarium of Botanical Garden of Pavol J. Šafárik University in Košice (acronym KO). Specimens were identified by standard microscopy (including UV light) under dissecting and light microscope in water-mounted preparations. Chemistry was studied by standard spot reagents. The lichen nomenclature follows Guttová et al. (2013) with addenda (https://ibot.sav.sk/lichens/checklist.html) and the red list data follow Pišút et al. (2001). All names of vascular plants follow Marhold et al. (2007). Abbreviations of host wood species used and its classification according to bark pH (Barkman 1956):

- subneutral: AH – *Aesculus hippocastanum* L., AP – *Acer platanoides* L., APs – *Acer pseudoplatanus* L., AS – *Acer saccharinum* L.,FE – *Fraxinus excelsior* L., PC – *Pyrus communis* L., PCa – *Populus ×canadensis* Moench, PT – *Populus tremula* L., RP – *Robinia pseudoacacia* L., FS – *Fagus sylvatica* L., NA – *Negundo aceroides* Moench, SAb – *Salix alba* L., SC – *Salix caprea* L., SA – *Sorbus aucuparia* L.,
- acidic: AG – *Alnus glutinosa* (L.) Gaertn., BP – *Betula pendula* Roth, CA – *Cerasus avium* (L.) Moench, CB – *Carpinus betulus* L., CC – *Corylus corulna* L., PA – *Picea abies* (L.) H. Karst., PM – *Pseudotsuga menziesii* (Mirb.) Franco, PN – *Pinus nigra* J. F. Arnold, PS – *Pinus sylvestris* L., PSp – *Prunus spinosa* L., QP – *Quercus petraea* (Matt.) Liebl., QR – *Quercus robur* L., TC – *Tilia cordata* Mill., TP – *Tilia platyphyllos* Scop. GB – *Ginkgo biloba* L., LS – *Liquidambar styraciflua* L., P – *Platanus* sp., SJ – *Sophora japonica* L.

Results

Overall, 160 trees were studied, and we report 756 lichen records of 60 lichen species (Tab. 2). 30 of them are considered as threatened in Slovakia (Pišút et al. 2001), e. g. *Arthonia radiata* CR, *Evernia prunastri* EN, *Flavoparmelia caperata* EN, *Graphis scripta* EN, *Parmelina quercina* CR, *Pleurosticta acetabulum* EN, *Punctelia subrudecta* EN, *Pyrenula nitida* EN, *Ramalina farinacea* EN and *Ramalina fastigiata* EN.

The studied sites reached the IAP index of 4.7-104.1 (Tab. 1). According to the IAP index, locations with the lowest lichen diversity can be found in the southern part of the city and its surroundings (loc. 15, 16, 18, 25, 26, 27, 30) with IAP index 4.7-18. Residential locations (3, 9, 19, 22, 23, 24, 32), locations in the close proximity to the city border (5, 6, 7, 8, 10, 12, 13, 14, 21, 28) and the large parks in the inner city (1, 2, 17) reached the IAP 20-50. Since loc. 4 consisted only of *Betula pendula* trees we were unable to determine IAP value of this location. The highest IAP 105.4 was found at loc. 11. This location, a park surrounded by *Fagus-Abies* forest on the top of the hill Bankov (400 m a.s.l.), it is an old recreational area. In average, urban locations reached IAP 27.3 and peripheral locations IAP 42.56.

In general, the ecological index of the species (Q) (Tab. 2) was low for species commonly found in the city, e. g. *Amandinea punctata* 4.6, *Lecanora conizaeoides* 2, *Parmelia sulcata* 5.6, *Phaeophyscia orbicularis* 3.9, *Physcia adscendens* 4.6, *Xanthoria parietina* 4.5, and high for rare species sensitive to pollution, e. g. *Alyxoria varia* 11.7, *Graphis scripta* 9.3, *Lecanora argentata* 16, *Pertusaria pertusa* 11, *Platismatia glauca* 12 or *Usnea hirta* 12.

Several species (*Alyxoria varia*, *Bacidia rubella*, *Arthonia radiata*, *Lecanora argentata*, *L. conizaeoides*, *L. pulicaris*, *Parmelia saxatilis*, *Pertusaria albescens*, *P. coccodes*, *Physconia perisidiosa*, *P. distorta*, *Platismatia glauca*, *Pleurosticta acetabulum*, *Ramalina fastigiata*, *R. pollinaria* or *Usnea hirta*) were found only at the one of the locations. Among common ubiqist species *Amandinea punctata*, *Candelariella efflorescens* auct. europ., *Evernia prunastri*, *Hypogymnia physodes*, *Parmelia sulcata*, *Phaeophyscia orbicularis*, *Physcia adscendes*, *P. tenella*, *Physconia grisea* and *Xanthoria parietina* were the most frequent species.

Overall, lichen diversity was low near the sources of pollution and in the southern part of the city, intermediate in residential areas, parks, and forest parks and highest in the recreational area on the edge of the forest (Fig. 1). Oligotrophic species were found mostly on the north-eastern border of the city (Fig. 2A) and loc. 4. On the other hand, nitrophilous species were frequent and widely distributed (Fig. 2B).

Discussion

In the City of Košice, epiphytic lichens were present at each site we visited, with the exception of areas unsuitable for lichens due to human activities. The lichen flora of the City of Košice has been, until now, only studied to limited extent. Bačkor et al. (2003) studied the impact of S pollution on lichens in the Košice in 2000-2001. Before them, there is no study dealing with epiphytic lichen diversity in the city – except for the work by Pišút (1999) made during 1970-1981 period.

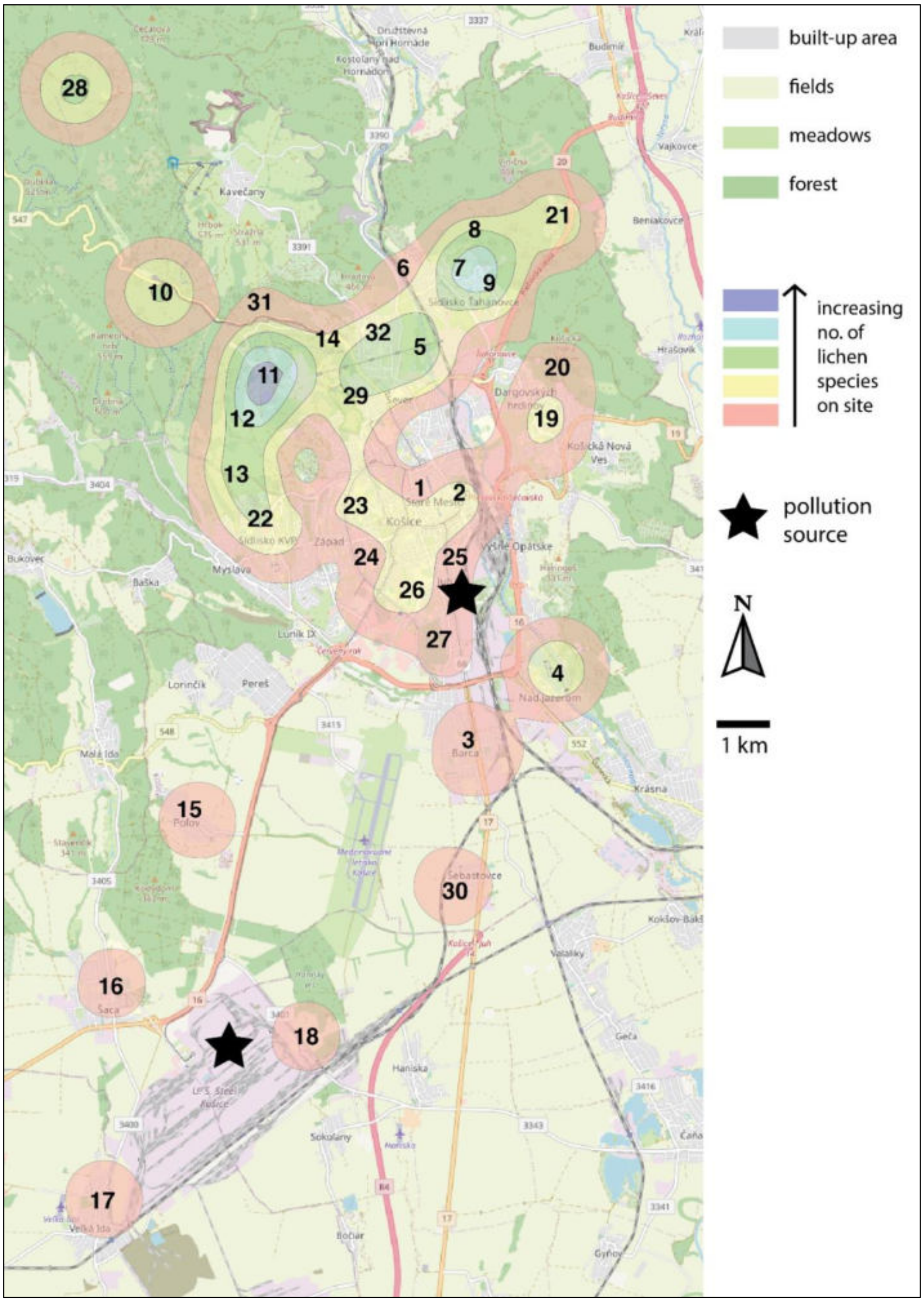

Fig. 1 Map of locations and lichen diversity in the City of Košice. No. 1-32 represent locations as in Tab. 1. Changing colours of the heatmap represent the number of lichen species at each location with blue being the highest. Each colour represents no. of species on a site: 31-26 dark blue, 25-20 light blue, 19-13 green, 12-7 yellow and 6-0 red.

Bačkor et al. (2003) studied several of our locations (loc. 1, 4, 7-10, 15, 18, 19, 23, 24, 29). In Košice, they observed 17 lichen species overall. The highest diversity was found at the Botanical Garden with 11 species (we found 13 species) and at the Alpinka hut with 8 species (we found 19 species). As the most frequent species they listed *Lecanora* sp., *Lepraria* sp., *Lecidea* sp., *Physcia adscendens*, *Hypogymnia physodes*, *Xanthoria parietina*, *Melanelia* sp. (now should be treated as *Melanelia* s.l.) and *Parmelia sulcata* but note that these species were not present in the city

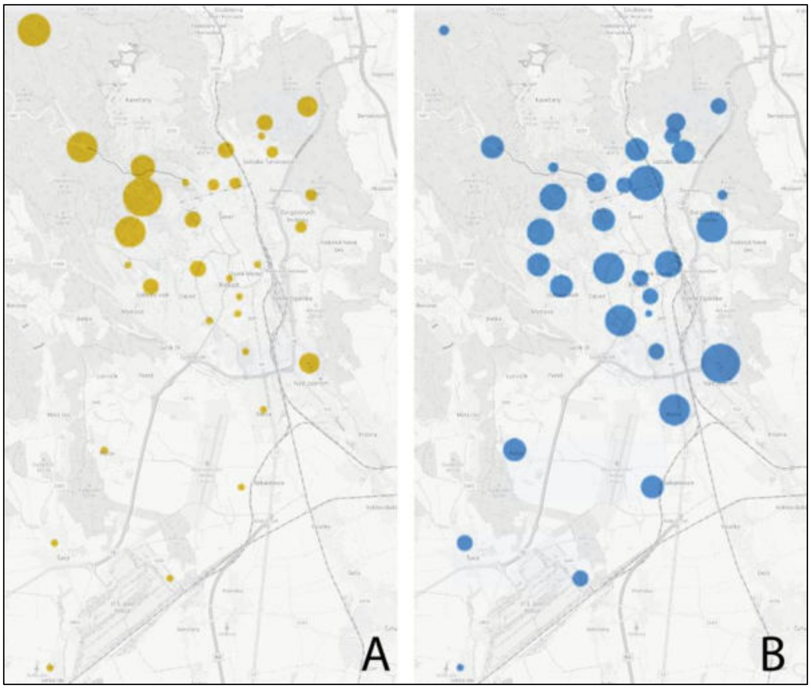

Fig. 2 Overview of distribution of lichen species throughout the studied area: (A) oligotrophic species, (B) nitrophilous species. Size of the circles indicates number of species (starting with 0 species) on respective locations according to Tab. 2.

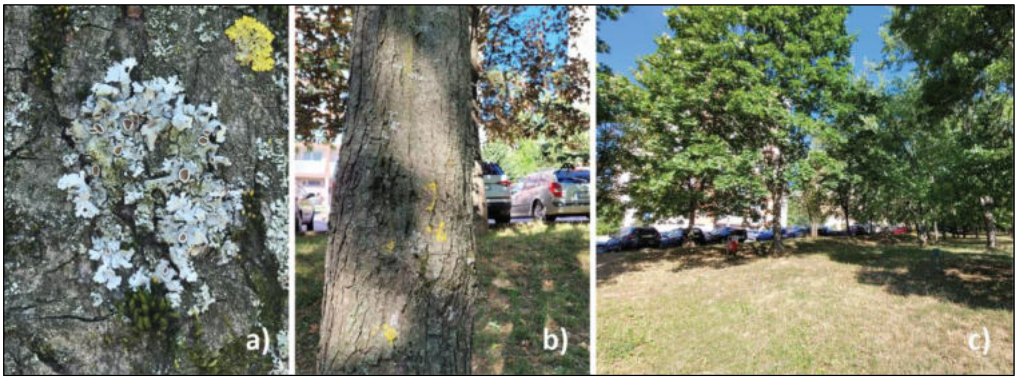

Fig. 3 Thallus of *Parmelina quercina* a) growing on *Acer saccharinum* tree on loc. 22 (12th August 2022), b) +c) overview of the location 22.

centre. *Ramalina fastigiata* was reported previously at loc. 10 (Alpinka) also by Bačkor & Bodnárová (2002) as very rare. In the same work, they reported at loc. 10 species *Vulpicida pinastri* growing on the bark of mature fruit trees not recorded during our fieldwork.

We report several new records for the square 7293 of Central European mapping grid system (for details regarding Slovakia see Pišút 1999) already reported by Pišút (1999), Bačkor & Bodnárová (2002) and Bačkor et al. (2003): *Alyxoria varia*, *Chaenotheca furfuracea*, *Hypogymnia tubulosa*, *Lecanora argentata*, *Parmelia saxatilis*, *Pleurosticta acetabulum*, *Punctelia subrudecta*, *Pertusaria amara*, *P. coccodes*, *P. pertusa*, *Physconia distorta*, *P. perisidiosa*, *Platismatia glauca*, *Pseudevernia furfuracea*, *Pyrenula nitida*, *Ramalina farinacea*, *R. pollinaria* and *Xanthoria polycarpa*.

Some common ubiquist species such as *Phaeophyscia orbicularis*, *Physcia stellaris*, *Physconia grisea*, *Xanthoria parietina* or *Lecidella elaeochroma* are missing from Pišút (1999). The species *X. parietina* is widely spread throughout the whole studied area with most of the thalli growing on tree twigs in the immediate proximity to the roads with heavy traffic. Therefore, we chose not to include these trees in our sampling. Hence, *X. parietina* is extremely widespread species in the inner city but it is bound to the roads and twigs and not that common elsewhere.

There are two gradients of lichen diversity in the city. In the southern part (loc. 3, 25, 26, 27; IAP 4.7-28.1) only a few lichen species were found: this is probably due to cumulated pollution from the city by northern winds since similar locations in the northern part of the city exhibited higher IAP values (loc. 5, 6, 14, 22; IAP 34.7-46.5). The second one can be seen from the city centre (loc. 1, 2, 23, 24, 25; IAP 10.1-39.1) to the residential areas of the city (loc. 4, 9, 14, 19, 22, 32; IAP 22.3-38.7). These gradients agree with the long-term air-pollution controlling stations reports in the city (Amurská, Ďumbierska and Štefánikova streets and Veľká Ida village) (Anonymous 2022). The forests surrounding Košice are both original mixed *Fagus-Abies* (loc. 10, 11, 12, 28, 31) and planted monoculture (*Pinus* spp. for loc. 7, 8; *Quercus* spp. for loc. 20). Planted forests exhibit lower IAP values than original forests. Acidophilic species were found only on trees with acidic bark, e. g. *Betula pendula*. *Lecanora conizaeoides*, species known for its acidophilic nature (Hauck et al. 2011), was found only at 1 location (loc. 10). In contrary, nitrophilic and ubiquitous species were widely spread in the city but missing at the periphery and adjacent forests (e. g. loc. 28). Air-pollution sensitive species *Evernia prunastri* was recorded at several locations in the city (4, 7, 9, 22, 23), which indicates lower level of eutrophication and a likely recolonisation in the urban area, as previously reported by Lackovičová et al. (2013) in Bratislava. Interestingly, loc. 31, Vrabčie skaly, gained lower IAP than expected. This location is in the northern part of the city surroundings at well-lit *Quercus* forest with dominant limestone outcrops suitable for several terrestrial lichen species such as *Peltigera* spp. and *Cladonia* spp. The epiphytic species *Ramalina farinacea*, *Bacidia rubella* and *Calicium* sp. were recorded here.

Overall, this was the lichenologically and botanically most diverse location we had studied, and it is worth for further research.

Some remarks on selected species

Parmelina quercina (Fig. 3), a rare species, was found in Košice on 2 sites, loc. 22, in a housing estate park on planted *Acer saccharinum* tree, and loc. 29, the Botanical Garden, on several *Quercus* sp. trees. At loc. 22 we report one fertile thallus, at loc. 29 several fertile thalli on multiple *Quercus* sp. trees. This species is critically endangered with a few records from Považský Inovec Mts. (Czarnota et al. 2006) and several scattered records in Guttová & Lackovičová (2010). The closest reports to Košice are those from Slanské vrchy Mts. – Ruská Nová Ves village (Pišút 1985) and the Slanec Castle hill (Pišút & Liška 1985) and more recently from the village of Drieňovské kúpele in the Slovak Karst National Park (Peksa 2008).

Parmelina tiliacea was reported as new for Košice square 7293 in 2003 (Bačkor et al. 2003) and later recorded in 2019 (Marcinčinová et al. 2020). This species is common in the Slanské vrchy Mts., east of Košice (*Fagus* prevalent forests with *Quercus* in lower altitude) (Pišút & Liška 1985; Marcinčinová, unpublished data) but findings of healthy thalli in the housing estates of Košice, loc. 22 and 32, are unexpected since this is species usually not found in the urban areas in Slovakia.

Punctelia subrudecta is a species with a temperate-Mediterranean distribution in Europe regularly reported from Slovakia (Czarnota et al. 2006; Guttová & Pišút 2007; Guttová et al. 2017b; Fačkovcová & Paoli 2019) with increasing number of records in Europe (Szymczyk et al. 2015), which could be caused both by decreasing sulphur dioxide air-pollution (Christensen & Søchting 2007) and climate change (Stapper & John 2015).

Pyrenula nitida is an endangered species in Slovakia (Pišút et al. 2001). All of our three locations 10, 11 and 28 represent shaded *Fagus sylvatica-Abies alba* forests with mixed *Carpinus betulus* trees and *P. nitida* often grew in abundance with *Graphis scripta*, *Arthonia radiata* and *Pertusaria pertusa*. *Graphis scripta* in Pišút (1999) is missing for this square, we report this species as commonly present in suitable biotopes.

Throughout the locations we often found somewhat damaged thalli of *Melanelia* s.l. that we were unable to identify. *Melanelixia exasperatula* is a widespread species common in urban areas (Slaby & Lisowska 2012; Sündhofer et al. 2021) with only a few records from Košice so it is possible that these damaged thalli could belong to this species.

Conclusion

Lichen diversity was strongly correlated to both air-pollution levels and various substrata availability. *Lecanora conizaeoides* was recorded only at one location, indicating low acidification level in the City of Košice. On the contrary, sensitive species such as *Evernia prunastri* or *Parmelina tiliacea* are colonising city parks. Several threatened species were found, e. g. *Parmelina quercina*. Our findings indicate strong recolonisation of urban area by lichens and provide comprehensive insight into lichen diversity in the City of Košice and its surrounding region.

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Tab. 1 List of locations and number of lichen species found at each site. IAP – Index of atmospheric purity, UPJŠ – University of Pavol Jozef Šafárik in Košice, KVP – Košického vládneho programu (housing estate),* – urban location, ^ – peripheral location.

#	Site name	Type of biotope	GPS (WGS-84)	Eleva-tion	Distance and direction from the city centre (loc. 1) (km)	Number of species on the site	IAP
1*	**Faculty of Science, UPJŠ, Dean's Office**	urban area in the city center, considered as city center	48°43'10.615"N, 21°15'3.998"E	200 m	0	5	22.7
2*	**Mestský park (City park)**	large main city park near railway and city center, old trees but mostly cultivated alochthonous species	48°43'26.254"N, 21°15'51.959"E	200 m	1.1 E	11	39.1
3*	**Barca**	old park originally belonging to a manor house, with a small lake, urban area	48°40'42.039"N, 21°16'2.310"E	200 m	4.7 S	10	28.1
4*	**Nad Jazerom housing estate**	public park in-between Jazero lake and Hornád river, urban area	48°41'34.695"N, 21°17'20.909"E	200 m	4.1 SE	15	-
5*	**Anička park**	old large recreational park near Hornád river, semi-urban area	48°44'57.422"N, 21°15'14.069"E	210 m	3.3 N	14	46.5
6*	**Súdky**	recreational area along the Hornád river, near railway, semi-urban area	48°45'35.135"N, 21°14'58.117"E	220 m	4.5 N	10	34.7
7*	**Ťahanovce housing estate – Sahara**	peripheral part of residential area Ťahanovce, self-seeded trees and ungroomed meadows	48°45'50.742"N, 21°15'59.104"E	300 m	5.1 N	14	42.4
8^	**Ťahanovce housing estate – Planíkovo pleso**	artificial *Pinus* spp. forest with addition of *Fagus sylvatica* and *Carpinus betulus*, around flood control artificial lake and swamp	48°46'5.762"N, 21°16'4.589"E	300 m	5.6 N	13	23.5
9*	**Ťahanovce housing estate**	residential urban area	48°45'32.818"N, 21°16'17.373"E	290 m	4.6 N	8	38.7
10^	**Alpinka**	original mixed *Fagus sylvatica* and *Abies alba* forest, peripheral area	48°45'38.063"N, 21°10'51.890"E	310 m	6.9 NW	19	55.4
11^	**Horný Bankov**	original mixed *Fagus sylvatica* and *Abies alba* forest, old park at peripheral area	48°44'41.607"N, 21°12'35.441"E	400 m	4.1 NW	31	104.1
12^	**Čičky**	allotment gardens, semi-urban area	48°44'2.457"N, 21°12'14.082"E	360 m	3.8 NW	17	47.3
13^	**Above KVP housing estate**	fields and meadows with hedgerows, next to KVP housing estate, semi-urban area	48°43'25.617"N, 21°12'10.374"E	340 m	3.6 W	14	20.9
14*	**Čermeľ**	park greenery near crossroads, urban area	48°44'58.172"N, 21°13'49.051"E	250 m	3.7 N	12	35.8
15*	**Poľov**	park in the middle of the housing estate Poľov, urban area	48°39'56.840"N, 21°11'29.706"E	275 m	7.4 SW	7	18.1

Tab. 1 - cont.

16*	**Šaca**	park in the middle of the housing estate Šaca, urban area	48°38'11.920"N, 21°10'4.826"E	250 m	11 SW	6	12.1
17*	**Veľká Ida**	park in the middle of Veľká Ida village, formerly belonging to a manor house, with a small lake, urban area very close to the S end of the US Steel plant	48°35'51.404"N, 21°9'56.963"E	210 m	14.9 SW	8	18.9
18*	**US Steel plant**	hedgerows in the immediate proximity to the N end of the US Steel plant	48°37'31.967"N, 21°13'21.996"E	220 m	10.7 S	3	10.8
19*	**Dargovských hrdinov housing estate**	residential urban area	48°44'7.889"N, 21°17'6.625"E	310 m	3 NE	11	27.6
20^	**Zelený dvor**	forest park, artificial oak forest, semi-urban area	48°44'44.087"N, 21°17'23.973"E	350 m	4 NE	6	17.4
21^	**Crematorium**	park of the crematorium, semi-urban area	48°46'24.241"N, 21°17'17.581"E	310 m	6.6 NE	15	44.8
22*	**KVP housing estate**	residential urban area	48°43'1.438"N, 21°12'49.446"E	300 m	2.7 W	12	35.2
23*	**Západ housing estate – New Hospital**	residential urban area	48°43'21.692"N, 21°14'10.064"E	245 m	1.2 W	12	33.6
24*	**Západ housing estate – Spoločenský pavilón**	residential urban area	48°42'22.711"N, 21°14'30.199"E	230 m	1.6 W	9	15.5
25*	**Kasárne Kulturpark**	park, urban area	48°42'50.076"N, 21°15'21.139"E	200 m	0.7 S	3	10.1
26*	**Stará nemocnica (Old Hospital)**	hospital's park, urban area	48°42'30.701"N, 21°15'18.472"E	210 m	1.3 S	6	12.2
27*	**Verejný cintorín) Public Cementery**	cemetery, urban area	48°41'47.897"N, 21°15'31.714"E	220 m	2.6 S	5	4.7
28^	**Chata Diana Cottage**	original mixed *Fagus sylvatica* and *Abies alba* forest, in a valley with Čermeľský potok stream, peripheral area	48°47'49.456"N, 21°9'29.529"E	410 m	11 NW	19	47.7
29*	**Botanical Garden**	large closed and protected area, semi-urban area	48°44'16.401"N, 21°14'1.518"E	300 m	2.4 N	13	27.9
30*	**Šebastovce**	orchard in a private garden in the housing estate Šebastovce, urban area	48°39'10.829"N, 21°15'53.320"E	200 m	7.5 S	7	16.1
31^	**Vrabčie skaly Rocks**	limestone outcrops in *Quercus* and *Fagus* forest, peripheral area	48°45'13.477"N, 21°12'34.910"E	320 m	4.9 NW	7	16.9
32*	**Podhradová housing estate**	residential urban area	48°44'58.842"N, 21°14'38.378"E	250 m	3.4 N	7	22.3

Tab. 2 List of species recorded in Košice. Red list category (RL) is based on Pišút et al. (2001). Q – ecological index of the species expressed as a mean number of accompanying species on the tree. f – frequency of the species on the tree trunk. For the location numbers see Tab. 1. Collected specimens stored in KO herbarium are accompanied with ID number. Abbreviations of substrates: AG – *Alnus glutinosa* (L.) Gaertn., AH – *Aesculus hippocastanum* L., AP – *Acer platanoides* L., APs – *Acer pseudoplatanus* L., AS – *Acer saccharinum* L., BP – *Betula pendula* Roth, CA – *Cerasus avium* (L.) Moench, CB – *Carpinus betulus* L., CC – *Corylus corulna* L., FE – *Fraxinus excelsior* L., FS – *Fagus sylvatica* L., GB – *Ginkgo biloba* L., LS – *Liquidambar styraciflua* L., NA – *Negundo aceroides* Moench, P – *Platanus* sp., PA – *Picea abies* (L.) H. Karst., PC – *Pyrus communis* L., PCa – *Populus* ×*canadensis* Moench, PM – *Pseudotsuga menziesii* (Mirb.) Franco, PN – *Pinus nigra* J. F. Arnold, PS – *Pinus sylvestris* L., PSp – *Prunus spinosa* L., PT – *Populus tremula* L., QP – *Quercus petraea* (Matt.) Liebl., QR – *Quercus robur* L., RP – *Robinia pseudoacacia* L., SA – *Sorbus aucuparia* L., SAb – *Salix alba* L., SC – *Salix caprea* L., SJ – *Sophora japonica* L., TC – *Tilia cordata* Mill., TP – *Tilia platyphyllos* Scop.

#	Species	RL	Sites (substrate, frequency; ID in herbarium)	Q
1	*Acrocordia gemmata* (Ach.) A. Massal.	-	10 (APs 1; KO 36183), 11 (CB 1, 3), 31 (QP 3, 3)	8
2	*Alyxoria varia* (Pers.) Ertz & Tehler	VU	10 (APs 3; CB 1, 3)	11.7
3	*Amandinea punctata* (Hoffm.) Coppins et Scheid.	-	2 (APs 5; BP 3, 3), 3 (TC 3; PN 3; QR 1), 4 (BP 5), 5 (BP 3, 3), 7 (PT 3, 3; SC 1), 11 (TC 5; QP 5), 13 (QR 3), 16 (BP 3), 17 (PM 5; PS 1, 1), 20 (QP 1), 21 (PS 5, 5), 22 (AS 3), 23 (PN 1), 24 (PN 1, 1), 26 (PM 1), 28 (PA 5), 29 (QP 3), 30 (PS 3)	4.6
4	*Anisomeridium* sp.	-	11 (CB 1)	16
5	*Arthonia radiata* (Pers.) Ach.	CR	11 (CB 1), 28 (CB 3, 3)	9.3
6	*Bacidia rubella* (Hoffm.) A. Massal.	VU	31 (QP 3; KO 36179)	1
7	*Buellia griseovirens* (Turner et Borrer ex Sm.) Almb.	-	28 (CB 3; AG 1)	7.5
8	*Calicium* sp.	-	31 (wood 1)	0
9	*Caloplaca pyracea* (Ach.) Th. Fr.	-	7 (PT 5, 3; SC 1), 14 (SA 1), 30 (PT 3)	5.6
10	*Candelariella efflorenscens* auct. europ.	-	1 (SJ 3), 3 (QR 1; AH 1), 4 (BP 3, 3, 3), 5 (CA 3; BP 3), 6 (BP 3, 3; RP 3), 7 (SC 1), 8 (CB 1), 10 (AP 1), 11 (TC 5; QP 1), 12 (QP 5), 14 (SA 3), 19 (BP 1, 1), 21 (SC 1; BP 1), 24 (BP 1), 29 (QP 1)	6.6
11	*Chaenotheca furfuracea* (L.) Tibell	LR:nt	11 (QP 3, 3), 20 (QP 3, 3, 1, 1), 28 (CB 1)	5.1
12	*Cladonia chlorophaea* (Flörke ex Sommerf.) Spreng.	-	20 (QP 1, 5, 3, 1, 3)	2.6
13	*Cladonia coniocraea* (Flörke) Spreng.	-	3 (PN 3), 8 (QP 5), 20 (QP 3), 29 (QP 3), 31 (QP 3; KO 36181)	3.6

Tab. 2 - cont.

#	Species	RL	Sites (substrate, frequency; ID in herbarium)	Q
14	*Cladonia fimbriata* (L.) Fr.	-	11 (QP 1, 1), 29 (QP 1)	7
15	*Evernia prunastri* (L.) Ach.	EN	4 (BP 1, 1), 6 (SAb 1), 7 (PSp 1; PC 1), 8 (QP 1), 9 (BP 1), 10 (AP 1), 11 (CB 1; TC 1; QP 3, 1, 3), 12 (PSp 3; QP 1), 13 (CA 1), 21 (SC 1; BP 1), 22 (Aps 1; AS 3), 23 (TC 3)	8.2
16	*Flavoparmelia caperata* (L.) Hale	EN	2 (LS 1), 4 (BP 1), 12 (QP 1), 21 (SC 1), 23 (TC 1), 28 (AG 1)	8
17	*Graphis scripta* (L.) Ach.	EN	10 (CB 3, 3), 11 (CB 3, 3), 28 (CB 5, 3)	9.3
18	*Hypogymnia physodes* (L.) Nyl.	-	3 (PN 1), 4 (BP 1, 1, 3), 5 (BP 1, 1), 7 (PC 3; PSp 3), 8 (PS 1; QP 1, 3), 9 (BP 1, 3), 11 (TC 1; QP 1, 1, 3), 12 (PSp 5; QP 3), 13 (CA 3), 19 (BP 1), 21 (PS 3, 5; BP 3), 23 (TC 1), 28 (PA 1), 29 (QP 3)	6.8
19	*Hypogymnia tubulosa* (Schaer.) Hav.	LR:nt	7 (PC 1, PSp 1), 12 (PSp 3), 13 (CA 1), 21 (PS 1; BP 1)	8.5
20	*Lecanora argentata* (Ach.) Malme	-	11 (CB 1)	16
21	*Lecanora chlarotera* Nyl.	-	2 (LS 1, TP 1), 10 (AP 1), 11 (CB 5, 1), 13 (QR 1), 28 (AG 3; CB 1)	8
22	*Lecanora conizaeoides* Nyl. ex Cromb.	-	26 (PM 3)	2
23	*Lecanora pulicaris* (Pers.) Ach.	-	28 (CB 1)	7.3
24	*Lecidella eleaochroma* (Ach.) M. Choisy	-	2 (TP 5; LS 5), 8 (CB 1), 10 (AP 3; CB 5), 11 (CB 1), 14 (SA 3, 5, 3), 28 (CB 3)	6
25	*Lepraria incana* (L.) Ach.	-	10 (CC 3; CB 1, 3), 17 (QP 3)	3.8
26	*Lepraria* sp.	-	5 (BP 1), 8 (PS 1; SC 5; QP 3; CB 3), 10 (APs 3), 11 (CB 1), 14 (SA 1, 1), 15 (TC 1), 17 (PS 1), 20 (QP 3, 3, 5, 1, 3), 27 (TC 3; BP 3), 29 (QP 3, 3)	4
27	*Melanelixia subaurifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. et Lumbsch	LR:nt	2 (LS 1), 7 (PSp 1), 8 (PS 1; CB 3), 12 (PSp 3), 13 (QR 1), 14 (SA 1), 21 (SA 1)	6.9
28	*Melanohalea elegantula* (Zahlbr.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. et Lumbsch	LR:nt	4 (BP 1, 1, 1), 5 (CA 1; BP 3; Aps 1), 6 (SAb 1), 10 (CC 5)	6.4
29	*Melanohalea exasperatula* (De Not.) O. Blanco et al.	-	11 (TC 3; QP 5, 3), 12 (QP 3)	8
30	*Melanelia* spp. s.l. (damaged)	-	14 (SA 1, 1; BP 1), 19 (BP 1, 3), 20 (QP 3, 1), 21 (PS 1, 3; BP 3, 1), 22 (AS 1), 23 (TC 1, 1), 24 (BP 1), 28 (CB 1; AG 3), 29 (QP 3, 3, 3)	6.4

Tab. 2 - cont.

#	Species	RL	Sites (substrate, frequency; ID in herbarium)	Q
31	*Micarea* sp.	-	10 (CB 5, 3), 11 (CB 3)	8.3
32	*Parmelia saxatilis* (L.) Ach.	LR:nt	11 (TC 1)	8
33	*Parmelia sulcata* Taylor	-	1 (SJ 1), 3 (QR 1; AH 3), 30 (PS 1), 4 (BP 1, 5, 5, 3, 3), 5 (CA 3; QR 1; BP 3, 1, 5; APs 5, 1), 6 (SAb 1; BP 3, 1), 7 (PC 3; PSp 1; PT 1; SC 1), 8 (QP 1, 5), 9 (BP 1, 3), 10 (AP 3; CC 1), 11 (TC 3; QP 1, 3, 5), 12 (PSp 5; QP 3), 13 (QR 3; CA 1), 14 (SA 1, 1; BP 3), 15 (TC 1, 3; BP 1), 16 (BP 1), 19 (FE 1; BP 1, 3; QP 1), 21 (PS 1, 3; SC 3; BP 3, 3), 22 (APs 1, 3; AS 3), 23 (TC 3, 1, 1; FE 1), 24 (BP 1, 1), 26 (QP 1), 27 (BP 1), 28 (AG 5), 29 (QP 5, 3, 5), 32 (AP 3; FE 3)	5.6
34	*Parmelina quercina* (Wild.) Hale	CR	22 (AS 1), 29 (QP 1; KO 35340)	7
35	*Parmelina tiliacea* (Hoffm.) Hale	LR:nt	5 (CA 1), 11 (TC 1; QP 5), 12 (QP 1), 22 (APs 1), 32 (NA 1)	6.7
36	*Pertusaria albescens* (Huds.) M Choisy et Werner	LR:nt	28 (CB 1)	9
37	*Pertusaria amara* (Ach.) Nyl.	LR:nt	11 (QP 3, 5; CB 5), 31 (QP 5; KO 36178)	8.5
38	*Pertusaria coccodes* (Ach.) Nyl.	VU	11 (QP 1; KO 36175)	8
39	*Pertusaria pertusa* (Weigel) Tuck.	LR:nt	11 (CB 1), 28 (CB 3)	11
40	*Phaeophyscia orbicularis* (Neck.) Moberg	-	1 (SJ 5; TC 5; AH 5, 5; APs 5), 2 (APs 5, 5; BP 5, 5), 3 (TC 3; QR 3; AH 5), 4 (BP 5, 3, 3, 3), 5 (QR 1; BP 3, 5,1; APs 5), 6 (BP 5, 3, 5; RP 5; SAb 3), 7 (PC 1; PT 1, 1; SC 3), 8 (CB 1), 9 (PCa 5; BP 5; SC 5; APs 5), 10 (AP 1; APs 3; CC 5; CB 1), 13 (QR 1, 1), 14 (SA 5, 5; BP 3), 15 (TC 5, 5; AH 3), 16 (TP 5; P 3), 17 (PM 3; FE 3; PS 1), 18 (PT 3; SAb 3; PCa 1), 19 (FE 5; BP 3, 3; QP 3; PT 5), 21 (BP 5), 22 (APs 3, 5, 5, 1; AS 5), 23 (TC 3, 5, 5; FE 5; PN 3), 24 (BP 5, 5; PN 1, 1; TC 1), 25 (AH 5, 5; BP 3), 26 (GB 5; QP 3; FE 5; FS 3), 27 (FE 1; AH 3,	3.9
41	*Phlyctis argena* (Spreng.) Flot.	-	7 (SC 1), 8 (CB 3), 10 (AP 1; CC 3; CB 1, 5), 11 (CB 5), 28 (CB 5; AG 3), 31 (QP 5; KO 36184)	7.1
42	*Physcia adscendens* H. Olivier	-	1 (SJ 5; APs 1; AH 3), 2 (APs 1, 5; TP 3; BP 3, 3; LS 3), 3 (TC 3; QR 3; PN 1; AH 5), 4 (BP 3, 3, 3, 3, 3), 5 (CA 3; QR 3; BP 5, 3, 3), 6 (BP 3, 3, 3; RP 3; SAb 5), 7 (PC 5; PT 3, 3;	4.6

Tab. 2 - cont.

#	Species	RL	Sites (substrate, frequency; ID in herbarium)	Q
42	(cont.) *Physcia adscendens* H. Olivier	-	PSp 5; SC 5), 8 (CB 3), 9 (PCa 3; BP 5, 5; SC 5; APs 5), 10 (AP 1), 11 (CB 1), 12 (PSp 3; QP 1), 13 (QR 1, 5; CA 5), 14 (SA 3, 3; BP 3), 15 (TC 3), 16 (BP 5, 1, 5; TP 3; P 1), 17 (PM 1; PS 1, 5), 18 (SAb 3), 19 (FE 5; BP 3, 5; QP 1; PT 3), 21 (PS 3, 3; SC 5; BP 1, 5), 22 (APs 3, 5, 3, 1; AS 3), 23 (TC 5, 5, 1; FE 3), 24 (PN 1, 5; TC 1), 25 (AH 3, 3; BP 3), 26 (GB 3; PM 1; QP 3; FE 1; FS 1), 27 (AH 1), 28 (AG 1), 29 (QP 3), 30 (PT 3; PS 3; PSp 3), 32 (NA 3, 3, 1; AP 3; FE 3)	4.6
43	*Physcia stellaris* (L.) Nyl.	-	2 (LS 1), 4 (BP 1), 5 (QR 3), 7 (PC 1; PT 1; PSp 1), 9 (BP 3, 3; SC 1; APs 3), 12 (PSp 1; QP 1), 13 (QR 3), 19 (FE 1; BP 3), 22 (AS 1), 23 (TC 1, 1), 30 (PS 1)	6.6
44	*Physcia tenella* (Scop.) DC.	-	2 (TP 1), 3 (AH 3), 4 (BP 3, 3, 1) 5 (CA 1; BP 3, 1, 3; APs 3), 6 (BP 3), 7 (PT 1), 9 (BP 3; SC 5; APs 1), 10 (AP 5), 11 (QP 3), 12 (PSp 5; QP 1), 13 (QR 1, 1), 14 (SA 3, 5; BP 3), 15 (TC 3; BP 3), 19 (BP 1; QP 1), 21 (PS 1, 1; SC 3; BP 3), 22 (APs 3), 23 (TC 3, 1; FE 1), 24 (PN 1), 26 (FE 1; FS 1)	6.3
45	*Physconia distorta* (With.) J. R. Laundon	LR:nt	11 (QP 1)	8
46	*Physconia grisea* (Lam.) Poelt	-	2 (APs 1; BP 1), 3 (TC 5; QR 3, 5), 4 (BP 1), 5 (BP 1), 11 (TC 1), 14 (SA 1), 15 (BP 3; TC 1), 16 (P 3), 17 (PM 3; FE 5; QP 1; PS 5), 19 (BP 3; PT 3), 21 (PS 3; SC 1; BP 3), 22 (APs 1; AS 1), 23 (TC 1, 1; FE 1), 24 (BP 5, 5, 1; PN 1), 27 (BP 1), 29 (QP 3, 3), 32 (NA 1, 1, 1)	5
47	*Physconia perisidiosa* (Erichsen) Moberg	VU	4 (BP 3; KO 36186)	7
48	*Platismatia glauca* (L.) W. L. Culb. Et E. F. Culb.	LR:nt	12 (PSp 1)	12
49	*Pleurosticta acetabulum* (Neck) Elix & Lumbsch	EN	4 (BP 1)	9
50	*Pseudevernia furfuracea* (L.) Zopf	LR:nt	5 (BP 1), 8 (QP 1), 12 (PSp 5; QP 3), 13 (CA 1), 19 (BP 1), 21 (PS 1; BP 1), 28 (PA 1)	7.4
51	*Punctelia subrudecta* (Nyl.) Krog	EN	6 (BP 3; KO 36176), 29 (QP 1; KO 36177), 32 (AP 1)	5
52	*Pyrenula nitida* (Weigel) Ach.	EN	10 (CB 1), 11 (CB 1), 28 (CB 1)	9
53	*Ramalina farinacea* (L.) Ach.	EN	11 (QP 3; KO 36188), 12 (QP 3), 31 (QP 3; KO 36185)	6
54	*Ramalina fastigiata* (Pers.) Ach.	EN	10 (AP 5)	10

Tab. 2 - cont.

#	Species	RL	Sites (substrate, frequency; ID in herbarium)	Q
55	*Ramalina pollinaria* (Westr.) Ach.	VU	11 (QP 5)	8
56	*Ropalospora viridis* (Tønsberg) Tønsberg	-	28 (CB 1; AG 1, 1)	5.7
57	*Scoliciosporum* sp.	-	17 (PM 1)	5
58	*Usnea hirta* (L.) F. H. Wigg.	VU	12 (PSp 3)	12
59	*Xanthoria parietina* (L.) Th. Fr.	LR:nt	1 (SJ 1; AH 3), 2 (APs 3; TP 5; BP 1; LS 3), 3 (AH 3), 4 (BP 1, 1, 1, 1), 5 (CA 1; QR 5; BP 1; APs 3), 6 (BP 5, 5, 1; RP 3; SAb 1), 7 (PC 3; PT 3; PSp 1; PT 5; SC 3), 8 (QP 1), 9 (PCa 2; BP 3, 3; SC 5; APs 5), 10 (AP 1), 12 (PSp 1), 13 (QR 1, 1; CA 1), 14 (SA 1, 1, 1; BP 1), 15 (AH 1), 16 (BP 1, 1; TP 1; P 1), 17 (PM 3; FE 1; QP 3; PS 1, 1), 18 (PT 5, 1; SAb 3, 5; PCa 1), 19 (FE 3; QP 1; BP 1; PT 3), 21 (PS 1; SC 1; BP 1), 22 (APs 5, 3, 3, 3; AS 1), 23 (TC 3, 1, 3; FE 3), 24 (BP 5, 1; TC 1; PN 5), 25 (AH 1, 1; BP 3), 30 (PT 5; PS 5; PSp 5), 32 NA 3, 3, 1; AP 1; FE 1)	4.5
60	*Xanthoria polycarpa* (Hoffm.) Th. Fr. ex Rieber	LR:nt	12 (PSp 1), 13 (QR 1)	9.5