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The occurrence of European mistletoe under the conditions of high human impact in the central part of Warsaw, Poland

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Abstract: The distribution of the European mistletoe (*Viscum album* L. subsp. *album*) was described for the central part of Warsaw, taking into account the taxonomic composition of its hosts and the spatial distribution of the mistletoe stands determined by the differentiation of biotic and abiotic factors. The mistletoe occurred on 27 host species, belonging to 15 genus and 8 families. The parasite showed a strong preference for alien, planted tree species (*Acer saccharinum*, *Populus xeuramericana* and *Robinia pseudacacia*). The noted mistletoe stands were scattered unevenly among city habitats. The longest host lists belonged to the sites of city transportation complex and courtyards of old housing estates. Mistletoe distribution was influenced indirectly by abiotic factors, which determined life conditions of the infested hosts. To a much higher degree the direct impact of biotic factors, especially a close relation to the number and distribution of breeding and migratory birds – disseminators of mistletoe seeds, was remarkable. It was recognised that *Viscum album* L. subsp. *album* adapts well to the most heavily changed and contaminated habitats of a big city, thus can be treated as a synanthropic species.

***Key words*:** European mistletoe, *Viscum album* L. subsp. *album*, distribution, city habitats, hemiparasitic plants

Introduction

Viscum album L. is a shrubby, evergreen hemiparasite of deciduous and coniferous trees and shrubs. It is one of the most common species from the family *Viscaceae,* and is distributed throughout most of Eurasia. In Europe *Viscum album* L. has been recorded on 384 host taxa, including many species introduced to Europe (Barney et al. 1998). The most common subspecies of *Viscum album* L. is the European mistletoe (*Viscum. album* L. subsp. a*lbum*), which was described for 230 deciduous hosts, including at least 186 introduced species (Hawksworth 1983). Stypiński (1997) found it to infest 118 host species in Poland.

Despite having broad host ranges, the European mistletoe tends to hemiparasitise some hosts more frequently than others (Stypiński 1997, Briggs 1999, 2003, Banister, Strong 2001). This is to a large degree

related to the resistance characteristics of potential hosts, as well as the dispersal capacities of birds – the main vectors of mistletoe seeds. Moreover, the European mistletoe seems to prefer domestic habitats, often strongly changed by human activities (Stypiński 1997, Briggs 1999, 2003).

Within the city environment, many biotic and abiotic factors influence the mistletoes distribution. Among biotic factors are the presence of suitable hosts and the occurrence of certain fruit-eating birds. Birds play a passive, as well as an active role in the dissemination of mistletoe to potential host trees, either by wiping the sticky seeds off their beaks or by defecating partially digested seeds onto tree branches. In the case of abiotic factors, which are responsible for quicker germination of seeds and the more productive mistletoe assimilation, higher temperature sunlight access and increased concentration of carbon dioxide in the atmosphere have probably the greatest influence in urbanised areas.

Several Polish towns and cities have detailed inventories of mistletoe hosts and maps of mistletoe distribution (Hryniewiecki 1954, Olaczek 1960, Kownaś 1961, Szymanowski 1964, Markowski, Szmajda 1971, Stypiński 1980, Danielewicz, Urbański 1984, Czekalski 1985, Stypiński 1980, Stypiński et al. 1990, Roniewicz 1997, Zieliński 1997, Kubus 1998, Nienartowicz 1998, Jurzyk, Kluczyński 2000, Święs 2001, Święs, Majkut 2003, Kutyna, Włodarczyk 2004). However, as yet there have been no detailed surveys of *Viscum album* L. subsp. *album* distribution in Poland's largest city and most modified environment Warsaw. Previous data regarding the occurrence of the hemiparasite is generalised and incomplete (Karmazyńska 1928, Szymanowski 1964, Sudnik-Wójcikowska 1987).

The study aims to investigate the conditions of the mistletoe occurrence in areas of heavy anthropogenic influence.

The general aims of the research were to:

- analyse mistletoe host preferences in Warsaw;
- find the relationships between the spatial distribution of *Viscum album* L. subsp*. album* and conditions characteristic of different habitats within the city;
- discuss the role of biotic and abiotic environmental factors that influence the mistletoe occurrence.

This research was conducted in Warsaw, over an area compromised of 100 km^2 (20% of the whole city area) situated in the central part of the city on the both sides of Vistula River (Fig. 1). The real vegetation coverage in the central parts of the city consists mainly of the greenbelts along roadsides, green sites in the complex of built-up areas, ruderal sites and cultivated green sites of cemeteries, parks and gardens. The remnants of natural vegetation are small and strongly fragmented.

The average annual air temperature in the central part of Warsaw is 8,4°C, which is about 1°C higher than in the peripheral parts of the city (during some seasons the "heat island" effect in Warsaw can reach even more than 3°C). The annual sum of sunshine duration in the city centre amounts about 1450 hours. The mean annual precipitation ranges from 550 to 600 mm (Kozłowska-Szczęsna et al. 1996, Woś 1999, Błażejczyk 2001).

All parts of the research area were designated into a certain habitat type, from the semi-natural to the most modified by human activities. The following eight types of habitats were distinguished:

1. Close city centre – densely built-up part of the city with rarely distributed green areas and single trees.

2. Older housing estates – parts of the city built up between 1945–1965. Complex of older apartment houses and courtyards including well developed green areas with older trees.

3. Modern housing estates – areas built up after 1965. Modern blocks of flats accompanied by open-spaced courtyards, mostly covered with the grass lanes, include the low fraction of higher vegetation.

4. Villa estates – single-family households with gardens.

5. City transportation complex – tree belts situated along the roadsides.

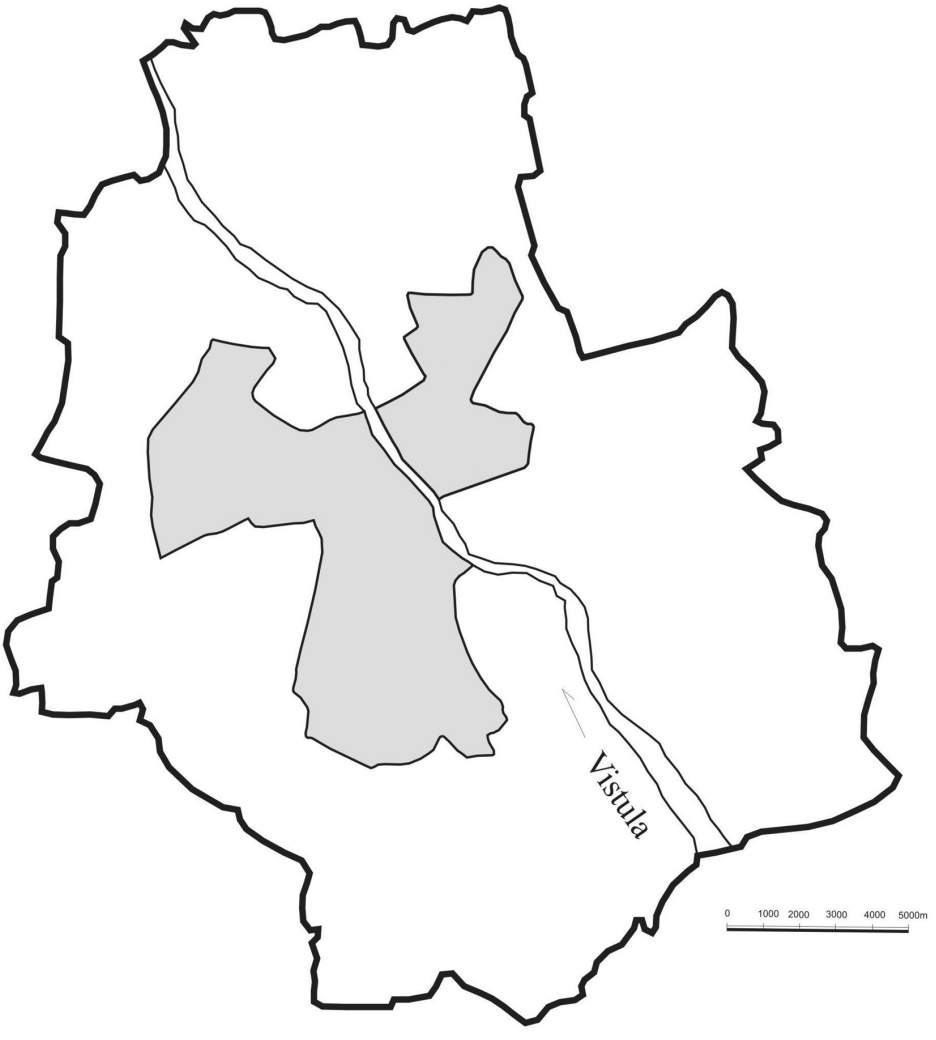

Fig. 1. Research area located in the central part of Warsaw

6. Green city sites – extensive areas of higher vegetation, such as parks, city forests, garden plots, squares and cemeteries.

7. Industrial sites – railway complex, transport bases, factories, military areas.

8. Waterway banks – green belts along natural and artificial waterways.

Materials and methods

The mistletoe inventory and host identification were conducted in fall and winter of the years 2002/2003, 2003/2004 and 2004/2005. During this period evergreen clumps of mistletoe were readily observed on leafless trees. The accuracy of host tree identification was confirmed in spring and summer. Nomenclature of the host taxa was given after Mirek et al. (2002).

A single mistletoe specimen was considered as each generative or vegetative mistletoe shoot growing directly from the endophytic system situated in the host tissue (Stypiński 1997, after Rabotnov 1969).

The number of mistletoe specimens was counted for every infested host tree in the research area. Two categories of the infestation degree of the host's crown were distinguished: "low abundance" – less than 20 specimens of *V. a*. L. subsp. *album* on a single host tree and "mass" occurrence – more than 20 specimens of *V. a*. L. subsp. *album* on a single tree.

The frequency of the mistletoe occurrence was determined for the eight types of city habitats in order to state how the land use influences the spatial distribution of *V. a*. L. subsp. *album* in the research area.

Results

In the investigated area of Warsaw over 9500 mistletoe specimens were recorded on 2988 host trees. 2226 trees were infested with "low abundance" and 762 hosts had more than 20 mistletoe specimens per tree (Tables 1, 2).

Viscum album L. subsp. *album* was recorded on 27 host taxa: 12 natives, 10 aliens and 6 hybrids. The range of hosts included 15 genus and 8 families, where *Rosaceae* (12 taxa) and *Salicaceae* (7 taxa) were the most highly represented. Despite of being represented by fewer taxa, the members of *Aceraceae* and *Betulaceae* were abundantly infested with *V.a.* subsp. *album.*

The most numerous hosts of mistletoe were: *Acer saccharinum* (40%), *Populus xeuramericana* (28%), *Betula pendula* (13%), *Sorbus aucuparia* (8%), *Populus simonii* (4%) and *Robinia pseudacacia* (3%). These six host species accounted for 96% of the total number of records.

Additionally, the degree of the host's crown infestation in relation to the host species was checked. The "mass" occurrence of mistletoe was recorded only on 8 host species. Hosts with 20–50 mistletoes accounted for 85% of the "mass" occurrence of mistletoe. Only for *Acer saccharinum* and *Populus xeuramericana* did the infestation exceeded the number of 50 specimens for a single tree (Table 2).

The mistletoe stands were highly scattered among city habitats (Fig. 2). In relation to "low abundance" of mistletoe, the most numerous groupings were found in the city transportation complex (37% of all infested hosts), the courtyards of the older housing estates (24%) and the green city sites (24%). Significantly less numerous mistletoe stands were observed within area of villa estates (5%) and in the industrial sites (4%). In the close city centre, the areas of modern housing estates and at the waterway banks mistletoe occurred only sporadically (Fig. 3).

The most frequent "mass" occurrence of mistletoe was recorded in courtyards of the old housing estates (36%) and along the city transportation complex (30%). Relatively numerous mistletoe stands were observed in the green city sites (25%) with the highest abundance of mistletoes in parks and cemeteries. Like in the case of "low abundance", hemiparasite occurred rarely in habitats, such as gardens of the villa estates (3%), in the areas of the modern housing estates (4%) and in the industrial sites (1%). In the close city centre and at the waterway banks the "mass" occurrence of mistletoe was not stated at all (Fig. 3).

Within habitats, mistletoe host preferences varied (Table 3). Sites along the transportation complex and courtyards within the older housing estates had the longest host list and were dominated by *Acer saccharinum* and *Populus xeuramericana*. The green city sites were dominated by three species in sequence: *Acer saccharinum, Betula pendula* and *Populus xeuramericana*. In gardens of the villa estates mistletoe infested with similar frequency *Acer saccharinum, Populus xeuramericana, Betula pendula* and *Sorbus aucuparia*. Additionally, mistletoe occurred quite frequently on *Populus xeuramericana* in the most recently built up areas, such as the modern housing estates and the industrial sites.

Table 1. Mistletoe “low abundance” (less than 20 specimens per tree)

Host species	Number of host trees	Number of mistletoe specimens
Acer saccharinum	795	3487
Populus xeuramericana	612	2407
Betula pendula	323	1954
Sorbus aucuparia	208	836
Populus simonii	95	306
Robinia pseudacacia	79	219
Crataegus monogyna	19	75
Fraxinus pennsylvanica	18	88
Sorbus aria	18	41
Salix xsepulcralis	10	30
Sorbus intermedia	10	31
Tilia cordata	8	21
Crataegus laevigata	6	12
Salix fragilis	6	20
Populus xcanescens	3	4
Prunus padus	3	12
Malus baccata	2	6
Pyrus communis	2	2
Aesculus hippocastanum	1	2
Crataegus persimilis	1	2
Crataegus xmedia	1	1
Fraxinus americana	1	1
Malus xpurpurea	1	1
Populus nigra “Italica”	1	1
Prunus cerasus	1	1
Rhus typhina	1	2
Tilia xstellata	1	1
Total	2226	9563

Table 2. Mistletoe “mass" occurrence (more than 20 specimens per tree)

Host species	Number of host trees		
	total	with 20–50 specimens/ tree	with more than 50 specimens/tree
Acer saccharinum	414	341	73
Populus xeuramericana	220	189	31
Betula pendula	56	54	2
Populus simonii	36	28	8
Sorbus aucuparia	26	26	–
Robinia pseudacacia	6	4	2
Crataegus monogyna	3	2	1
Malus baccata	1	1	–
Total	762	645	117

Discussion

The distribution and host range preferences of *Viscum album* L. subsp. *album* are still largely unknown. Despite having a broad host range, mistletoe prefers to infest some host species more abundantly than others and tends to occupy some habitats with special partiality. Especially susceptible to mistletoe infestation are alien and planted tree species growing in urbanised habitats (Petrović et al. 2007).

In Warsaw mistletoe was noted on 27 tree species, with the significant representation of alien ones (Tables 1, 2). 68% of all recorded mistletoe hosts in the research area (e.g. *Acer saccharinum*, *Populus xeuramericana, Robinia pseudacacia* and *Fraxinus pennsylvanica*) originally come from North America, where they are attacked by another species from the *Viscaceae* family, namely *Phoradendron macrophyllum*. These trees are commonly planted in urban areas for their fast growth, small habitat needs and tolerance of contamination. Therefore, the reasons for these species to be the most common mistletoe hosts might lie in their broad availability in the city habitats, or since they have not developed enough morphological, biochemical and physiological mechanisms of resistance to this species of hemiparasite. Findings from different Polish and European towns and cities (i.e. Torun, Poznan, Stetin, Belgrade, Brussels, Berlin, etc.) confirm that *Viscum album* L. subsp. *album* infests the pretty similar range of alien host trees, with *Acer saccharinum*, *Populus xeuramericana* and *Robinia pseudacacia* among them (Markowski, Szmajda 1971, Jovanović 1982, Roniewicz 1997, Zieliński 1997, Kubus 1998, Nienartowicz 1998, Olivier 1998).

The representation of native tree species infested with *Viscum album* L. subsp. *album* was unexpectedly low in Warsaw. Of such hosts, the mistletoe occurred commonly only on *Betula pendula* and *Sorbus aucuparia. Betula pendula* is a heliophilous species characterised by a low dense crown evenly permeating light which enables the development of thermophilous and heliophilous mistletoe (Jentys-Szaferowa, Zarzycki 1979). In the case of *Sorbus aucuparia*, the abundance of fruits during winter period attracts the numerous bird species – dispersers of mistletoe seeds.

The majority of host species recorded in Warsaw were already known from other Polish towns and cities, only *Rhus typhina*, being alien to Polish flora, was reported for the first time. This particular case is

remarkable, since *Rhus typhina* is characterised by the high acetic acid concentration and strong allelopathy.

It is evident that despite having potentially a broad host ranges, mistletoe attacks in majority only a subset of species, omitting some potential hosts. For example, limes are noted as one of the most common mistletoe hosts in Poland and other European countries (Stypiński 1997, Briggs 1999, 2003), yet were attacked with a low frequency, although species from genus *Tilia* were quite common in the investigation

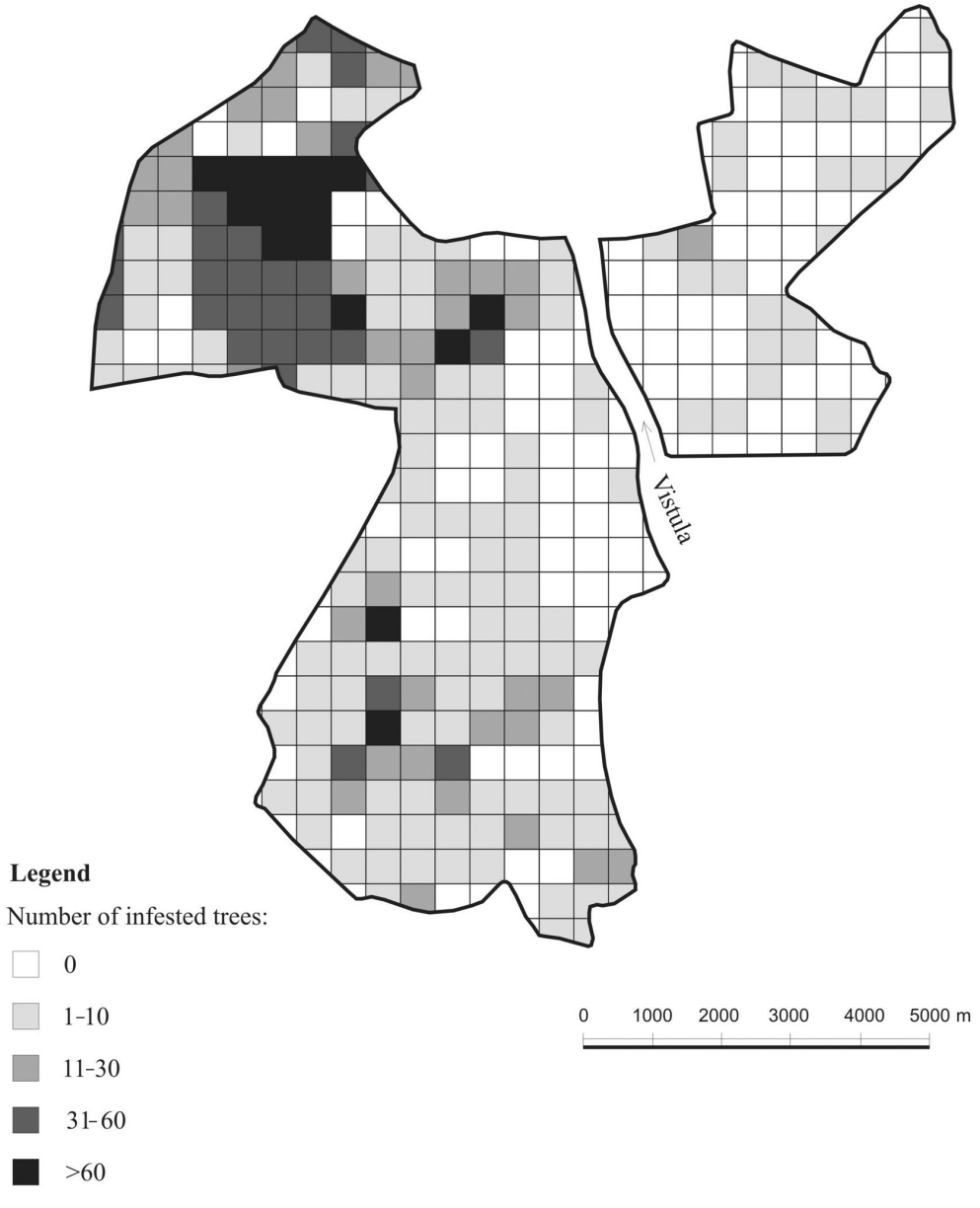

Fig. 2. The frequency of occurrence of host trees attacked by *Viscum album subsp. album* in the research area

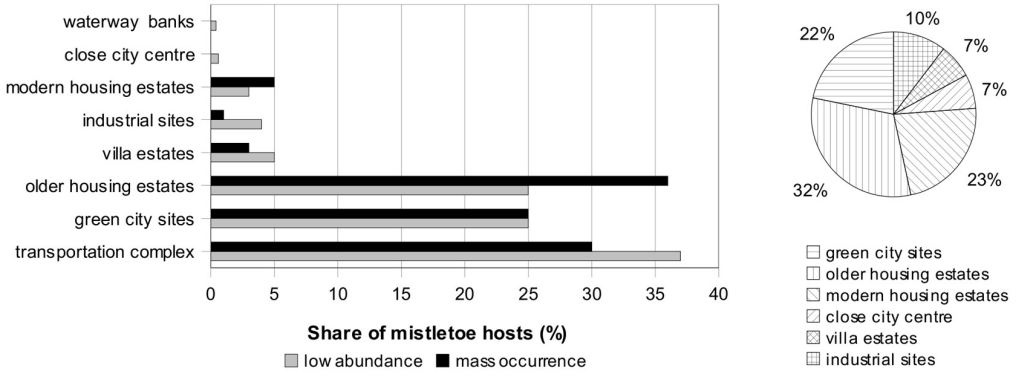

Fig. 3. The percentage share of hosts with "low abundance" and "mass" mistletoe occurrence in different types of habitats (illustrated by the share of habitat types)

area in Warsaw. There was also an absence of mistletoe on *Acer platanoide*s, despite frequently growing nearby heavily infested *Acer saccharinum*.

It is probable that mistletoe may use diverse host species within different parts of their geographic range or even show differences in host preference in different parts of their local populations (Press, Phoenix 2005). Why mistletoe may have different host preferences in different locations is still not known – the changes in host susceptibility to infection between different regions have been suggested as one of the mechanisms.

According to Downey (2004), mistletoe expansions may occur either accidentally through the introduction of the hosts that are not indigenous to the particular area or as a result of evolutionary changes being a consequence of environmental pressures, such as habitat modifications and climate change. In this context the research on the relationships between the mistletoe occurrence and local habitat conditions seem to be crucial.

The occurrence of mistletoe in different types of habitats in Warsaw was disproportionate and its distribution was highly uneven (Fig. 2, 3).

Table 3. The mistletoe host preferences in different types of habitats, for the most commonly infested host species

Type of habitat	Host species					
	Acer saccharinum	*Populus xeuramericana*	*Betula pendula*	*Sorbus aucuparia*	*Populus simonii*	*Robinia pseudacacia*
transportation complex	483	265	55	119	48	31
older housing estates	353	254	55	48	59	20
green city sites	287	163	225	27	6	14
villa estates	28	32	28	22	8	4
modern housing estates	38	40	12	8	3	11
industrial sites	17	70	3	7	5	4
close city centre	1	5	1	3	–	1
Total	1207	829	379	234	129	85

The most frequent occurrence of *Viscum album* L. subsp. *album* was observed within habitats of the older housing estates, the city transportation complex and the green city sites (86% of "low abundance" and 91% of "mass" occurrence) (Fig. 3, Phot. 1). These findings corresponded with the data of historical land use (Kłopociński 1975) and the map of real vegetation (Chojnacki 1991) performing that the most abundant mistletoe occurrence was noted on hosts growing in the areas built up between 1949–1965 and belonging to the 'complex of arranged urban vegetation composed of planted tree species'.

Not all green city sites were infested with the same frequency. Generally, parks were attacked with higher intensity than cemeteries and city forests. Among cemeteries, very high abundance of mistletoe was observed only at the Military Cemetery "Powązki", which could be explained by the great share of *Betula pendula* in this area. The trees growing at other cemeteries were infested only sporadically. This contrasts with Olivier (1998), who found cemeteries were the most preferred mistletoe habitats in Brussels.

In the city forests, *Viscum album* L. subsp. *album* was observed rarely, probably because of the insufficient sun light access to tree crowns. Also in Great Britain only small rate of mistletoe records was coming from woodland habitats (Briggs 1999, 2003), while in extensive woodlands of Bialowieża Primeval Forest in Poland (Sokołowski, Faliński 1961) the quite abundant occurrence of the hemiparasite was observed only on the forest edges. That points on the hemiparasite's preference to more open habitats with the direct sunlight access.

The trees growing in the gardens of villa estates were attacked far less frequently than those growing in the areas of older housing estates, transportation complex and green city sites, but the rate of mistletoe occurrence was still significantly high. It seems that apart from quite favourable microclimatic conditions and regular visits of birds, the activity of man could be a factor influencing mistletoe spreading in this habitat. Likewise in other Polish and European cities, also in Warsaw the mistletoe shrubs are sold during Christmas and the tradition orders to place the shrub at a home's front entrance. This custom is favourable for mistletoe dispersal by birds feeding in the neighbourhood. It is interesting to add, that in the Great Britain the most favourite mistletoe habitats were gardens and orchards with *Malus* sp. as the main mistletoe host (Briggs 1999, 2003). In Warsaw area, despite of the quite frequent occurrence of tree species from family *Rosaceae*, the mistletoe attacked *Malus* sp. and *Pyrus* sp. only sporadically.

In the habitats of the close city centre, the modern housing estates, the industrial sites and the waterway banks only 8% of all infested mistletoe hosts occurred (Fig. 3). Little mistletoe representation in the close city is probably caused by the lack of high vegetation and only few tree species susceptible to infestation. In the case of modern housing estates, inadequate microclimatic conditions (in particular decreased air humidity) and the presence of juvenile, homogenous, often coniferous vegetation cover are almost certainly the substantial reasons for the rare *Viscum album* L. subsp. *album* occurrence.

The areas along waterways were reported by several authors (Sokołowski, Faliński 1961, Stypiński 1978, 1997, Święs 2001) as places of the frequent mistletoe rates and correlated to the groundwater level – recognised as a factor influencing the mistletoe occurrence. Such regularities were not observed in Warsaw.

The physical and chemical features of habitats influenced the mistletoe occurrence in the research area, but their role was indirect.

According to the topoclimatic map of central Warsaw (Błażejczyk 2001), the abundant occurrence of mistletoe was recorded in the stands of slightly reduced airflow and solar radiation and slightly increased mean annual temperature. Substantial for the germination phase of mistletoe development are especially air temperature, air humidity and sunlight access. Zenkteler (1996) stated that the sufficient amount of temperature should be not less than 8–10°C and air humidity at least 50–60%. The high concentration of CO_2 in the city environment enable more productive assimilation and faster transpiration that influences further development of mistletoe specimens (Stypiński 1997).

Phot. 1. *Viscum album* subsp. *album* in different city habitats
A) city transportation complex, B) older housing estates, C) green city sites, D) example of mistletoe mass occurrence on the east site of Vistula River (photo K. Petrović, M. Zachwatowicz)

The analysis of mistletoe preferences concerning the soil type was difficult to conduct, since most of the soils occurring in Warsaw are anthropogenic (Czerwiński, Pracz 1990). Findings from other Polish cities like Poznan, Wroclaw and Stetin (Stypiński et al. 1990) showed the frequent mistletoe occurrence on hosts growing on alkaline soils. Some authors (Bojarczuk 1971, Stypiński 1978) reported that soils rich in calcium make the favourable conditions for the *Viscum album* L. subsp. *album*.

The increased soil contamination with salt, lead, zinc and copper in Warsaw (Kozłowska-Szczęsna 1996) does not look as a strong inhibitor of mistletoe growth. What is interesting, Michalczyk and Stypiński (1981), who investigated the susceptibility of the mistletoe to soil contamination with heavy metals and salt in Olsztyn town, found that the examined subpopulation was characterised by a greater production of basic organic compounds than the control subpopulation from the countryside. These findings may indicate that the *Viscum album* L. subsp. *album* has a high resistance to the harmful effects of city environment and attacks hosts with lowered viability caused by environmental pollution.

Finally, the expansion of *Viscum album* L. subsp. *album* in the research area was not only determined by the presence of suitable hosts and habitats, but was also strictly related to the number of breeding and migratory birds feeding on mistletoe berries. According to the data from Atlas of Birds of Warsaw (Luniak et al. 2001), the main avian disperser of mistletoe seeds in the research area was waxwing (*Bombycilla garrulus*), since its winter population counts from 300 to 3000 individuals and it is attached to the human settlements in the urban area. Other vectors of mistletoe in Warsaw could be *Parus major* (winter population counts 3200–5200 individuals), *Turdus pilaris* (3000–6000) and *Sylvia atricapila* (200–340), occurring frequently in the parks and cemeteries. The role of mistle trush (*Turdus viscivorus*) reported from other parts of Europe as a main mistletoe disseminator (Snow, Snow 1988, Josephsen 1993, Wunderwald, Lawrenz 1997, Olivier 1998, Briggs 1999, 2003) is much less significant, since it prefers the pine forests and occurs mostly in the peripheral parts of the city.

In summary, *Viscum album* L. subsp. *album* finds good conditions for growth and development in the heavily changed and contaminated anthropogenic habitats where apart from the plethora of potential hosts mainly of non-native origin and abundance of bird species – the main disseminators of mistletoe seeds, also specific microclimatic conditions contribute to the abundant mistletoe occurrence. Therefore, *Viscum album* L. subsp. *album* could be considered as a synantrophic species, having a wide spectrum of ecological adaptations to the negative influences of the city environment.

The further research should concentrate especially on determining the driving forces of mistletoe occurrence in different environmental conditions of the urban areas. The constant monitoring of the hemiparasite is needed to understand the long-term dynamics of mistletoe host range and distribution, as well as to undertake an appropriate management measures either to protect the hemiparasite at stands were it is rare or to prevent further invasions in the areas of overabundance.

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