

## THE STRUCTURE AND DIFFERENTIATION OF THE SYNANTHROPIC FLORA OF THE BOTANICAL GARDENS IN POLAND

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### ABSTRACT

Floristic studies were carried out in eight botanical gardens in Poland in the years 1992-1999. It was demonstrated that the spontaneous synanthropic flora of the gardens consisted of 1092 taxa in the rank of a genus or lower, among which alien species constituted 55% of the flora studied. Ergasiophygophytes, of which the introduction is closely associated with the activities of the botanical gardens, dominated in the latter group of species.

It appeared that the flora of the studied botanical gardens was rather similar. However, the structure of the flora of different spatial units (six types of microhabitats) distinguished in the particular gardens varied, which was associated with the various management practices. The flora of microhabitats identified in the gardens differed with respect to the number of taxa and spectra of geographical-historical groups of species and life forms. Ruderal sites, arable lands and roadsides supported the highest number of taxa (the flora of the above spatial units was represented by 646, 645 and 597 taxa, respectively). Moreover, they were characterized by a high proportion of annual plants in the flora (43, 38 and 34%, respectively) and by a relatively small representation of apophytes (39% in all the three types of microhabitats). The flora of wet areas and parks was, however, poor in species (154 and 403 species, respectively), but relatively rich in apophytes (72 and 55% of the flora, respectively) and with a low contribution of therophytes (19 and 20%, respectively).

The present data were compared with the findings of other authors who investigated the synanthropic flora of cities in which the botanical gardens were located. The comparative analysis of the flora of Poznań and Łódź showed a great richness of species (in relation to size of the area studied) and a high incidence of aliens (especially those, which had not become established permanently) in the botanical gardens. However comparative studies of the flora of Warsaw and that of the two botanical gardens established in the city revealed that the proportion of alien species was lower in case of these gardens.

In Warsaw the flora of areas, which had been managed in the same way as those of the botanical gardens, was also investigated. It was found that the botanical gardens in Warsaw were more similar to cemeteries with respect to the structure of flora than they were to the allotments. The present study showed that the high variability of flora within the particular gardens is attributed to the different ways the area is utilized.

**KEY WORDS:** synanthropic flora, flora of urban areas, microhabitats, botanical gardens.

### INTRODUCTION

Botanical gardens are associated with banking, cultivation and exhibition of plants. The way the botanical garden is managed is determined by introduction of a large number of plants for cultivation (which belong to many taxa: species, subspecies, varieties and hybrids).

The plant cover of botanical gardens was investigated in different aspects by a number of authors. However little attention was paid to the spontaneous flora of botanical gardens. The synanthropic flora of vascular plants (Adam-

czewska et al. 2000) and bryophytes (Filipiak 1996; Kalinowska-Kucharska 1998, 2001) was surveyed in the Botanical Garden of Łódź. In the Botanical Garden of Wrocław the flora of algae, bryophytes, myxomycetes, lichens and fungi was determined (Panek, Burzyński 1985; Berdowski 1988; Stojanowska 1992; Wójcik 1996; Kossowska 1997). The mycoflora of the Botanical Garden of the Warsaw University was also identified (Szober 1965). Studies on weeds accompanying the plants cultivated in greenhouses of the Botanical Garden in Powsin (near Warsaw) were published as well (Galera, Ratyńska 1999). In other European

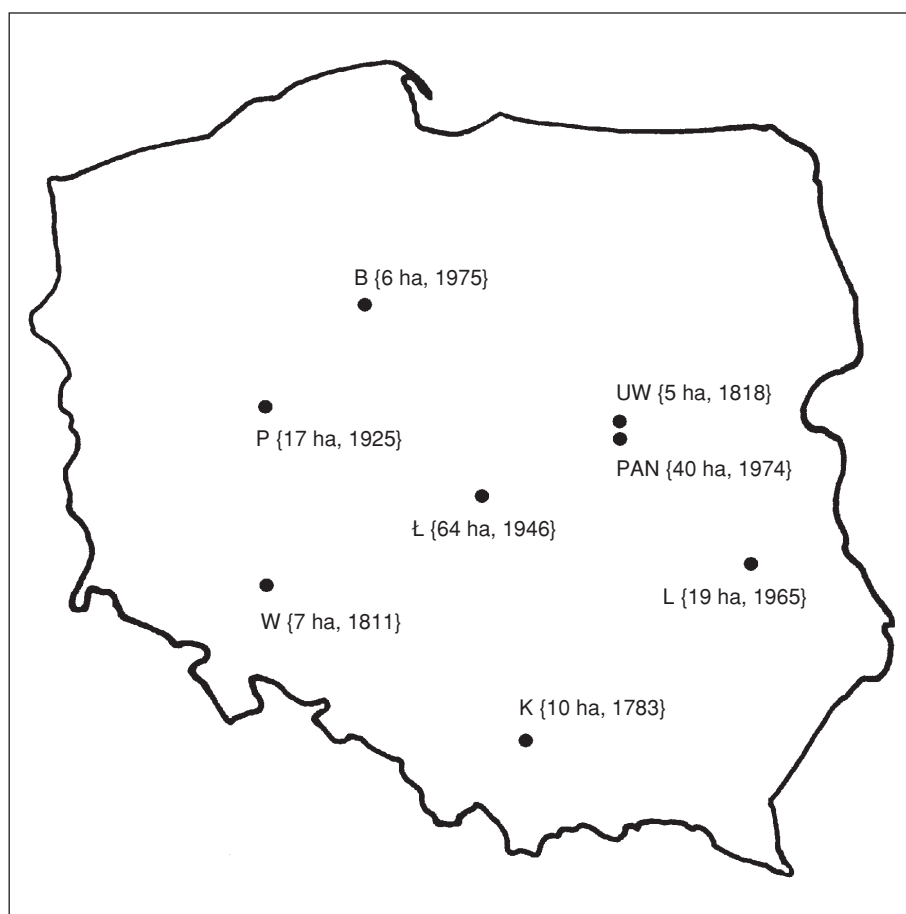


Fig. 1. Location, age and size of the botanical gardens studied: B – Botanical Garden of the Institute of Plant Cultivation and Acclimatization in Bydgoszcz, K – Botanical Garden of the Jagiellonian University in Cracow, L – Botanical Garden of M. Curie-Skłodowska University in Lublin, Ł – Botanical Garden in Łódź, P – Botanical Garden of A. Mickiewicz University in Poznań, PAN – Botanical Garden of the Polish Academy of Science in Warsaw-Powsin, UW – Botanical Garden of Warsaw University, W – Botanical Garden of Wrocław University. In brackets the size and year of establishment of the particular gardens.

countries extensive studies of flora of the botanical gardens have been carried out, among others, in Berlin-Dahlem (Straus 1967; Menzel 1984; Graf, Rohner 1984; Klawitter et al. 1984).

A small number of papers dealing with the flora of botanical gardens results from the fact that the methodology of data collection is very problematic. It is sometimes difficult to establish which plants occur spontaneously in the botanical gardens (this mainly applies to garden escapes). The floristic composition is very unstable. A number of weeds are introduced temporarily – persisting for only one growing season (Galera 2003). Therefore, the determination of the specific character of the flora requires different methods of approach. This study presents the results of the floristic analysis of the botanical gardens.

The aim of the present work is to determine the influence of different land management activities on development of the spontaneous flora of botanical gardens. An attempt was made to determine the character and scale of the process. Therefore, the specificity of synanthropic flora in the botanical gardens in Poland was investigated.

## MATERIAL AND METHODS

### *Study area*

In the present study the spontaneous flora of vascular plants was investigated. Only plants occurring spontaneously, including garden escapes (individuals which were self-perpetuating outside their plot without control), were taken into account (Galera 2003).

Specialistic collections, such as medicinal plant gardens and arboreta (dendrological gardens) were not included in the present study. In total eight botanical gardens, which had been operating in Poland for at least 25 years, were chosen for the study. Each of the gardens occupied an area of over 5 ha and contained a large and rich collection of plants. Moreover all the gardens were engaged in a regular international exchange of plant material (collaboration within Index Seminum).

In the years 1992-1999 floristic observations were made in the botanical gardens and their immediate surroundings. A complete list of species was published in an earlier work (Galera 2003).

The investigated gardens were internally differentiated with respect to their habitat conditions, as a result of various land management practices (forms of utilization of the area). Therefore six types of microhabitats (designated as spatial units in the present work) characterized by different forms of land use were distinguished: a) park and forest complexes (in short: parks); b) lawns and meadows (grasslands); c) road surfaces and roadsides (designated as roadsides); d) wet areas; e) ruderal sites; f) arable lands.

The spontaneous flora of the above spatial units was determined separately for each of the gardens (Galera 2003). The absence of wet areas in the Botanical Garden of the Warsaw University as well as parks and wet areas in the Garden of Bydgoszcz was noteworthy.

### *The analysis of the flora of the botanical gardens studied*

The synanthropic flora of Polish botanical gardens was determined. In addition a comparative analysis of flora of

the particular gardens and their spatial units was conducted. Data relating to species richness, spectra of life forms and historical-geographical groups of plants were presented.

A group of hemiapophytes *sensu* Krawiecowa, Rostański (1972) was identified among the synanthropes distinguished in the historical-geographical classification of Korňaś (1981) due to considerable differences in location of the particular botanical gardens (7 cities in various regions of Poland, Fig. 1). A species was considered to be a hemiapophyte if it was native to Poland, but recorded at least in one of the botanical gardens outside its original area of distribution.

Among the taxa native to Poland (apophytes and hemiapophytes) a group of oekiophytes, native species, which have escaped from cultivation (as opposed to spontaneous hemiapophytes and apophytes; Naegelli, Thellung 1905 cited after Sudnik-Wójcikowska, Koźniewska 1988), was recognized. Ergasiophygophytes are recognized as alien species, which have escaped from cultures in the botanical gardens studied and failed to establish. In the case of the group known as the agriophytes, the potential success of their invasion in natural and semi natural habitats in Poland was taken into consideration.

The classification of life forms follows that of Raunkiaer (1934). Among the annual species a group of “pseudotherophytes” was distinguished. These are perennial and woody plants originating in warm climatic zones, which in our weather conditions (in Poland) cannot survive cold winters (they are not likely to persist through winter as generative diaspores).

#### Comparative analysis

Results of floristic studies conducted in the botanical gardens were compared with the data obtained from those cities of Poland in which the gardens were established. The

richness of taxa and spectrum of historical-geographical groups of species were analysed. The synanthropic flora of botanical gardens was compared to:

a) the flora of entire cities in which the gardens were set up – the publications on Warsaw (Sudnik-Wójcikowska 1987, 1998a), Poznań (Jackowiak 1990) and Łódź (Olańczek et al. 1990) were considered;

b) the flora of areas of similar land use (which were managed in the same way as the botanical gardens) – in Warsaw the synanthropic flora of two botanical gardens was compared to that of the allotments (unpublished data regarding 6 allotment complexes in Warsaw-Mokotów and 6 complexes in Warsaw-Ochota) and cemeteries (Galera et al. 1993 – 24, cemeteries situated on the left bank of the Vistula River and unpublished data regarding 7 cemeteries on the right bank of the Vistula).

During comparison of flora of the particular cities, it was possible to distinguish native (apophytes) as well as alien species (anthropophytes) among the hemiapophytes recorded in the botanical gardens studied.

## RESULTS

The synanthropic flora of the eight botanical gardens in Poland was relatively rich in taxa. It consisted of 1092 taxa in the rank of a genus or lower and was represented mainly by aliens (55% of the total flora, Fig. 2). Among the latter, taxa which were planted and escaped via cultivation (ergasiophygophytes represented by 350 taxa and comprising 32% of the flora) prevailed. The proportion of native taxa in the flora of the botanical gardens was as follows: apophytes – 38% (417 species, including 71 oekiophytic apophytes) and hemiapophytes – 6% (72 species, including 56 hemiapophytes-oekiophytes). Synanthropes occurred in eight

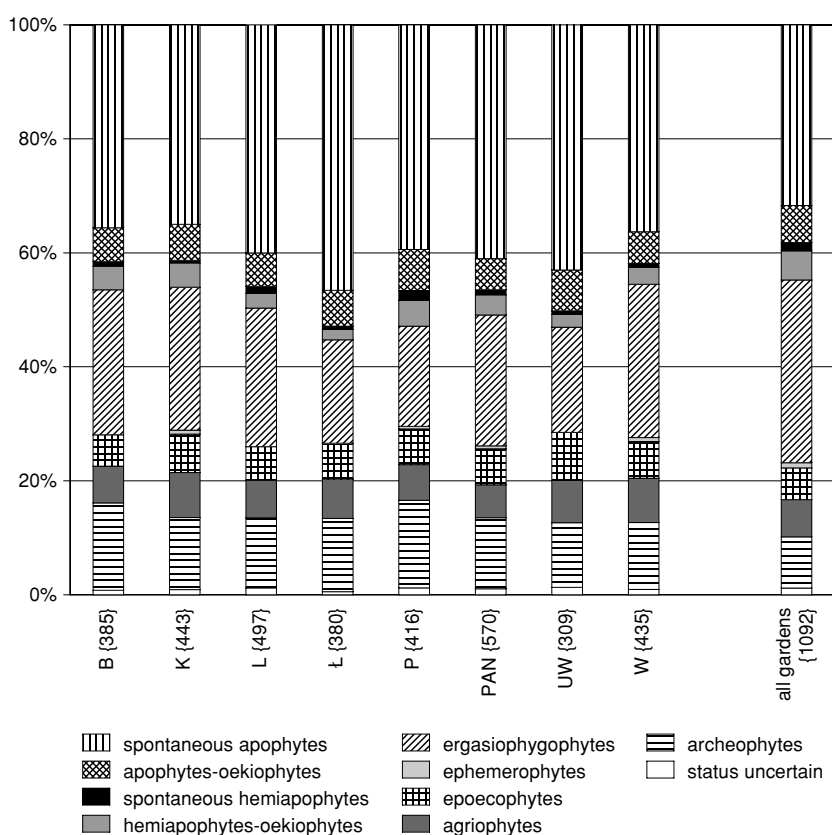


Fig. 2. The proportion of historical-geographical groups of synanthropes in the flora of the particular botanical gardens (for abbreviations of gardens see Figure 1) and all the eight gardens studied (in short: all gardens). In brackets the total number of taxa in the flora.

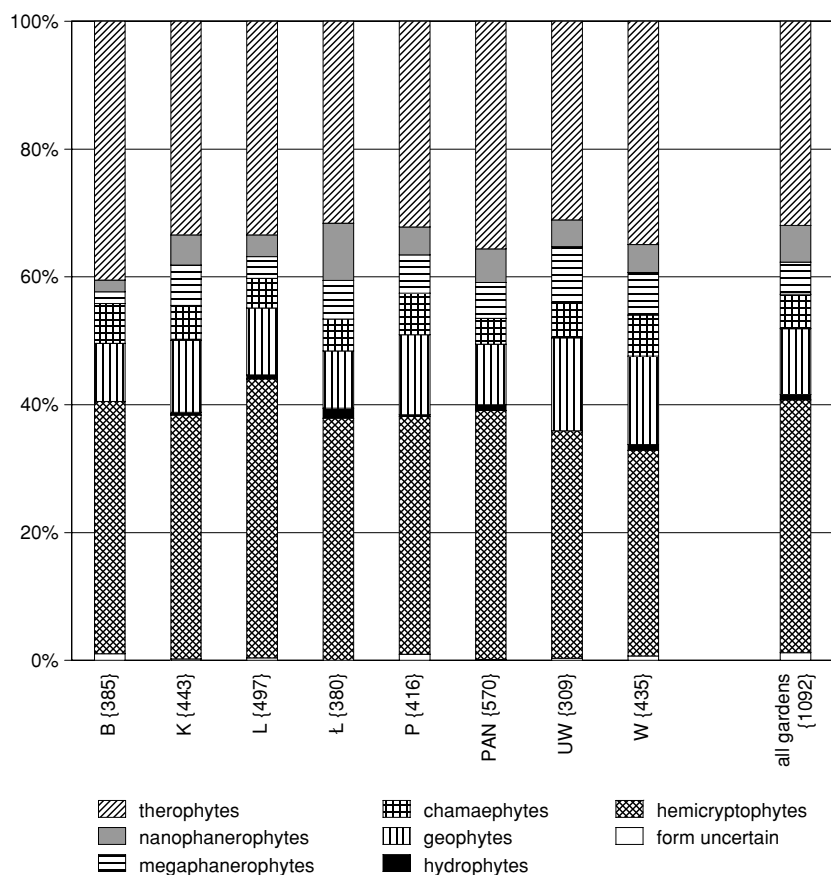


Fig. 3. The spectrum of life forms in the flora of the particular botanical gardens (for abbreviations of botanical gardens see Figure 1) and all the eight gardens studied (in short: all gardens). In brackets the total number of taxa in the flora.

gardens with a mean frequency of 39% (365 taxa were encountered only in one of the gardens, and 73 taxa occurred in all the gardens studied). The highest mean frequency was exhibited by archeophytes (57%), while ergasiophygophytes (28%), spontaneous and oekiophytic hemiapophytes (23 and 25%, respectively) as well as ephemerophytes (14%) occurred with a much lower frequency.

With regard to life forms, the dominance of hemicryptophytes and therophytes in the entire studied flora was recognized (40 and 33%, respectively, Fig. 3). A total of 430 taxa of hemicryptophytes were noted. Among the 360 taxa of therophytes recorded in the gardens, 13 species were classified “pseudotherophytes”. The contribution of hydrophytes (and helophytes) to the flora of the gardens was insignificant (1% of the total flora, mean frequency of occurrence – 29%). Megaphanerophytes accounted for 5% of the total flora and occurred with a frequency of 44%, being the most permanent element of the flora studied (compare the frequency of therophytes and hemicryptophytes – 41 and 38%, respectively).

The flora of the particular botanical gardens varied with respect to species composition, which was not related directly to the age and size of the areas studied (cf. Figs 1 and 2). It is worthy of notice that the spectra of historical-geographical groups of species and life forms in the flora studied were rather similar (Figs 2 and 3).

#### *Comparison of the flora of the various spatial units within botanical gardens*

It was found that the botanical gardens were internally differentiated with respect to their habitat conditions, as a result of various forms of utilization of their area. The analysis of the flora of the six types of microhabitats (spa-

tial units) distinguished in the gardens showed considerable differences in the richness of taxa (Fig. 4).

The qualitative analysis of the flora of the various land-use forms showed significant differences in species composition. In the group of synanthropes, marked differences were found in the case of apophytes and ergasiophygophytes (Fig. 4). The proportion of apophytes ranged from 72% (wet areas) and 55% (parks), to 39% (roadsides, arable lands and ruderal sites), whereas that of ergasiophygophytes varied from 3% (wet areas) to 30% (ruderal sites). It is interesting to note that apophytes contributed significantly to the flora of the sites studied.

Hemicryptophytes and therophytes prevailed in the flora of all the spatial units studied and their contribution varied considerably (Fig. 5). Wet areas and parks harboured the lowest number of species of short life cycles (19 and 20%, respectively), while ruderal sites, arable lands and roadsides were the richest in the above plants (43, 38 and 34%, respectively). Grasslands and wet areas were characterized by the highest proportion of hemicryptophytes (50 and 47%, respectively), whereas the lowest incidence of hemicryptophytes was noted in the case of ruderal sites and arable lands (34 and 36%, respectively). It is worthy of notice that ruderal sites supported the highest number of “pseudotherophytes” (among the ten taxa recorded, four species occurred along roadsides, two in arable lands and one in grasslands).

#### *Comparison of the flora of botanical gardens and cities (exemplified by Warsaw, Poznań and Łódź)*

Comparative studies of the synanthropic flora of botanical gardens and urban areas indicated that the gardens were rich in species in relation to the area they occupied. In the

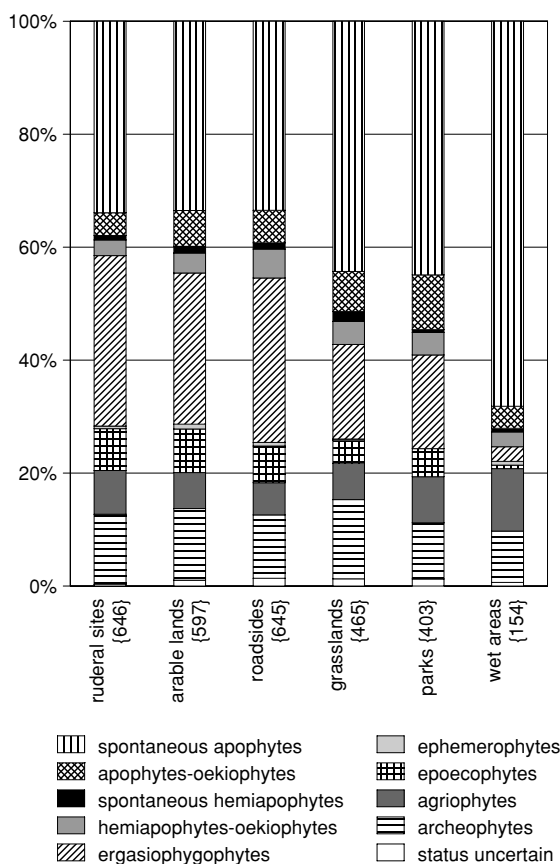


Fig. 4. The proportion of historical-geographical groups of synanthropes in the flora of various spatial units (microhabitats). In brackets the total number of taxa in the flora.

Botanical Garden of Warsaw University (5 ha) 309 synanthropic taxa were recorded, whereas the flora of Warsaw (43,000 ha) was composed of 945 species (cf. Figs 1 and 6). It is interesting to note that among the 720 taxa encountered in the Botanical Gardens of Warsaw University and Warsaw-Powsin, 112 species had not been reported earlier from Warsaw (not recorded by Sudnik-Wójcikowska 1987 and 1998a). A total of 416 taxa were recorded from the Botanical Garden of the University of A. Mickiewicz, including 85 species which were new to the city of Poznań (not reported by Jackowiak 1990).

The comparative analysis of the flora of Poznań and Łódź and that of the botanical gardens established in the above mentioned cities showed that the flora of the latter was characterized by a higher proportion of aliens, among which diaphytes (ergasiophygophytes and ephemeroophytes) dominated. A reverse tendency was, however, observed in the case of the flora of Warsaw and its two botanical gardens; the representation of anthropophytes, especially diaphytes, was much lower (Fig. 6).

*Comparison of the flora of botanical gardens and areas of similar land use (exemplified by allotments and cemeteries in Warsaw)*

Further comparisons of the synanthropic flora of areas of similar land use (areas of intensive cultivation: botanical gardens, allotments and cemeteries) in Warsaw pointed to a greater richness of species in the spontaneous flora of the botanical gardens (Fig. 7). The differences in proportion of the particular historical-geographical groups of species were

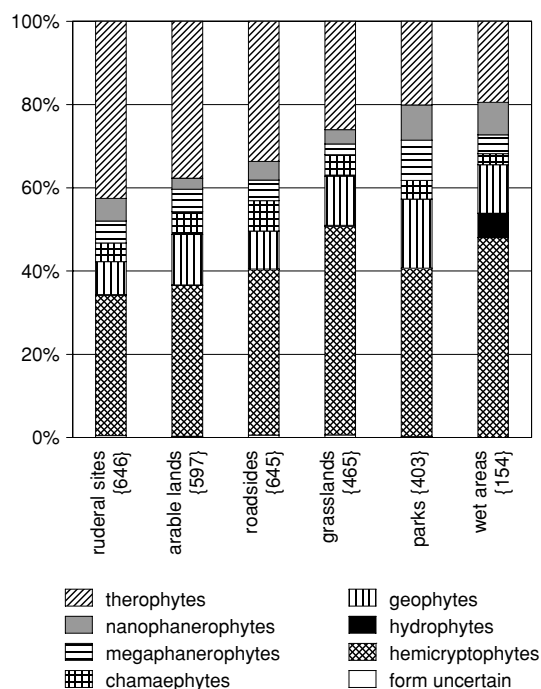


Fig. 5. The spectrum of life forms in the flora of various spatial units (microhabitats). In brackets the total number of taxa in the flora.

relatively small. The flora of the botanical gardens in Warsaw was, however, more similar to that of the cemeteries than it was to the allotments: it had a higher proportion of ergasiophygophytes and a lower incidence of archeophytes, which were found to occur more frequently in the allotments.

## DISCUSSION

*Specific character of the flora of the botanical gardens in Poland*

The spontaneous flora of the Polish botanical gardens was very rich in species. In total 1092 taxa were reported from an area of 167.5 ha, whereas the total flora of Poland (31.3 million ha) comprised about 2500-3000 species (Pawłowska 1972; Rostański 1989; Mirek et al. 1995).

The specific character of the flora of the gardens is determined by ergasiophygophytes, a group of alien garden escapes. The above taxa contribute significantly both to the flora of cities and botanical gardens, but they occur with a low frequency. The composition of ergasiophygophytes is diversified and varies in each of the gardens. The role of taxa which have escaped from cultivation (both alien and native garden escapes) is significant, which is manifested in the high number of taxa (but high frequency of some of them only, cf. Galera 2003).

Hemicryptophytes and therophytes prevail in the flora studied (40 and 33%, respectively). The flora of Poland (Pawłowska 1972) is also represented mainly by hemicryptophytes and annual plants (54 and 19%, respectively). The above trends in the spectrum of life forms reflect the high degree of synanthropization of the flora, since plants, which are capable of surviving in extreme conditions only in the form of generative diaspores, dominate in disturbed sites (Sowa, Warcholińska 1992; Jackowiak 1998; Sudnik-Wójcikowska 1998b).



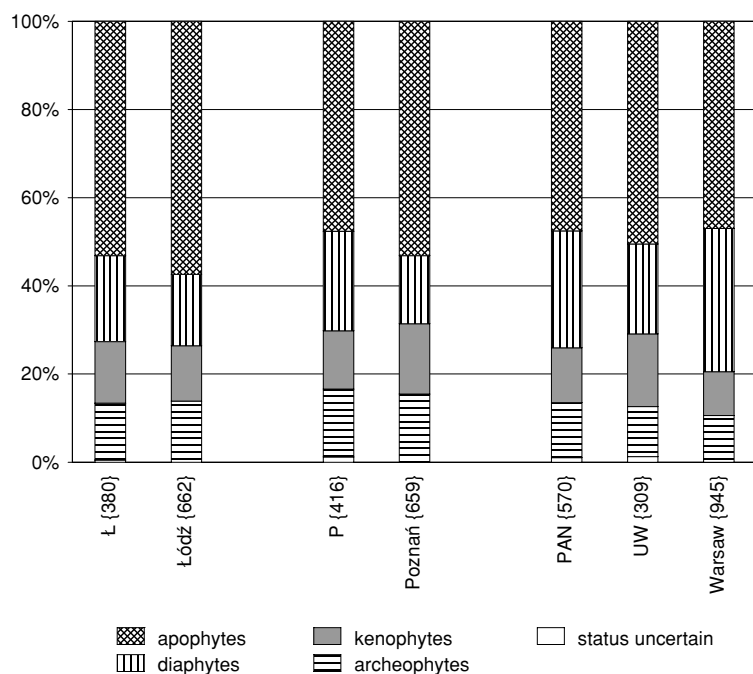


Fig. 6. The proportion of historical-geographical groups of synanthropes in the flora of: Łódź (22 000 ha, Olaczek et al. 1990), Poznań (24 000 ha, Jackowiak 1990), Warsaw (43 000 ha; Sudnik-Wójcikowska 1987, 1998a) and the botanical gardens established in the above cities (for abbreviations of botanical gardens see Figure 1). In brackets the total number of taxa in the flora.

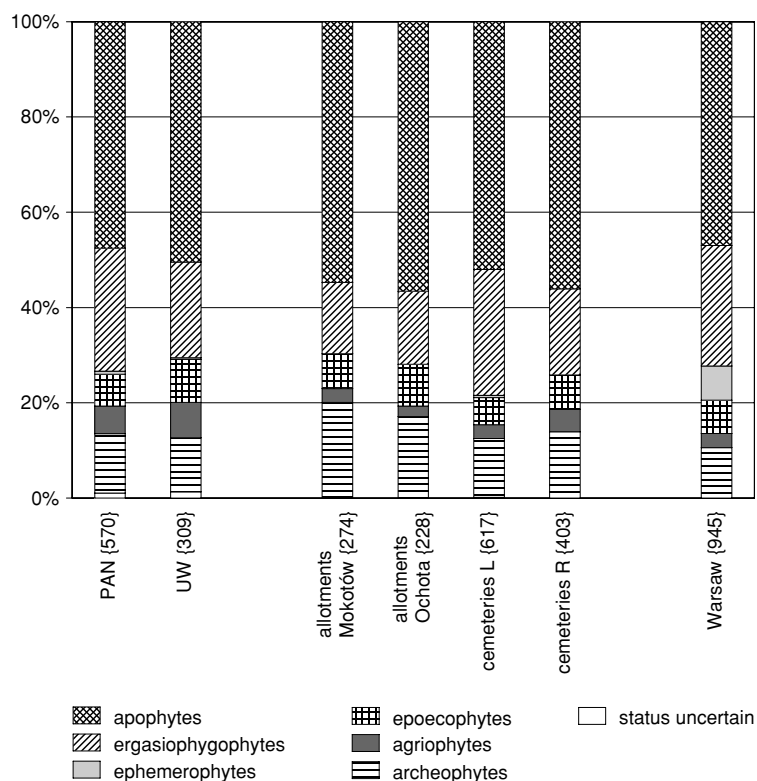


Fig. 7. The comparison of the spectra of historical-geographical groups of synanthropes in the flora of 2 botanical gardens in Warsaw (PAN – Botanical Garden of the Polish Academy of Science in Warsaw-Powsin, UW – Botanical Garden of Warsaw University) with the data concerning the flora of: Warsaw (43 000 ha; Sudnik-Wójcikowska 1987, 1998a), the allotments in Warsaw-Mokotów (135 ha, unpublished data) and Warsaw-Ochota (72 ha, unpublished data), cemeteries on the left (283 ha, Galera et al. 1993 – in short: cemeteries L) and right bank of the Vistula River in Warsaw (128 ha, unpublished data – in short: cemeteries R). In brackets the total number of taxa in the flora.

#### Comparison of the spontaneous flora of botanical gardens and cities

The present findings, as well as recent floristic data obtained from the cities in Poland in which the botanical gardens were established, show a great richness of species in the flora of the gardens in Warsaw, Poznań and Bydgoszcz. A total of 823 species of spermatophytes were reported from Bydgoszcz (area of 17 000 ha, Korczyński 1996), whereas 385 taxa (pteridophytes were absent) were recorded in the Botanical Garden of the Institute of Plant Cultivation and Acclimatization (5.5 ha). In the case of the Botanical Garden in Łódź the number of species recorded (391 taxa from an area of 64 ha) was lower in relation to

the size of the area studied. Łódź, which covers an area of 22 000 ha, yielded 983 species (Olaczek et al. 1990).

The comparative analysis of the flora of Łódź, Poznań and the botanical gardens, showed an increased representation of anthropophytes, especially ergasiophygophytes, following the influence of man. The results obtained by Sudnik-Wójcikowska (1987, 1998a) point to a high diversity of ergasiophygophytes in the flora of Warsaw. The number of the above group of taxa is much higher in the flora of Warsaw (239 taxa recorded by Sudnik-Wójcikowska 1987 and 1998a), than in that of Poland (149 taxa, Rostański 1989), and the botanical gardens studied. Moreover the number of ergasiophygophytes is considerably higher than

that of all the diaphytes noted in Łódź (Olaczek et al. 1990) and Poznań (Jackowiak 1990). It has already been established that the former group of species is a casual component of the flora. Their presence depends on the duration of the studies and size of the area studied (Kornaś 1977). The observations made by Sudnik-Wójcikowska (1987, 1998a) over a period of 20 years are up-to-date and covered a large area of study, which may account for the high richness of alien garden escapes.

#### *The flora of spatial units in the botanical gardens*

The present study showed floristic similarities between the particular botanical gardens, while the floristic composition of the various microhabitats identified in the gardens was markedly different. Ruderal sites, arable lands and roadsides are easily penetrated by alien taxa, especially by garden escapes. Such sites are a suitable environment for invaders and are close to abundant sources of diaspores of alien plants, which include plants cultivated in the gardens or (in the case of ruderal areas) plant remains. This leads to a greater richness of taxa and higher proportion of annual plants, as a result of disturbances in these sites. By contrast, parks and wet areas are more resistant to the penetration of aliens. The above microhabitats are characterized by a compact plant cover, which makes seed germination difficult. Due to the increased competition between plants, some species are not capable of further development (especially annual plants). Grasslands are difficult to classify: the structure of the plant cover is close to that of natural plant communities. The mode and intensity of land utilization (regular cutting, fertilization, treading) have a great impact on the species composition of the flora. Thus the proportion of therophytes is relatively low. However the species richness and the incidence of apophytes varies in the particular gardens.

It may be assumed that the differences in the spectra of life forms and historical-geographical groups of species are attributed to the selective pressure of the local conditions existing in areas close to natural, e.g. parks and wet areas (including watersides). Highly disturbed ruderal areas, arable lands and roadsides are inhabited mainly by plants with short life cycles. The flora of these microhabitats, especially that of ergasiophygophytes (alien garden escapes), is determined by the taxa which are cultivated in the particular botanical gardens.

The intensity of anthropopressure varies in different types of microhabitats, which results in the spatial variation of the flora in each of the botanical gardens studied. Since arable lands, grasslands, ruderal sites and roadsides can be distinguished within all the gardens (wet areas and parks were identified only in some of them and were relatively poor in species), the above factor (management activities) does not seem to be responsible for the differences in structure of the flora between the botanical gardens. The above differences are not attributed to age, size and location of the particular gardens either. It appears that the mode of land utilization has the greatest impact on the synanthropic flora of the botanical gardens in Poland.

#### *Comparison of the flora from areas of similar land use*

Botanical gardens and allotments, in which intensive horticulture practices are conducted, are characterized by similar forms of utilization of the area. In the north of Łódź allotments covering an area of 40 ha harboured 304 species (Adamczewska, Janowska 1998), whereas the spontaneous

flora of the Botanical Garden (64 ha) comprised 380 synanthropic species (and 11 nonsynanthropic species, Galera 2003). The number of taxa recorded in both areas is comparable.

However, the Botanical Garden in Łódź can be distinguished from the other Polish botanical gardens by a low richness of taxa in relation to the size of the area studied (cf. Figs 1 and 2). Ergasiophygophytes make up 18% of the flora of the garden and are the most numerous group of alien species. The above results are consistent with those of Janowska and Adamczewska (2000). The aforementioned authors identified 285 herbaceous species in the allotment gardens in the north of Łódź. Ergasiophygophytes (59 species, 21% of the total flora of herbaceous plants) dominated among the alien species.

The comparative analysis of the two allotment complexes in Warsaw (in Warsaw–Mokotów and Warsaw–Ochocka) and botanical gardens (Botanical Garden of Warsaw University and Botanical Garden of the Polish Academy of Sciences) showed that the flora of the botanical gardens was highly diversified. A considerable number of taxa were also reported from the cemeteries in Warsaw but from a much larger area. With respect to the spectrum of historical-geographical groups of synanthropes it was found that the cemeteries were more similar to the botanical gardens. They had an identical proportion of ergasiophygophytes, although the composition of plants cultivated in the botanical gardens was much more diversified (by contrast, the composition of species cultivated in the cemeteries and allotments is similar).

The similarities in the flora of cemeteries and botanical gardens may be attributed to the application of similar methods of research (Galera et al. 1993; Galera 2003) and degree of penetration of the studied areas (the access to some allotments was restricted), as well as much the same variety of habitat conditions. In some places cemeteries and botanical gardens were devoid of trees (and often highly transformed due to intensive management practices), while in other parts they were covered by massive and compact stands of trees. By contrast intensively cultivated allotments were loosely and regularly planted with fruit trees.

The analysis of the various types of spatial units distinguished in the botanical gardens confirmed the significant role of management activities in determining the spontaneous flora of the gardens. Various forms of utilization of the area (diversity of microhabitats) within each botanical garden are of great importance. This leads to a great variability of habitat conditions. As a result the synanthropic flora of the botanical gardens is highly diversified.

## CONCLUSIONS

1. The process of flora synanthropization in Polish botanical gardens is manifested by a great richness of taxa and high proportion of alien taxa, especially garden escapes.
2. Ergasiophygophytes are the most characteristic element of the flora of the botanical gardens. They are closely associated with the activities of the gardens and determine the specific character of the flora.
3. The spontaneous flora of botanical gardens is determined by the mode of land use.

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