

Plant communities with *Helianthus tuberosus* L. in the towns of the Upper Silesian Industrial Region (southern Poland)

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Abstract: The aims of the research were: to show the floristic composition of patches with participation of *Helianthus tuberosus*, to find the major environmental gradients in species composition of these patches and to compare plant communities with this species from Poland with those recorded in neighbouring European countries. Fifty four phytosociological relevés, made in a variety of ruderal habitats in the towns of the Upper Silesian Industrial Region (Poland), were analysed using the Correspondence Analysis (CA). To identify the main environmental gradients in the floristic composition of relevés the CA site scores were correlated, using the Kendall correlation coefficient, with the following explanatory variables: Shannon *H'* index of species diversity, the number of species from the *Convolvuletalia sepium* order, the *Calystegion sepium* alliance, the *Onopordetalia acanthii* order, the *Molinio-Arrhenatheretea* class, the *Stellarietea mediae* class; mean Ellenberg indicator values for light, moisture, temperature, soil reaction and nitrogen. Two major gradients in species data were detected: (i) from plant communities of abandoned meadows of the *Molinio-Arrhenatheretea* class to nitrophilous communities of the *Convolvuletalia sepium* order and (ii) a gradient related to the number of species of the *Stellarietea mediae* class and to the indicator value for light.

Helianthus tuberosus stands recorded in European countries can be divided into two separate groups. The first group is differentiated by species of the *Onopordetalia acanthii* order and higher participation of meadow species from the *Molinio-Arrhenatheretea* and *Stellarietea mediae* classes. The second group is characterized by a high frequency of nitrophilous species from the *Convolvuletalia sepium* order.

Key words: alien species, plant communities, ecology, ordination, *Helianthus tuberosus*

1. Introduction

The strong human impact which has been taking place for many hundreds of years has led to negative changes in the environment, such as the extinction of some species with narrow ecological amplitude, a decrease or fragmentation of the area occupied by natural and semi-natural plant communities and the simplification of their vertical and horizontal structure resulting in the synanthropisation of plant cover (Faliński 1966). A serious problem can also arise when species which are alien to the Polish flora penetrate into native vegetation. What kind of influence it will have on resident vegetation depends on its ability to overcome different barriers, such as: geographical, environmental,

reproductive, local dispersal barriers and finally environmental barriers in natural or semi-natural vegetation (Richardson *et al.* 2000). An increase in participation of such alien species as *Solidago canadensis*, *S. gigantea*, *Bunias orientalis*, species from the *Aster* genus and *Helianthus tuberosus* successively can be observed in patches of vegetation in the study area. The last species, *Helianthus tuberosus* (Jerusalem artichoke), probably comes from the North America where its natural area of distribution ranges from Canada to the states of Minnesota and Kansas (Řehořek 1997). It was introduced into Europe in the 17th century and cultivated till the 18th century (Oberdorfer 1993). Then it escaped from cultivation and started to invade natural plant communities. This alien species (neophyte) in the Polish flora

was for the first time recorded in Poland in 1872 (Rostański 1872; Sudnik-Wójcikowska 1987; Pyšek *et al.* 2004; Tokarska-Guzik 2005). It was introduced intentionally as an ornamental or medicinal species and for use in forestry and cultivation (bee-keeping, cosmetics, lawns, landscaping, reclamation, biomass fuel plants). Its spread into natural and semi-natural habitats began in 1960 and at present it can be found in many regions of Poland (1416 localities in 2000) where it is permanently established (Tokarska-Guzik 2005). However, the largest concentrations can be found along Polish rivers, their tributaries and at the edges of forests (Zajac & Zajac 2001; Tokarska-Guzik 2003).

Its status of invasiveness varies in different countries in Europe. It is considered an invasive species in Poland, Austria, Italy, Germany, France and Hungary, whereas in other countries, such as Latvia, Denmark, Lithuania and Sweden, it is a rare species, non-invasive or its status is unknown. In Switzerland *Helianthus tuberosus* was placed on a “watch list” which comprises invasive alien species that have the potential to cause damage and therefore their spread should be monitored (Wittenberg 2005).

The aims of the research were:

- to document the floristic composition of patches with *Helianthus tuberosus*,
- to find main environmental gradients along which these communities are differentiated,
- to compare phytocoenoses with this species from Poland with those recorded in other European countries.

2. Material and methods

Phytosociological research on *Helianthus tuberosus* L. aggregations was carried out during 1999-2005 in the towns of the Upper Silesian Industrial Region (Silesian Upland, Poland). Using the Braun-Blanquet (1964) approach, 54 phytosociological relevés were made in a variety of ruderal habitats, such as: refuse dumps, allotments, roadsides, urban wastelands or fresh soil deposits.

The collected relevés were analysed using the Correspondence Analysis (CA), (Gauch 1982) with the CANOCO 4.5 package (ter Braak & Šmilauer 2002; Jongman *et al.* 1995). In order to find the major environmental gradients which shape the floristic composition of relevés, explained by the first two CA axes, the CA site scores were correlated, using the Kendall correlation coefficient, with Shannon diversity index (H'), the number of species from the phytosociological units (the *Convolvuletalia sepium* order, the *Onopordetalia acanthii* order, the *Calystegion sepium* alliance, the *Molinio-Arrhenatheretea* and the *Stellarietea mediae* classes) and mean Ellenberg indicator values for light (L), moisture (F), temperature (T), soil reaction (R) and

nitrogen (N) calculated from phytosociological relevés (Ellenberg *et al.* 1991).

Moreover, a synoptic table was made in order to compare related *Helianthus tuberosus* phytocoenoses from the investigated area with other regions of Poland and some neighbouring European countries, with the use of the computer program “Profit 2.0” (Balcerkiewicz & Sławnikowski 1998). Phytocoenoses with this species classified in a community rank as a facies of another association (*Impatienti-Solidaginetum*) or as a separate association (*Helianthetum tuberosi*) were chosen for analysis. For each species in the table the constancy degree and coefficient of cover (Pawłowski 1977) were given. The coefficient of cover was calculated according to the formula:

$$c = \sum a_i \cdot x100 / n$$

where:

c – coefficient of cover, a_i – abundance of i-th species in the table. The cover and abundance of species were recalculated according to the rule: r – 0.1; + – 0.5; 1-5; 2-17.5; 3-37.5; 4-62.5; 5-87.5; n – number of relevés in the table.

For some tables, instead of the coefficient of cover, only the range of cover-abundance was given because of a lack of full phytosociological relevés in the original papers (only synoptic tables).

The syntaxonomy of plant communities was based on Brzeg (1989) and Brzeg & Wojterska (2001). Names of plant associations were applied according to the rules of the International Code of Phytosociological Nomenclature (Barkman *et al.* 1995). The names of vascular plants follow Mirek *et al.* (2002).

3. Results

3.1. Differentiation of phytocoenoses with *Helianthus tuberosus* in relation to environmental gradients

In the area of the Upper Silesian Industrial Region phytocoenoses mainly occur with a higher abundance of *Helianthus tuberosus* which ranges from 25% up to 100% in the patch. They represent stages of invasion when the species already encroached into the community and started to push native species out of the plant community.

Indirect gradient analysis (CA) (Fig. 1) of *Helianthus tuberosus* phytocoenoses revealed two major gradients in species data. The more important first axis (eigenvalue 0.216) is closely related to the gradient ranging from plant communities which have some affiliation to the communities of the *Convolvulo-Agropyron* alliance (the *Artemisietea vulgaris* class) and meadow ones of the *Molinio-Arrhenatheretea* class to nitrophilous communities of the *Convolvuletalia sepium* order. The first

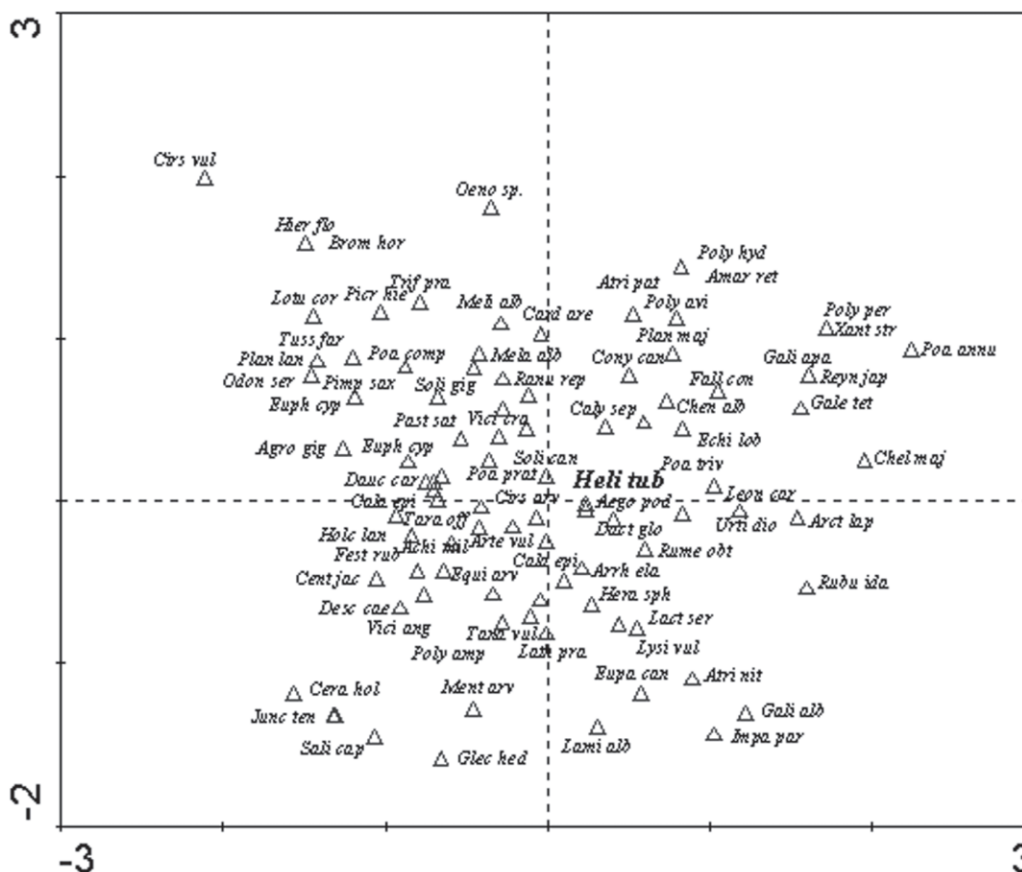


Fig. 1. Correspondence analysis of 54 relevés with *Helianthus tuberosus* occurring in the Upper Silesian Industrial Region
 Explanations: first 4 letters – the genus name, second 3 letters – the species name

group of relevés probably comprises patches of abandoned meadows of well-drained, relatively fertile mineral soils from the *Molinio-Arrhenatheretea* class after the cessation of mowing, grazing and fertilization. The second group consists of patches which were found on nitrogen-rich soils, mainly in the vicinity of allotments, gardens and in orchards. *Helianthus tuberosus* grows together with other dominants or subdominants of nitrophilous communities of semi-shaded margins (*Aegopodium podagraria*) or weed communities dominated by perennials of the *Artemisietea vulgaris* class (*Urtica dioica*, *Artemisia vulgaris*, *Cirsium arvense*,

Equisetum arvense), or with other alien species with robust growth, such as *Solidago gigantea*, *S. canadensis* or *Reynoutria japonica*. Some liana species (*Calystegia sepium*, *Echinocystis lobata*) are sometimes more abundant in patches with the dominance of Jerusalem artichoke and species which use alien plants as a support (*Galium aparine*).

This is indicated by a high Kendall correlation coefficient between the sample score on the 1st axis and Ellenberg N indicator value and also by higher scores for nitrophiles of the *Calystegion sepium* (= syn. *Convolvulion sepium*) alliance (Table 1). A strong negative correlation

Table 1. Kendall (t) coefficient between the scores of first two CA ordination axes and the selected explanatory variables. Only the significant p-values are shown (number of relevés = 54)

Variable	Ax1 (eig. = 0.216)			Ax2 (eig. = 0.173)		
	τ	Z	p-value	τ	Z	p-value
Shannon index (H)	-0.440	-4.698	0.000	0.072	0.770	
Nutrients	0.625	6.670	0.000	0.030	0.323	
Light	-0.113	-1.204		-0.274	-2.931	0.003
Tall herbaceous nitrophiles species of the <i>Calystegion sepium</i> alliance*	0.453	4.835	0.000	-0.079	-0.841	
Ruderal species of the <i>Onopordetalia acanthii</i> order*	-0.298	-3.185	0.001	-0.121	-1.290	
Species of the <i>Stellarietea mediae</i> class	-0.079	-0.841	0.400	-0.453	-4.835	0.000
Meadow species (<i>Molinio-Arrhenatheretea</i> class)*	-0.557	-5.947	0.000	0.123	1.318	

Explanation: *species are grouped according to Braun-Blanquet system

was found with meadow species of the *Molinio-Arrhenatheretea* class and weaker one with the number of species of the *Onopordetalia acanthii* order, particularly those which build communities confined to initial, skeletal soil, frequently rich in calcium content. *Helianthus tuberosus* stands developing on waste sites were significantly richer in species in comparison to phytocoenoses in which higher participation have species of the *Calystegion sepium* alliance.

In patches with a high density population of *Helianthus tuberosus*, other species were less abundant. Many occasional species were also recorded in the floristic composition of the community. However, no significant correlation with soil reaction or soil moisture was found. The second less important gradient is related to the number of species of weed communities of agricultural crops, garden and waste places of the *Stellarietea mediae* class and light indicator value (Table 1).

3.2. Comparison of phytocoenoses with *Helianthus tuberosus* recorded from Poland and other European countries

Helianthus tuberosus stands recorded in Poland and other European countries can be divided into two separate groups. The first group (columns 1 to 5 in Appendix) can be positively distinguished by ruderal species from the *Onopordetalia acanthii* order, such as *Convolvulus arvensis*, *Arctium lappa*, *A. tomentosum*, *Daucus carota*, *Tanacetum vulgare* and others. Nitrophiles from the *Convolvuletalia sepium* order occur in these patches with significantly lower frequency. A higher participation of meadow species from the *Molinio-Arrhenatheretea* class, species of grassy communities of recreational swards, gateways and roadsides from the *Lolio-Plantaginion* alliance (*Lolium perenne*) and short-lived ruderal species from the *Stellarietea mediae* class, such as: *Conyza canadensis*, *Chenopodium album*, *Fallopia convolvulus*, was also recorded. The patches cover mainly human-made sites, such as urban wastelands, road verges, edges of gardens, and fences.

The second group (columns 6-10 in Appendix) comprises phytocoenoses in which species of nitrophilous forbs from the *Convolvuletalia sepium* order and some tall graminoids on mineral and peaty soils, such as *Phalaris arundinacea*, were recorded with higher frequency.

4. Discussion

The research carried out in the area of the Upper Silesian Industrial Region and other regions of Poland and Europe shows that *Helianthus tuberosus*, because of its ability to overcome different barriers, has many traits characteristic for an invasive species, which can be a serious threat to the biodiversity of a given region. The species can invade different types of plant commu-

nities, both natural and anthropogenic ones. In its natural range, it is confined mainly to moist habitats, meadow and waste places, building phytocoenoses along with species with a wide ecological tolerance, such as *Cirsium arvense*, *Elymus repens* and meadow plants from the *Molinio-Arrhenatheretea* class. In root-crop fields, it can coexist with some segetal plants from the *Stellarietea mediae* class (Swanton *et al.* 1992). Oberdorfer (1993) gives some examples from Germany, where *Helianthus tuberosus* creates a distinct facies in some ruderal plant communities which belong to the *Onopordion acanthii* alliance, such as *Artemisio-Tanacetetum* and *Melilotetum albo-officinalis*. Jerusalem artichoke can also be found in the nitrophilous communities of tall perennial herbs from the *Aegopodion podagrariae* alliance or the *Convolvuletalia sepium* order.

Helianthus tuberosus can invade resident plant communities and cause a decrease in the number of native species or almost completely eliminate them from patches. As a result of the developing relationship of an invading plant a secondary, repeating combination of species is formed in which alien species play the main role (Faliński 1998). A good example is the *Impatiens-Solidaginetum* association which was described by Moor (1958). In the floristic composition of phytocoenoses, some alien species, among them *Helianthus tuberosus* (column 8 in the Appendix), play the dominant position. This plant community has impoverished floristic composition in comparison to fully developed nitrophilous forb community *Impatiens-Solidaginetum* (column 10 in the Appendix), where *Helianthus* coexists with other alien species, such as *Solidago gigantea* and *S. canadensis*. The patches are made up of 6 to 15 species. Most of them, with the exception of the dominant species, occur less frequently and attain lower values of coverage.

The phytocoenoses with *Helianthus tuberosus* were classified in different ways: only at the community rank, as a facies of other community (in case when character species of a given plant community can be found in patches) or as a separate association if the repeated combination of species in the field has been found.

In Poland, Jerusalem artichoke invades some natural communities, such as willow carr (*Salicetum albae*), which are confined to rivers. Some anthropogenic factors may be responsible for this situation, including the heavy eutrophication of habitats, habitat fragmentation, trampling, fire and deposition of garden rubbish (Borysiak *et al.* 2004). The similar role in its spread, like it was already mentioned in other papers (Feher & Končeková 2005), play some bio-corridors (roads, railways, small watercourses), where patches with *Helianthus tuberosus* were also recorded. Its invasiveness can be so strong that it almost completely transforms the floristic

composition of some rush communities, such as *Phalaridetum arundinaceae* and *Phragmitetum communis* (Moor 1958). It can create aggregations (almost monodominant patches) which develop on river embankments, in places where existing forest communities were completely cleared, at the edges of wet forests (carrs and alder carrs) or as replacement communities. The patches are usually poor in species because this strong and tall perennial plant (up to 3 metres in height) forms very dense clones, which annual growth can be up to 10-35 cm, and, in this way, it effectively occupies a given area and successfully overshadows species growing below and suppresses their growth (Moor 1958; Kopecký 1967).

Such traits as high competitive ability connected with robust growth form, perennial habit, very compact root system, which enable it to compete successfully with other plants, and wide ecological tolerance with respect to climate, soil types (loamy-silty, sandy or gravelly soils) and fertility (Kopecký 1967; Swanton *et al.* 1992) are responsible for its biocenotic success. Because it is a short day plant, it flowers very late during the vegetative season in Europe (September, October). It produces light seeds which can be dispersed by such agents as water and wind (Kopecký 1967). However, beyond the natural range of this species, the number of seeds which are capable of germination is relatively low. So, generative reproduction plays an important part when the species establishes on new sites and enables *Helianthus tuberosus* to maintain genetic diversity within populations (Konvalinková 2003). It spreads mainly in a vegetative way via rhizomes and tubers and their fragments (Schwabe & Kratochwil 1991; Konvalinková 2003). These organs can also be transported by water current, some animals (rodents), and sometimes also by humans

during the transport of soil and garden refuse.

It is commonly known that Jerusalem artichoke prefers mesic to moist habitats, mainly along river and pond embankments, regularly flooded during the high river stage and subject to erosion or being under influence of sedimentation processes (Moor 1958; Kopecký 1967, 1985; Hejný *et al.* 1979; Kornaś 1990; Swanton *et al.* 1992). Moisture of habitats was responsible for the differentiation of *Helianthus tuberosus* phytocoenoses which were examined in Slovakia by Jarolímek (1999). Those which developed in ruderal sites were positively distinguished by ruderal species from the *Onopordetalia acanthii* order and the *Stellarietea mediae* class. On the other hand, in patches which grew in the river valleys, hygrophilous species from the *Calystegion sepium* alliance and rush species of the *Phragmitetea* class had higher contributions. The phytosociological relevés from the study area were made on ruderal habitats (fallows, road verges, embankments and urban wastelands). These were sites situated rather far from the water courses which in the investigated area are frequently regulated or seriously transformed. However, the shade casted by the growth and development of trees can limit *Helianthus tuberosus* occurrence. A higher share of *Rubus caesius* and *Urtica dioica*, herbs that can successfully eliminate some neophytes, was also recorded in phytocoenoses which developed along rivers in Switzerland (Moor 1958). Its role also decreases in regulated river valleys (Schwabe & Kratochwil 1991).

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