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Excavations of the Twardowice Plateau (Silesian Upland) as refuges for xerothermic plant species

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Abstract: Paper concerns the flora of excavations from the area of the Twardowice Plateau, one of the regions of the Silesian Upland. These are rather shallow and small pits, which are remnants of exploitation of Triassic limestone and, rarely, iron ore. The studies showed that these excavations are the places where many species of vascular plants occurred. Xerothermic plants, which penetrated from adjacent grasslands, form the largest group (33%) among the 212 noted species. Some of them occurred much more frequently in the excavations than in the grasslands and some were found only in the excavations. It should be emphasized that 8 protected species were present in the investigated objects. Results from the Twardowice Plateau proved that many xerothermic plants could find suitable conditions for growth and survival in limestone excavations.

Key words: biodiversity, human-disturbed habitats, limestone excavations, spontaneous succession, xerothermic species

1. Introduction

Different types of pits form an integral part of the landscape of many regions both in Poland and in Europe. They are particularly numerous in areas where surface rocks are important for building or mining industries. Excavations may be of different sizes-from very small ones, covering the area of several square meters to large quarries and gravel- or sand-pits. When the exploitation is finished, vegetation succession starts there. This often results in developing of valuable phytocoenoses important for biodiversity of the region (Kompała 1997; Kwiatkowski 1998, 1999; Bąba & Kompała 2003; Badora *et al*. 2003; Beczała 2006; Nowak 2006; Wika *et al.* 2006; Bzdon 2008, 2009a, 2009b; Czylok *et al.* 2008; Czylok & Szymczyk 2009; Kompała-Bąba & Bąba 2009; Maciejczak 2010). They are sometimes accompanied by valuable animal species (Wheater & Cullen 1997; Beneš *et al.* 2003; Rademacher & Tränkle 2006).

Various limestone excavations cover vast areas in the Silesian Upland. Pits of different sizes (from large quarries to small shallow excavations) occur in the regions where Triassic limestones and dolomites build the bed. The excavations are mostly the remnants of exploitation of the rocks but there are also some places (so called "warpie") where mining of zinc and lead ores, and less frequently – iron ore, took place in the past centuries. In Poland, researchers have been mainly interested in large quarries until now (Stojanowska 1973; Kwiatkowski 1998, 1999; Badora *et al*. 2003; Beczała 2006; Wika *et al.* 2006; Maciejczak 2010). Little attention was given to small limestone excavations, scattered among fields, fallow lands, grasslands and scrubs.

The Twardowice Plateau – a subregion of the Tarnowskie Góry Ridge (Garb Tarnogórski) which is built of Triassic limestone, especially Muschelkalk (Mid-Triassic), is one of the regions of the Silesian Upland (Kondracki 2001) where small pits occur quite frequently. The relief of the Twardowice Plateau is very characteristic – long and broad humps with steep slopes are separated by numerous valleys running latitudinally (Gilewska 1972). It is an area of the old settlement and therefore, its natural vegetation is substantially transformed. Forests cover only a small area there and the xerothermic grasslands are a particularly interesting element of the vegetation; they cover steep hill slopes, which are unsuitable for agricultural purposes. Grassland patches representing the *Adonido-Brachypodietum pinnati* association occupy the largest areas there. Phytocoenoses of two subassociations (*A.-B. p. phleetosum* and *A.-B. p. typicum*) are the most common among them. Moreover, the *Teucrium*

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botrys-Sedum acre community was described from limestone excavations of the Plateau (Babczyńska-Sendek *et al*. 2010). The grasslands were used as pastures in the past, but in the last decades, grazing has been abandoned as the whole region has generally lost its agricultural character. That concerns especially its southern part, situated in the close vicinity of the towns of the Upper Silesian Industrial District. The ungrazed grasslands are threatened by the secondary succession. Moreover, such human activities as: afforestation of grasslands, driving quads or motorcycles and usage of the highest elevations by hang-gliders as starting places (which causes significant treading of the vegetation) are sometimes another important threats.

Exploitation of limestone was carried on in the whole area of the Twardowice Plateau – both in large quarries, as well as in small excavations. Apart from them, there were also small opencast mine exploiting iron ore, which remnants can still be found on some hills. Vegetation cover has already developed in most of excavations and species penetrating from the nearby grasslands played an important role in its formation.

Data concerning vascular plants, including xerothermic species, in the Twardowice Plateau area can be found in the study dedicated to the flora of the eastern part of the Tarnowskie Góry Ridge (Nowak 1999). More detailed data, concerning xerothermic species and grasslands of the region, are presented by Babczyńska-Sendek *et al*. (2010). They can be also found in the study relating to this kind of vegetation in the whole Silesian Upland (Babczyńska-Sendek 2005).

The aim of the research on the flora of excavations (excluding large quarries) from the area of the Twardowice Plateau was to determine to what extent, in situation of threat to grasslands, small pits can be the local refuges for xerothermic species.

2. Materials and methods

The investigations were carried out in 50 small pits, which were located mainly in the southern part of the Twardowice Plateau (Fig. 1) and adjoin patches of xerothermic grasslands. They were mostly excavations, which remained after exploitation of limestone for building purposes and partly, pits that were probably the remnants of old iron ore mines. Their area was about 2-50 m^2 and their depth usually did not exceed 2 m. The pits, especially the small ones, occurred close to each other and formed groups of various sizes.

The investigations of flora in the above-mentioned excavation were carried out during the vegetative season of 2009. A detailed inventory of the vascular plant species was prepared for each of the object. The obtained data were then used to prepare a floristic list of those sites and to make further detailed analysis. Five groups of species were distinguished due to their frequency in the excavations. The historical-geographical groups of anthropophytes were identified according to Zając (1979), Zając *et al*. 1998 and Tokarska-Guzik (2005). The participation of the species from different sociological groups was also analysed. Nine such groups were distinguished basing on phytosociological affiliation of species and their habitat preferences (Matuszkiewicz 2001; Zarzycki *et al*. 2002). In case of several plants, when phytosociological attachment was hard to determine, their frequent occurrence in xerothermic grasslands of the Twardowice Plateau (Babczyńska-Sendek *et al*. 2010) was taken into consideration. They were classified to the group of species connected with xerothermic grasslands and thermophilous edge communities. The frequency of the particular species most frequent in the flora of the examined excavations was compared with constancy of these plants in the phytocoenoses of main xerothermic grasslands of the Twardowice Plateau (according to Babczyńska-Sendek *et al*. 2010). The names of vascular plants follow Mirek *et al*. (2002).

3. Results

The flora of the investigated excavations was rather rich; 212 species of vascular plants were found here. Native species prevailed (86.5%) among them and anthropophytes constituted 13% (Fig. 2A).

Plants of xerothermic grasslands and thermophilous edge communities were the largest group (38%) among native species. If other thermophilous species are added, they made up together to 44% of the whole investigated flora (Fig. 2B). Quite numerous were also the groups of meadow plants (18%), and native species associated mainly with ruderal and segetal habitats (14%). Among the other distinguished ones, forest plants were the most numerous (9%); together with shrub species, they represented 15% of the flora. It should also be noted that among the meadow plants, which grew in the excavations there were many ones, which were permanent components of the xerothermic grasslands in the Twardowice Plateau. This shows clearly that species associated with the grasslands were the main components of the flora of the investigated objects.

Archaeophytes (39%) and agriophytes (39%) clearly predominated among anthropophytes (Fig. 2C). Majority of archaeophytes (25%) were crop weeds. Particular archaeophytes were very rare in the investigated excavations (they have been recorded in 1, 2 or 3 pits). Only *Lactuca serriola* was present in 11 of them. Among agriophytes 4 species: *Medicago sativa* (18 excavations), *M.* ×*varia* (11), *Senecio vernalis* (11) and *Solidago canadensis* (8) were recorded more frequently and others were very rare.

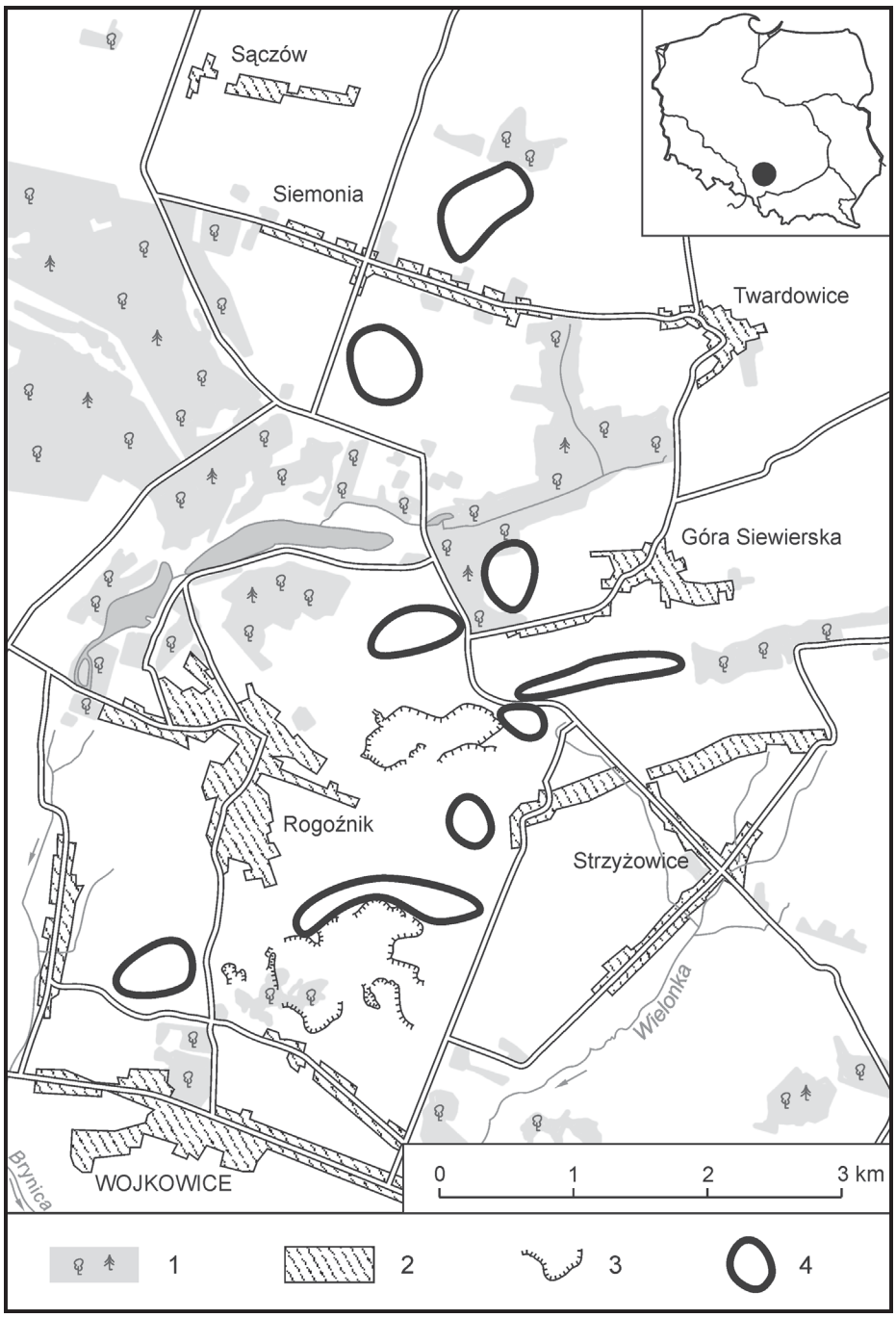

Fig. 1. Location of the groups of the investigated excavations in the Twardowice Plateau
Explanations: 1 – forests and woodlots, 2 – built-up areas, 3 – quarries, 4 – areas of occurrence of excavations

Analysis of the frequency of particular species in the investigated excavations (Fig. 3) showed that rare species (occurring in less than 10 pits) were the most numerous (67%). More than a half of them (38% of the whole flora) were noted only once or twice. The second relatively big group (14%) comprises the plants observed in 10-19 excavations. The species found in 20-29 pits are slightly less numerous (11%). Plants occurring in 30-39 excavations form a small group (less than 5%) and the least numerous (slightly over 2%) are those, which were found in 40 and more investigated objects.

The most frequently noted species (the two least numerous groups in Fig. 3) are almost only plants of xerothermic grassland. *Galium album, Sanguisorba minor* and *Thymus pulegioides* (Table 1) are the most common ones among them. Xerothermic plants dominate (58%) also among the species found in 20-29 excavations. They have a smaller percentage share in the two most numerous groups, although their number (32) is the highest in the group of the most rarely recorded plants. However, due to the largest number of species in the group, their percentage share is the lowest there.

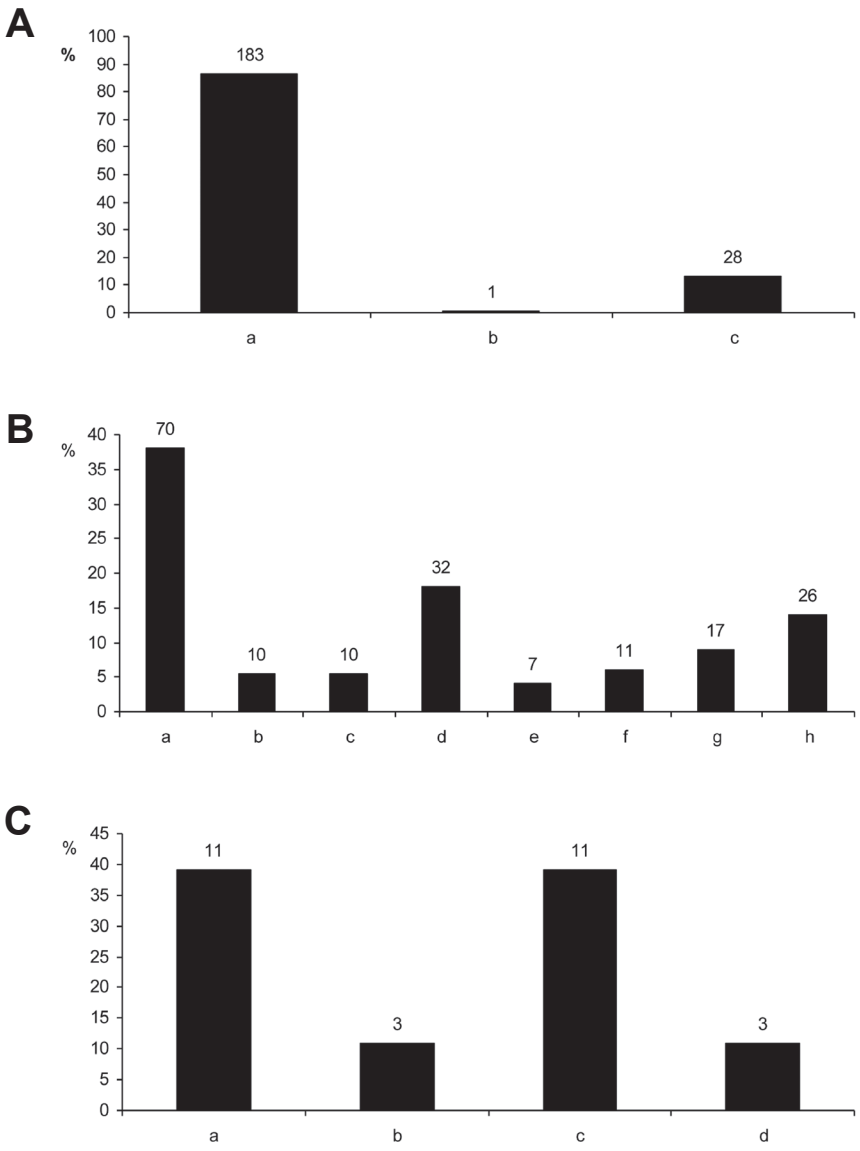

Fig. 2. Participation of native and alien species in the investigated flora

Explanations: A – main groups, a – native plants, b – probable anthropophytes, c – anthropophytes; B – habitat groups of native plant species, a – species of xerothermic grasslands and thermophilous edge communities, b – other thermophilous species, c – species of psammophilous grasslands and poor meadows, d – meadow species, e – species of forest clearings, f – scrub species, g – woodland species, h – ruderal and segetal native species; C – groups of anthropophytes, a – archaeophytes, b – epecophytes, c – agriophytes, d – ergasiophygophytes

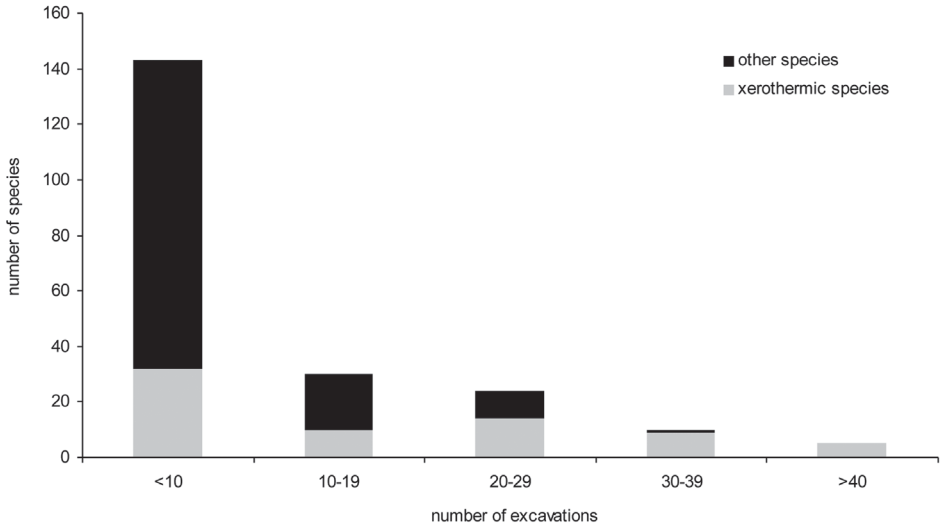

Fig. 3. Number of species in particular groups distinguished on the basis of their frequency in the investigated excavations

Table 1. The most frequent plant species – their frequency in excavations vs. their presence degrees in main xerothermic grasslands of the Twardowice Plateau

Species	Frequency in excavations		Presence degree in grasslands*	
	Number of excavations	Percentage of excavation	*A-Bp*	*A-Bt*
Galium album	47	94	IV	V
Sanguisorba minor	44	88	V	V
Thymus pulegioides	42	84	V	V
Brachypodium pinnatum	40	80	V	V
Euphorbia cyparissias	40	80	V	V
Convolvulus arvensis	39	78	III	II
Scabiosa ochroleuca	38	76	V	IV
Potentilla heptaphylla	37	74	V	V
Medicago falcata	35	70	V	V
Helianthemum numularium subsp. *obscurum*	34	68	V	IV
Linum catharticum	34	68	I	III
Centaurea scabiosa	31	62	V	IV
Centaurea stoebe	30	60	V	II
Achillea collina	30	60	V	V
Carlina acaulis	30	60	V	V

Explanations: * – according to Babczyńska-Sendek *et al.* (2010), *A-Bp – Adonido-Brachypodietum phleetosum* (26 relevés), *A-Bt – Adonido-Brachypodietum typicum* (26 relevés), I – 0.1-20.0%, II – 20.1-40.0%, III – 40.1-60.0%, IV – 60.1-80.0%, V – 80.1-100.0%

Some xerothermic plants (*Poa compressa*, *Acinos arvensis*, *Ajuga genevensis*) occurred much more frequently in the excavations than in the grasslands, while some of them (*Orchis militaris, Stachys recta, Teucrium botrys*) were recorded only in the excavations.

The investigated objects were places where 8 protected plant species were noted. Among them, there are 6 species which are under strict protection in Poland (*Carlina acaulis, Epipactis atrorubens, Gentianella ciliata, Jovibarba sobolifera*, *Orchis militaris* and *Orobanche lutea*) and 2 which are partially protected (*Ononis spinosa* and *Primula veris*). *Carlina acaulis* and *Ononis spinosa* were the most frequent (30 and 15 excavations respectively). *Jovibarba sobolifera*, *Epipactis atrorubens* and *Orobanche lutea* were found less frequently (8, 7 and 6 excavations) while *Gentianella ciliata*, *Orchis militaris* and *Primula veris* had only single localities. The abovementioned *Orchis militaris* belonging to very rare species in the Silesian Upland (Błońska *et al*. 2011), is especially worthy of attention.

4. Discussion and conclusions

The studies have shown that excavations in the southern part of the Twardowice Plateau are the places where many species of vascular plants occur. Plants penetrating from xerothermic grasslands play an important role among them. Comparing to large quarries from various regions of the southern Poland (Stojanowska 1973; Kwiatkowski 1998, 1999; Badora *et al.* 2003; Nowak 2006; Maciejczak 2010) the investigated flora was poorer and less ecologically differentiated. This is because habitat conditions in small and rather shallow excavations are not as diversified as in large and deep quarries, where even water reservoirs occur sometimes at the bottom.

Since the investigated excavations were located either in the immediate vicinity of xerothermic grassland patches, or relatively close to them, settling of grassland species in them was easy, especially because the most of them are plants adapted to wind dispersal over smaller or larger distances. In case of quarries it has been shown that the direction of succession depends on the type of vegetation in their immediate vicinity and that the occurrence of semi-natural xerothermic grasslands in the neighbourhood has a decisive influence on development of valuable grassland communities (Novák & Prach 2003; Novák & Konvička 2006).

Habitat conditions in small excavations are similar to those occurring on slopes with xerothermic grasslands and they promote settling of xerothermic plants. Wika (1986) pointed that succession was faster in shallow limestone excavations than in big quarries. The experience with rehabilitation of quarries in the UK proved that artificial formation of geomorphological forms similar to natural ones favoured development of grassland communities (Cullen *et al.* 1998).

Steep walls where the succession of vegetation is usually very slowly are the most common in large quarries where also exploitation levels and bottoms are flat. Therefore, habitat conditions are not always suitable for xerothermic vegetation there. The largest groups

of the species in the quarries in Opole area represented the *Molinio-Arrhenatheretea, Stellarietea mediae* and *Artemisietea vulgaris* classes and the total share of plants from the classes *Festuco-Brometea* and *Trifolio-Geranietea* was lower than 9% (Badora *et al.* 2003). The participation of xerothermic and termophilous species was more considerable (19%) in quarries from the Kadzielniańskie Range in the Świętokrzyskie Mts. (Maciejczak 2010) but it is still distinctly lower than in small excavations from the Twardowice Plateau. However, a significant amount of xerothermic species was found in calamine excavations in Jaworzno Długoszyn in the Silesian Upland (Jędrzejczyk-Korycińska 2006), which due to small depth and similar geological conditions resemble the investigated objects.

The most common species among the flora of the excavations belong to xerothermic plants, which were the most frequent in the *Adonido-Brachypodietum pinnati phleetosum* and *A.-Bp typicum* phytocoenoses – two types of dry grasslands, which are characteristic for the Twardowice Plateau (Babczyńska-Sendek *et al*. 2010). However, some plants that occurred exclusively or significantly more often in the excavations belong to the species associated with loose grasslands developing in the excavation, on limestone rubble or in crevices of uncovered rocks, and representing the *Teucrium botrys-Sedum acre* community (Babczyńska-Sendek 2005, Babczyńska-Sendek *et al*. 2010).

Occurrence of protected species in the flora of the investigated excavation increases their natural values but is not unusual. Studies on the vegetation of different quarries in fact proved that protected and endangered plant species often occurred in their areas (Kwiatkowski 1998, 1999; Badora *et al*. 2003; Beczała 2006; Nowak 2006; Maciejczak 2010), and sometimes even plant species considered to be extinct in the region could be found there (Rademacher & Tränkle 2006).

Studies on spontaneous succession occurring in various human-disturbed habitats proved that it usually leads to creation of sites of high natural values (Prach & Pyšek 2001). Results from the Twardowice Plateau showed that succession occurring in limestone excavations led to its colonization by numerous xerothermic species. Therefore, these anthropogenic sites became valuable nature objects. Many plants forming a local species pool (Zobel *et al.* 1998) of xerothermic grasslands can find suitable conditions for growth and survival there. It is especially important when many patches of grasslands in the area are endangered by the natural succession resulting from the lack of usage, afforestation and different forms of anthropopression.

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