

New localities of *Orobanche bartlingii* Griseb. in the Silesian-Cracow Upland as a result of the spread of *Libanotis pyrenaica* (L.) Bourg. due to the changes in land use

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Abstract: Human activity is a factor strongly influencing the current state of vegetation. The abandonment of traditional land use enables uncontrolled secondary succession. *Libanotis pyrenaica*, a host plant for *Orobanche bartlingii*, is a great example of species that spread as a result of this process, especially in the area of the Silesian-Cracow Upland. The aim of this study is to show that the expansion of *L. pyrenaica* caused by changes in land use promotes spreading of *O. bartlingii* – a species rare in Poland and Europe. During the field research conducted in the last decade, further localities of *O. bartlingii* were found. The gathered data were summarized to supplement the known distribution of the species and to present floristic and ecological characteristics of the phytocenoses with the participation of *L. pyrenaica* and *O. bartlingii*.

Key words: *Orobanche bartlingii* spreading, *Libanotis pyrenaica* expansion, vegetation changes, the Cracow-Częstochowa Upland, the Silesian Upland

1. Introduction

Vegetation is a dynamic and constantly changing formation. Changes are connected both with natural factors, having no direct connection with human activity, as well as with anthropogenic factors of various kinds and diverse intensity.

Human activity has long been a factor strongly influencing vegetation. This human impact has led to creation of species-rich semi-natural communities which, for centuries, have been associated with relatively stable traditional methods of use. Large-scale changes in human activity, occurring in recent decades, in particular, the abandonment of traditional use of semi-natural communities, enables the secondary succession process. This results in homogenization and trivialization of vegetation (Kornaś 1990).

In many regions of Poland, acceleration of the pace of landscape changes caused by changes in the land use has been observed approximately since 1990. The area

of arable land is decreasing and the area of fallow lands, extensive meadows, scrubs and forests is increasing (Solon 2003a). Acreage of rare plant communities, including semi-natural, associated with a specific way of use, is also shrinking (Solon 2003b). This causes changes in floras. Some species withdraw, becoming increasingly rare or they even disappear and others, particularly alien invasive and native expansive plants, spread.

The Silesian-Cracow Upland is a region where, in recent decades, changes in land use have taken place over a wide area and on a very large scale. People living in villages located near the Upper Silesian agglomeration and near numerous other urban-industrial centers have more possibilities of finding other ways to earn their living than agriculture. First of all, on a large-scale, farming has ceased on poor sandy soils and on skeletal soils (such soils have a large acreage in the Częstochowa Upland – mezoregion of the Cracow-Częstochowa Upland) as well as around large industrial facilities,

especially Katowice Steelworks. The abandonment of mowing of large meadow areas and cessation of grasslands grazing occurred also at the same time.

The succession takes place on multiannual fallow lands and plant communities occurring nearby often influence floristic composition of developing vegetation (Babczyńska-Sendek *et al.* 2012). Fallow lands are occupied by certain plant species. Most often, it is *Solidago canadensis* L. but in dry and moderately dry soils, rendzinas or pararendzinas type, *Libanotis pyrenaica* (L.) Bourg. has increased the area of its occurrence. Moreover, this species sometimes spreads out over various other wastelands with soil rich in calcium carbonate.

Qualitative and quantitative changes in the floristic composition have been occurring in ungrazed xerothermic grasslands. Some plant species disappear or decrease their share, while others spread, often behaving like expansive plants. One of these species, which significantly increased its share in grasslands, especially in the Cracow-Częstochowa Upland, is *L. pyrenaica*.

L. pyrenaica is a host plant for *Orobancha bartlingii* Griseb. – a broomrape species rare in Poland. In Poland *O. bartlingii* is known from several localities (Piwowarczyk *et al.* 2009; Piwowarczyk 2012a), where it usually grew in xerothermic grasslands, thermophilous edge communities and, less frequently, on fallow lands. In recent years, in the Silesian Upland and the Częstochowa Upland, new, sometimes numerous localities of *O. bartlingii* were found in places where, during earlier investigations (Babczyńska 1978; Babczyńska-Sendek 1984, 2005), the species was not observed.

The aim of this study is: to show that the expansion of *L. pyrenaica* caused by changes in land use promotes spreading of *O. bartlingii*, to supplement the map of *O. bartlingii* distribution in the Silesian-Cracow Upland area and to show floristic as well as ecological diversity of plant communities involving this species.

2. Material and methods

The basis of this study was a comparison of old data (Babczyńska 1978; Babczyńska-Sendek 1984, 2005) with recent figures. Part of *O. bartlingii* localities were found during other field investigations. Literature data (Brzeg & Wika 2014), not included by Piwowarczyk (2012a), were also used. In addition, places of numerous occurrence of *L. pyrenaica* were surveyed. In localities where *O. bartlingii* was found or its presence was confirmed, the size of population was estimated and phytosociological relevés were made in plant communities with this species participation.

The occurrence of *O. bartlingii* in the Silesian-Cracow Upland is presented in cartograms (2 x 2 km grid) according to the methods set up for the “Distribution

Atlas of Vascular Plants in Poland” (ATPOL) (Zając 1978a, 1978b). Localities published by Piwowarczyk *et al.* (2009) and Piwowarczyk (2012a) as well as localities not included in these studies (authors’ position and the position from the publication of Brzeg & Wika 2014) were marked accordingly.

Phytosociological relevés were set together and classified using the TWINSpan program. The analysis of ecological requirements (moisture, pH and soil fertility) of vascular plant species which was made using Ellenberg indicators values (Ellenberg & Leuschner 2010) allowed us to compare the distinguished groups of communities. Ecological differences between them are shown in graphs made in the STATISTICA software (version 10). Names of vascular plants follow Mirek *et al.* (2002).

3. Results

3.1. *Libanotis pyrenaica* spreading

L. pyrenaica is a very common species on the Cracow-Częstochowa Upland (Urbisz 2004, 2012). In the past, it numerously occurred mainly in rock grasslands, especially in the area of larger and higher rock agglomerations. In early 1980s, patches of grassland communities with a large share of this species were very rare on slopes of hills or at their foots. They sporadically occupied a larger area and *L. pyrenaica* usually did not cover more than half of the vegetation patch. This type of phytocoenoses was found only at a few localities during the investigations carried out in years 1977-1982 on the grassland vegetation of the Częstochowa Upland (Babczyńska-Sendek 1984). After cessation of grazing, *L. pyrenaica* began to spread on slopes of hills, especially in places where it was present in rock grasslands (Fig. 1a-c). Today, in many places, its share in the plant cover is very large, thus in its flowering season, it often forms large white fields (Fig. 2). *L. pyrenaica* specimens occurring on slopes also spread into fallow lands situated at the foot of hills. Patches with its participation are sometimes very extensive.

In the Silesian Upland, *L. pyrenaica* occurs only in some areas of these mesoregions where geological base is built by Triassic limestone (Nowak 1999; Babczyńska-Sendek 2005). Large patches of communities dominated by this species can be encountered in the Ząbkowice Ridge (Garb Ząbkowicki) – the central-eastern part of the Tarnowskie Góry Ridge (Garb Tarnogórski), in areas located southeast of Katowice Steelworks. It is a vast area in which the agricultural use of the land was abandoned after the construction of the steelworks. The old abandoned fields occupy many hectares there and they are separated only by roads and railway lines leading to the steelworks. *L. pyrenaica* occupied there fallow lands, ungrazed grasslands, escarpments of



a



b



c

Fig. 1. Changes in the vegetation of the Góra Zamkowa hill in Olsztyn near Częstochowa (Cracow-Częstochowa Upland)
 Explanations: a – northern slopes of the Góra Zamkowa hill in 1987, b – the same slopes in 2008, c – extensive patches of the *Libanotis pyrenaica* community in 2011 (photograph by B. Babczyńska-Sendek)



Fig. 2. White cover of *Libanotis pyrenaica* on the Mirów Ridge (Grzęda Mirowska) in the Cracow-Częstochowa Upland (photograph by M. Palowska, July 2010)



Fig. 3. Fallow land overgrown with *Libanotis pyrenaica* on the Twardowice Plateau, the Silesian Upland (photograph by J. Hej-dysz, July 2009)



Fig. 4. *Orobanche bartlingii* Griseb. in Rzędkowice, the Cracow-Częstochowa Upland (photograph by B. Babczyńska-Sendek, June 2011)

railway trenches, railway embankments and roadsides at the same time (Babczyńska-Sendek 2005). Lately, *L. pyrenaica* also spreads in the Żąbkowice Ridge area situated north of Katowice Steelworks and in the Twardowice Plateau (central part of the Tarnowskie Góry Ridge) where it colonizes, in particular, abandoned fields (Fig. 3) (Babczyńska-Sendek *et al.* 2012). In the Twardowice Plateau, its expansion into patches of xerothermic grasslands can also be observed in recent years.

3.2. *Orobancha bartlingii* spreading

O. bartlingii (Fig. 4) is a broomrape species parasitizing on *L. pyrenaica* (Kreutz 1995). In Poland, it was found for the first time in 1992 in the Ojców National Park (Szelaǳ 2001). Then, the plant was found in other places in the Cracow-Częstochowa Upland such as: Rzędkowice in 1995 (Rakowski 2004), Podzamcze in 2003 (Babczyńska-Sendek unpublished data) and in 2007 (Piwowarczyk *et al.* 2009), Kobyłańska Val-

ley in 2005 (Nowak-Dańda & Dańda 2006). In 2010, next three localities of *O. bartlingii* were found in the Ojców National Park area (Piwowarczyk 2011). Furthermore, this broomrape was also found in 1996 in the Silesian Upland area – on the Wielka Góra hill situated on the border of Strzemieszyce Małe and Sławków (Babczyńska-Sendek 2005, 2009) and in the northern part of Żąbkowice Ridge (the exact location not given) (Piwowarczyk 2012a).

In subsequent years, other localities of *O. bartlingii* were found in the Silesian Upland and the Cracow-Częstochowa Upland (Fig. 5). In the area of the Silesian Upland, the extension of this species acreage was observed around the Wielka Góra hill – where the species was found for the first time in 1996. In years 2010 and 2011, on the border of Sławków and Okradzionów, *O. bartlingii* occurred frequently in several locations distant from the locality from 1996 approximately 1.5 to 2.5 km, among others, in places where it was not noticed during the phytosociological survey carried out in 2001

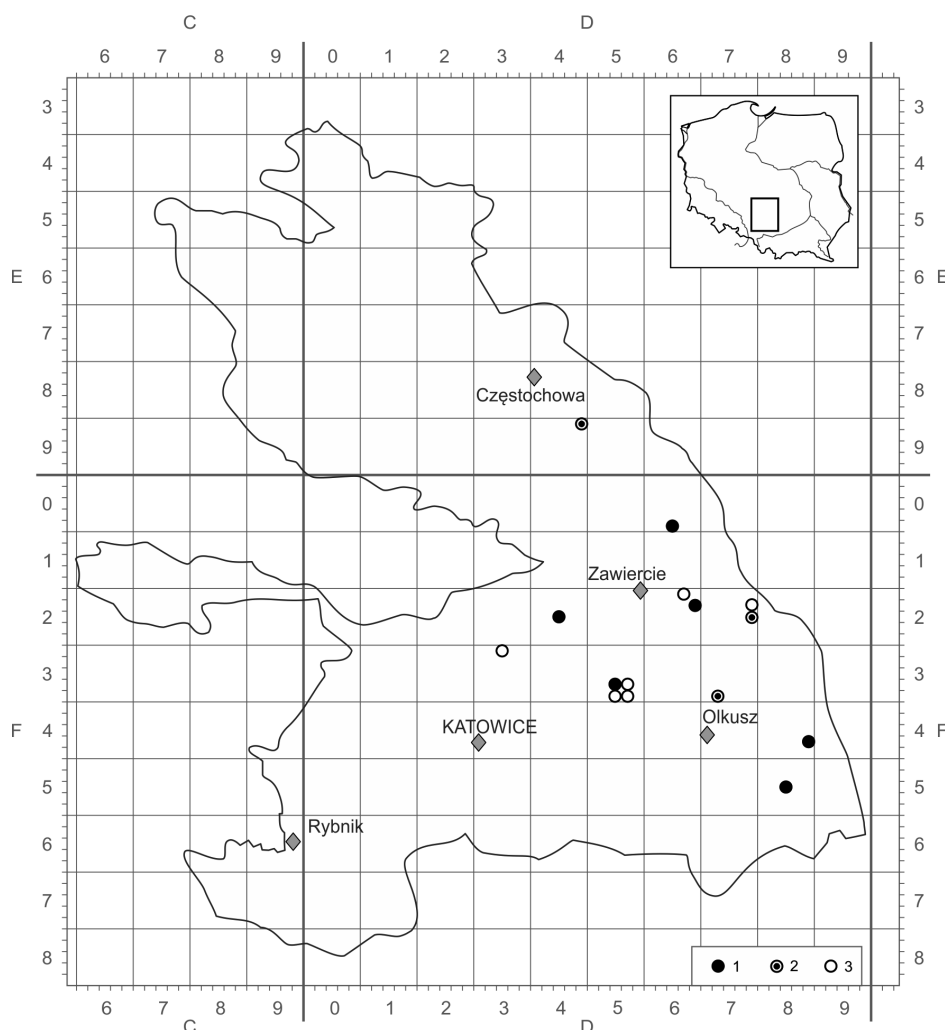


Fig. 5. Distribution of *Orobancha bartlingii* in the Silesian-Cracow Upland

Explanations: 1 – localities according to Piwowarczyk (2009, 2012a), 2 – localities according to Brzeg & Wika (2014), 3 – new localities

in patches of *L. pyrenaica* communities (Babczyńska-Sendek 2005). Due to the fact that the area occupied by *L. pyrenaica* in this region is extremely large, it can be expected that after a detailed field research, the number of *O. bartlingii* localities may be higher there. Krajewski (2011) reported over a thousand flowering shoots of this species in the area of Dąbrowa Górnicza and Sławków. However, he did not specify accurate positions. In addition, *O. bartlingii* was found in 2009 in the area of Strzyżowice on the Twardowice Plateau (central part of the Tarnowskie Góry Ridge), where the species occurred both on fallow lands dominated by *L. pyrenaica* (Babczyńska-Sendek *et al.* 2012) and on the adjacent slope occupied by xerothermic grassland, in which *L. pyrenaica* started to occur.

New localities of the Bartling's broomrape were also found by the authors in the Cracow-Częstochowa Upland: in the vicinity of Bzów near Ogrodzieniec (in 2005) and in the Sikorowa Skała hill in Smoleń (in 2012). *O. bartlingii* is also mentioned in recent phytosociological literature (Brzeg & Wika 2014) – from the hill with castle ruins in Rabsztyn (2005), from the Pocijówka hill in Smoleń (2006), and from the Biakło hill in Olsztyn near Częstochowa (2007).

In Poland, in addition to the above-mentioned localities from the area of the Silesian-Cracow Upland, *O. bartlingii* is known only from two other stations: from the vicinity of New Słupia in the Kielce Upland and from the valley of the Noteć river (Piwowarczyk *et al.* 2009; Piwowarczyk 2012a, 2012b).

3.3. The assessment of the *Orobancha bartlingii* population size in identified localities

The number of *O.* individuals in the populations was very diverse in different stands. The most abundant were the populations from Rzędkowice and Podzamcze in the Częstochowa Upland area.

In Rzędkowice in 1995 and 1996, *O. bartlingii* grew at the eastern edge of the Rzędkowice Rocks (between the Turnia Lechwora and Turnia Kursantów peaks and near Okiennik rock), and its population consisted of dozens of individuals (Rakowski 2004). Then, Piwowarczyk *et al.* (2009) reported the existence of several thousand individuals in this area. During the conducted surveys in this location in 2007, the population was estimated at approximately 3000 individuals. It was also found that this species occurred in large numbers throughout almost the whole range of Rzędkowice Rocks, far more numerous in the upper part of the ridge and on southern slopes. It occurred also numerous on the northern slope, in its unwooded part. Moreover, *O. bartlingii* grew in large numbers at the foothills of southern slopes on fallow lands which were covered by *L. pyrenaica*. In 2010 and 2011, a slight extent of the area occupied by the broomrape on these fallow lands

was observed. At the same time, the reduction of its population size was ascertained on the northern slope, where succession of trees and shrubs was taking place.

Piwowarczyk *et al.* (2009) wrote about the presence of *O. bartlingii* on the Góra Janowskiego hill in Podzamcze. The broomrape grew in dry grasslands near the outcrop of Jurassic rocks and the castle ruins, as well as on the edge of hazel shrubs, woods and paths. The population in 2007 was estimated at approximately 800 individuals. In contrast, observations made in 2008 showed that this population consisted of approximately 1500 individuals. The presence of this species was also reported in plantings of larch on the eastern slope which was still covered by numerous *L. pyrenaica* population. The species was present on fallow lands, at the foot of the eastern slope, which were covered by *L. pyrenaica* abundantly. In 2010, on these fallow lands, *O. bartlingii* individuals were found at a distance of 330 m from the foot of the slope. Unfortunately, in years 2009 and 2010, due to the construction of a hotel in upper part of the western slope of the Góra Janowskiego hill, a large part of the population, occurring in grasslands on the top part of the hill, below the Czubatka rock and on the adjacent slope, was devastated.

However, two new populations of *O. bartlingii* from the area of the Cracow-Częstochowa Upland were far less numerous and occupied small areas. The population from Bzów in 2010 consisted of approximately 300 individuals and covered the surface of about 1000 m². It was associated with a fragment of xerothermic grasslands in the upper part of the Jurassic cuesta slope in a close proximity to the old quarry. On the Sikorowa Skała hill, which was heavily overgrown with trees and shrubs, *O. bartlingii* grew in the fragment of xerothermic grassland with the presence of *L. pyrenaica* at the foot of the south-eastern part of the hill. Its population consisted of 32 individuals and occupied an area of approximately 100 m².

Among the *O. bartlingii* localities listed in the study of Brzeg and Wika (2014) concerning thermophilous edge communities, only the ones placed on the Biakło hill in Olsztyn near Częstochowa were investigated (during another research in 2011-2014). Despite thorough exploration of the hill and other hills in the adjacent area, the broomrape was not found, while *L. pyrenaica* occurred abundantly on most of them. Probably in 2007, *O. bartlingii* appeared there sparsely (it was noted in two phytosociological relevés and its share was estimated at less than 1%). Later, clearance of shrubs and undergrowth of pine trees on the hill was conducted. This action could have led to devastation of this sparse stand.

The size of *O. bartlingii* populations in the Silesian Upland also varied. The largest populations were found near the border of Strzemieszyce Małe, Okradzionów

(the Dąbrowa Górnicza districts) and Sławków. When this species was found for the first time on the western edge of the Wielka Góra hill near Strzemieszyce, its population from the grasslands, overgrown with trees and bushes included several individuals. However, the entire hill which is extensive and mostly occupied by fallow lands, was not surveyed thoroughly. In contrast, the field survey carried out in 2010 showed that the population of *O. bartlingii* in the first-found locality comprised 22 specimens. Single individuals of the species were also encountered along the field path on the back of the Wielka Góra hill and on the northern slope of the neighboring hill – Góra Tomalówki.

Quite a large population (63 specimens) was also found southwest of the Wielka Góra hill (approximately 1.2 km), on the verge of the road leading along the railway embankment. Another major group of specimens (252) was found on fallow fields overgrown by *L. pyrenaica* on both sides of the asphalt road leading from Strzemieszyce Małe to Okradzionów, about 2 km east of the Wielka Góra. Other localities of *O. bartlingii* were found in the distance of about 0.8 km at the edge of the same road (in a distance about 2 km in a straight line from the Wielka Góra) (68 individuals), on the verge of the road from Sławków to Okradzionów and on the nearby old fallow lands (about 2.2 km from the Wielka Góra) – the localities consisted of a dozen individuals. As observed, *O. bartlingii* did not occur in places with very high density of *L. pyrenaica* basal leaves.

The population of *O. bartlingii* found in Strzyżowice was not very numerous. Despite the abundant appearance of *L. pyrenaica* on fallow lands, only about 30 individuals of the broomrape were found. Single specimens occurred in the xerothermic grassland on the adjacent slope.

3.4. Plant communities with *Orobancha bartlingii* participation

Phytosociological relevés made in phytocoenoses of *L. pyrenaica* community with participation of *O. bartlingii* enabled us to present floristic and ecological characteristics of this community. Based on the results of the analysis carried out using the TWINSpan program, three groups of phytocoenoses were identified (Appendix 1):

Group 1 (relevés 1-4) – phytocoenoses with the participation of *L. pyrenaica* from the central part of the Tarnowskie Góry Ridge (Twardowice Plateau). These were both phytocoenoses developed on abandoned fields as well as on the hill slope (xerothermic grassland) and at its foot on the side of the field path. They were characterized by the presence of some species, which were rather associated with the local species pool.

Group 2 (relevés 5-10) – most of them were phytocoenoses dominated by *L. pyrenaica* growing on abandoned fields which were not directly adjacent to the xerothermic grasslands. One relevé was from a roadside. In this group, there were both phytosociological relevés from the area of the Silesian Upland, as well as from

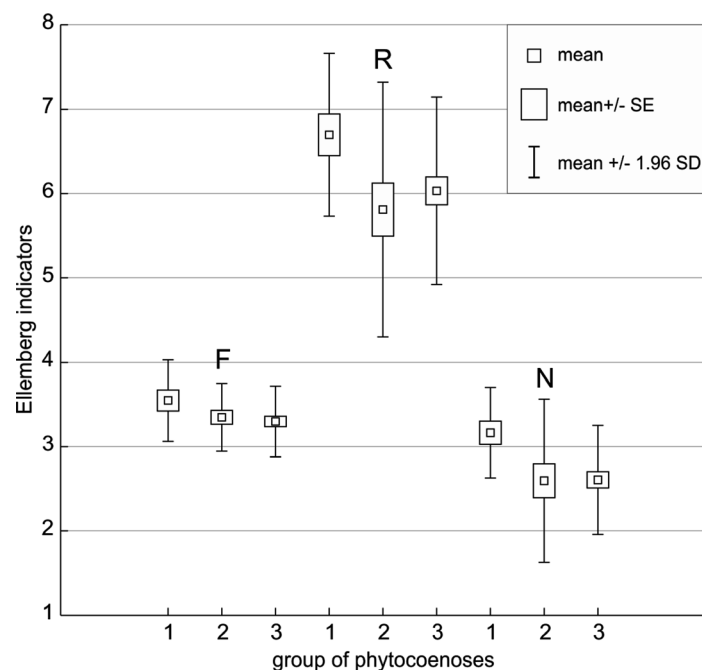


Fig. 6. Habitat characteristics of three distinguished groups of phytocoenoses with participation of *Libanotis pyrenaica* and *Orobancha bartlingii* using Ellenberg indicators

Explanations: F – moisture, R – reaction, N – nitrogen

the Cracow-Częstochowa Upland. Plant species that prefer places with a slightly less dense plant cover, such as *Arabis hirsuta*, *Artemisia campestris*, *Petrorhagia prolifera*, were more frequent and more numerous there. This is due to the fact that the plant cover generally did not achieve full coverage in these patches.

Group 3 (relevés 11-22) – communities with dominance of *L. pyrenaica* from the area of the Cracow-Częstochowa Upland, most of which developed on the site of xerothermic grasslands. This group also included three relevés from fallow lands which were situated at the foot of the hills in very close proximity to the slopes with grasslands. Patches included in this set were distinguished by a large group of species which were components of grassland phytocoenoses on slopes of hills.

Analysis of the habitat requirements of species forming particular phytocoenoses showed that the distinguished groups differed from one another in terms of participation of plants with different moisture requirements and different preferences regarding soil fertility and pH (Fig. 6). Phytocoenoses from group 1 were distinguished most clearly. The ecological indicators of moisture, pH and fertility reached the highest mean values in this group. Phytocoenoses of all groups consisted mainly of species which prefer dryer habitats and grow on soils moderately acidic to slightly alkaline and poor or slightly rich in nitrogen.

4. Discussion and conclusions

Vegetation freed from under long-term anthropopressure is a more widespread phenomenon in contemporary landscape. Ex-agricultural lands (among others, old fields and pastures) abandoned for different reasons are a good example of “liberated” vegetation. Very often, changes do not lead to a return of primary vegetation. Then plant cover arising spontaneously as a result of different ecological processes and creation of a new pattern of communities can be observed (Faliński 2000). *L. pyrenaica* expansion, followed by *O. bartlingii* spreading, is an example of this type of changes in vegetation.

In literature, very little information about the increasing role of *L. pyrenaica* in grassland communities can be found. In Poland, the increasing share of this species has been found in phytocoenoses of *Origanobrachypodietum* and *Gymnocarpietum robertiani* in the Pieniny National Park (Każmierczakowa & Grodzińska 2006). Beyond Poland, the spread of *L. pyrenaica* was observed, e.g., in Bavaria (Nieschalk & Nieschalk 1974) and Upper Normandy (Dutoit *et al.* 2003).

It is worth emphasizing that in the Silesian-Cracow Upland area, in most localities where *L. pyrenaica* occurs, very abundant populations are formed by this

species and they cover vast surfaces. Explanation for this must be sought in the biology of this species, and, especially, in its fecundity and dispersal types.

L. pyrenaica does not have a high capacity to spread over long distances. Its seeds are heavy; based on different sources their weight is 1.12-2.51 (mean 2.01) mg (Jongejans & Telenius 2001) or 1.3-1.7 (1.6) mg (Klotz *et al.* 2002). According to the criteria adopted by Kornaś (1972), species with such weight of seeds belong to heavy anemochorous (when their weight is less than 1.5 mg) or barochorous (when the weight exceeds 1.5 mg). Medwecka-Kornaś (1950), based on the average falling speed (2.16 m s^{-1}) of seeds from the height of 5 m, included *L. pyrenaica* in heavy anemochorous. Mean seed terminal velocity of *L. pyrenaica* is 2.90 m s^{-1} (Jongejans & Telenius 2001) and, according to Tackenberg *et al.* (2003), seeds that fall at $> 2 \text{ m s}^{-1}$ are very unlikely to be effectively dispersed by wind.

L. pyrenaica also belongs to boleochorous (Kleyer *et al.* 2008). Due to the fact that the stem with inflorescences grows up to 1.2 m (Koczwara 1960), seeds can be dispersed when the wind moves the stem. They will not be transferred to a long distance, but in relation to Jurassic hills, where *L. pyrenaica* grows on rocks often on hill tops, they can travel a considerable distance as a result of falling down the slope. Due to a large number of seeds produced usually per plant (an average of more than 13 000) (Kleyer *et al.* 2008), the spreading of this species on slopes can be rapid and its extensive populations can occur there. A lack of intensive grazing is a necessary condition for this to happen. *L. pyrenaica* is usually a biennial plant, less frequently *monocarpic-plurennial* (Klotz *et al.* 2002), and when its inflorescences are eaten by animals, it is unable to produce seeds and, thus, the creation of the next generation.

Regarding the abundant occurrence of *L. pyrenaica* in some places of the Silesian Upland, an extension of its area is likely to happen in a different way. In the past, this species was not very common in the region (Schube 1903; Sendek 1984). In the Silesian Upland, there are no rock outcrops from which *L. pyrenaica* can spread in the Cracow-Częstochowa Upland. There is also little information about habitats which this species had occupied in the past. Among others, the following are mentioned: the castle walls and on the slope of the Wzgórze Zamkowe hill in Będzin (Celiński *et al.* 1974-75), outcrops of limestone in Strzyżowice (most likely, in the excavation of limestone, because there are no natural outcrops) (Celiński *et al.* 1978-79) and railway areas (Nowak 1997). The spread of this species over a large area is related to abandonment of agricultural land use, particularly in a large area around the Katowice Steelworks. Probably, in the first stage of the species spreading, epizoochory played a decisive role. Wild

and farmed animals, especially sheep, can be dispersal vectors for *L. pyrenaica* (Kleyer *et al.* 2008). Its seeds can be dispersed by animals because of seed hairs which usually occur, although these hairs are not long. The experiment conducted by Fischer *et al.* (1996) showed that the effectiveness of that species spreading by sheep is substantial, despite a relatively short period of seed dispersal.

After the entering of *L. pyrenaica* into new outposts in the Silesian Upland area, the growth of population for a given locality was probably extensive. This process was undoubtedly strengthened by large seed production which is characteristic for this species (Kleyer *et al.* 2008). Moreover, the spread of the species was probably associated with geological aspects. In many places, the geological base built by Triassic limestone was uncovered during the laying of railway tracks to Katowice Steelworks, especially in places where the tracks were led in trenches. Their slopes are now overgrown with dense patches of *L. pyrenaica* at a distance of several kilometers. In addition, this area is poorly visited by people and sparsely populated undoubtedly favouring presence of wild animals there. Thus, epizoochory is certainly an important factor in the spread of this species. In addition, large areas of fallow lands on soils rich in calcium carbonate, and also quite fertile, create favourable conditions for the development of its numerous populations. As shown in France (Alard *et al.* 2005), soil of abandoned fields rich in P₂O₅ favors the development of *L. pyrenaica*.

Because of the life strategy (Grime 1979), *L. pyrenaica* is considered to be a representative of competitors. The share of plants of this group generally increases during the succession not only in grasslands (Moog *et al.* 2005; Dzwonko & Loster 1998), but also in other types of habitats (Prévosto *et al.* 2011). Furthermore, features of *L. pyrenaica* such as heavy seeds, relatively late flowering time (July and August), a significant height of flowering specimens are characteristic for plants whose share increased in ungrazed grasslands (Moog *et al.* 2005; Peco *et al.* 2005; Castro *et al.* 2010).

O. bartlingii, as well as other species of the Orobanchaceae family, is a parasitic plant with tiny and light seeds (weight generally much less than 0.01 g) which are dispersed by wind (Kreutz 1995). According to the division proposed by Kornaś (1972), it belongs to hovering anemochorous. Vittoz & Engler (2007) classified it (together with Orchidaceae, ferns, Pyrola-

ceae and trichometeorochory) to the self-proposed 5th dispersal type. It is a group of plants of which 99% diaspores is dispersed in open fields to a distance of 500 m. In exceptionally favorable conditions, even greater dispersal distances cannot be ruled out. A large number of seeds (from 350 to over 9000) produced in one bag of Bartling's broomrape individual and great seed production per shoot (1870 – 627250) are also features which promote efficient dissemination (Piwowarczyk & Jankowska-Błaszczuk 2014). The seeds are very easily washed down into the deeper layers of the soil because of their very small size. To germinate, they must make contact with roots of the host plant. Germination is triggered by certain chemical signals released by roots of the host (Kreutz 1995).

A mass occurrence of *L. pyrenaica*, a host plant of *O. bartlingii*, in the Cracow-Częstochowa Upland and in some regions of the Silesian Upland is a factor which favours the spread of this broomrape in these areas. Large areas covered by patches of plant communities dominated by *L. pyrenaica* significantly increase the probability that seeds of Bartling's broomrape find a host.

A significant number of new localities of *O. bartlingii* recently found allowed us to conclude that, in the Cracow-Częstochowa Upland and in some places of the Silesian Upland, *O. bartlingii* is spreading into new localities. Moreover, it can be stated that the broomrape acreage around many existing positions is substantially increasing. Due to large areas covered by plant communities with a significant share of *L. pyrenaica*, further enlargement of *O. bartlingii* range in the Silesian-Cracow Upland can be expected in coming years.

However, continued existence and possible spreading of *O. bartlingii* to new localities, especially at the Cracow-Częstochowa Upland area, where attempts to restore grazing are being made now, will depend on the intensity of grazing. If it is intense enough, *L. pyrenaica* will be eliminated from grasslands on hill slopes. However, in the absence of grazing, slopes will be overgrown by bushes and *L. pyrenaica* will also be gradually eliminated, as it was observed in the Czyżówki rocky ridge in the Ojców National Park (Michalik 2009). It seems that moderate grazing may be most optimal, because this type of land use allows *L. pyrenaica* and *O. bartlingii* to exist in grasslands on hills slopes.

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Appendix

11	12	13	14	15	16	17	18	19	20	21	22	Presence degree
Rz	12	16	24	17	18	11	21	22	23	25	14	
27	B	Rz	Rz	Rz	Rz	P	P	P	Rz	Sm	Rz	
8	2	27	4	27	27	2	4	4	4	4	27	
10	8	8	8	8	8	8	8	8	8	7	8	
50	10	10	11	10	10	10	11	11	11	12	10	
SSE	50	50	50	50	50	50	40	50	40	30	50	
3	NW	SSW	SSE	SW	SSW	SE	SSW	ENE	NNE	SSE	SW	
5	10	5	3	10	10	10	5	30	5	5	3	
100	5	5	20	-	-	-	-	+	20	-	10	
30	100	95	100	100	100	100	100	100	100	100	95	
f	-	20	+	10	5	-	5	+	20	5	20	
42	g	f	g	g	g	g	g	g	g	g	f	
	40	44	48	37	36	35	41	36	45	36	51	
3												
4	3	5	4	4	4	4	4	4	4	3	3	V
2	2	2	1	2	2	2	2	2	2	2	2	V
.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	.	.	.	1	.	I
.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	.	+	.	.	.	II
.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	.	.	.	.	.	I
.	1	.	+	.	.	+	.	.	.	2	.	III
.	.	.	.	.	.	.	.	.	.	.	.	II
+	.	1	.	1	2	.	.	.	.	.	+	III
.	+	.	.	.	+	.	.	.	+	+	.	III
.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	.	.	.	.	.	I
+	+	+	+	.	+	+	+	+	+	+	+	V
2	+	2	+	2	1	1	1	+	+	+	2	IV
1	.	2	1	2	2	+	2	.	2	.	2	IV
+	.	2	+	1	2	.	+	.	+	+	+	III
.	+	.	+	+	.	1	.	+	.	.	.	III
+	.	.	.	+	.	+	+	+	.	.	+	III
+	.	+	+	.	.	.	.	+	.	.	+	II
.	.	.	+	+	.	.	+	+	.	.	.	II
.	.	+	.	1	1	2	.	.	.	.	1	II
.	.	+	.	1	.	.	+	.	+	.	+	II
.	.	.	+	.	+	.	.	.	.	.	+	II
.	.	.	.	.	.	.	+	+	.	1	.	II
+	1	+	2	+	1	1	+	1	2	+	1	IV
+	.	+	.	+	+	+	+	+	.	+	+	III
.	2	+	+	1	2	.	+	+	+	1	.	III
+	+	.	+	.	+	+	.	.	+	+	+	III
1	.	+	+	+	.	.	+	.	+	.	.	II
/+	/3	/+	/+	.	.	.	.	/+	/+	.	1/+	II
+	.	.	+	+	.	.	1	+	+	1	.	II
.	.	.	+	+	+	.	.	+	+	.	+	II
.	.	.	+	+	+	.	.	.	+	+	.	II
.	.	+	+	.	.	.	.	+	+	+	.	II
+	.	+	+	+	+	.	.	.	.	.	.	II

Successive No. of relevé	1	2	3	4	5	6	7	8	9	10
Field No. of relevé	6	7	5	4	9	19	10	8	13	20
Locality	S	S	S	S	P	Sł	P	O	Rz	O
Date	12	12	12	12	2	4	2	2	27	4
Area of the relevé (m ²)	7	7	7	7	8	8	8	8	8	8
Exposure	10	10	10	10	10	11	10	10	10	11
Slope °	40	50	40	40	50	50	50	50	50	40
Density of b layer (%)	ENE	ESE	N	E	-	-	S	N	S	WSW
Cover of c layer (%)	3	5	3	25	-	-	5	5	10	3
Cover of d layer (%)	-	-	-	-	-	-	-	5	20	-
Type of habitat	100	100	100	100	100	90	95	90	90	95
No. of species in the relevé	f	f	r	g	f	f	f	f	f	r
Group No.	36	33	21	30	41	41	37	38	41	39
	1				2					
Ch. *Festuco-Brometea:										
* <i>Coronilla varia</i>	1	+	2	.	+	+	1	1	2	+
* <i>Achillea collina</i>	1	1	.	+	+	+	1	+	1	+
* <i>Galium album</i>	1	1	1	1	+	.	.	.	1	+
* <i>Euphorbia cyparissias</i>	+	.	.	2	+	+	2	.	1	.
* <i>Medicago falcata</i>	.	1	.	1	.	1	.	1	+	1
* <i>Pimpinella saxifraga</i>	.	+	.	.	.	.	+	.	.	.
* <i>Euphrasia stricta</i>	+	.	.	.	.	+	+	.	+	.
* <i>Verbascum lychnitis</i>	+	.	.	.	+	.	+	.	.	.
* <i>Polygala comosa</i>	.	.	.	.	.	.	.	.	.	+
Ch. °Molinio-Arrhenatheretea:										
* <i>Festuca rubra</i>	.	1	1	2	3	1	1	1	+	1
* <i>Dactylis glomerata</i>	+	1	.	+	+	+	1	+	+	+
* <i>Knautia arvensis</i>	.	+	1	1	.	1	+	+	+	+
* <i>Arrhenatherum elatius</i>	.	2	.	+	+	.	.	+	1	+
* <i>Lotus corniculatus</i>	1	+	.	2	.	+	.	+	.	1
* <i>Trifolium pratense</i>	+	+	.	.	+	.	.	+	.	+
* <i>Taraxacum officinale</i>	+	+	.	.	+	r	.	+	.	+
* <i>Agrostis stolonifera</i>	.	1	.	.	1	.	.	.	+	.
Accompanying species:										
* <i>Crataegus monogyna</i>	b/c	.	/+	.	.	.	.	1/	.	/+
* <i>Rhamnus catharticus</i>	b/c	.	.	.	.	.	.	1/	+/	/+
* <i>Rosa canina</i>	b/c	.	.	.	.	.	.	.	/+	.
* <i>Pinus sylvestris</i>	b	.	.	.	.	.	.	.	2	.
* <i>Cornus sanguinea</i>	b/c	.	.	.	.	.	.	.	+/	.
* <i>Linum catharticum</i>	.	.	.	+	.	+	.	+	.	2
* <i>Medicago lupulina</i>	.	+	.	.	.	+	.	+	.	+
* <i>Rubus caesius</i>	+	+	.	.	1	.	+	.	.	.
* <i>Fragaria vesca</i>	+	.	.	.	1	.	.	.	.	+
* <i>Hypericum perforatum</i>	+	+	.	.	.	.	.	.	.	.
* <i>Hieracium pilosella</i>	.	.	.	.	.	1	+	.	2	.
* <i>Veronica chamaedrys</i>	.	.	.	.	+	+	.	.	.	.
* <i>Senecio jacobaea</i>	+	.	.	.	+	.	+	.	.	.
* <i>Agropyron repens</i>	.	.	.	.	+	.	+	+	.	.
* <i>Daucus carota</i>	+	.	+	.	.	.	.	+	+	.
* <i>Trifolium arvense</i>	.	.	.	.	+	+	+	.	.	.
* <i>Carex hirta</i>	.	.	.	.	.	.	.	+	.	.
* <i>Melilotus officinalis</i>	.	.	.	.	.	.	.	+	.	.
* <i>Carex spicata</i>	.	.	.	+	.	.	.	.	.	.

11	12	13	14	15	16	17	18	19	20	21	22	Presence degree
15	12	16	24	17	18	11	21	22	23	25	14	
Rz	B	Rz	Rz	Rz	Rz	P	P	P	Rz	Sm	Rz	
27	2	27	4	27	27	2	4	4	4	4	27	
8	8	8	8	8	8	8	8	8	8	7	8	
10	10	10	11	10	10	10	11	11	11	12	10	
50	50	50	50	50	50	50	40	50	40	30	50	
SSE	NW	SSW	SSE	SW	SSW	SE	SSW	ENE	NNE	SSE	SW	
3	10	5	3	10	10	10	5	30	5	5	3	
5	5	5	20	-	-	-	-	+	20	-	10	
100	100	95	100	100	100	100	100	100	100	100	95	
30	-	20	+	10	5	-	5	+	20	5	20	
f	g	f	g	g	g	g	g	g	g	g	f	
42	40	44	48	37	36	35	41	36	45	36	51	
3												
2	1	1	+	1	2	2	1	1	+	3	2	V
1	.	1	+	2	1	1	1	1	+	+	+	V
1	1	+	1	+	+	1	2	2	2	2	1	V
+	.	1	+	.	1	1	2	.	+	+	1	IV
+	.	.	2	+	.	.	.	.	+	.	+	III
.	+	.	.	.	.	1	2	2	+	.	.	II
+	.	+	.	+	.	.	.	.	.	.	.	II
.	.	+	.	1	.	.	.	.	.	.	+	II
.	.	+	+	.	.	.	+	.	+	.	.	II
2	1	1	2	2	2	2	1	2	2	2	1	V
+	+	+	+	+	.	+	+	1	1	+	+	V
.	1	+	+	+	+	+	+	1	.	+	+	V
2	1	1	1	1	.	1	2	2	2	1	2	IV
.	.	.	+	+	+	+	.	+	+	.	.	III
+	.	.	+	.	+	+	.	+	.	.	.	III
.	+	+	.	.	.	+	.	.	+	.	r	III
.	+	.	.	2	1	.	.	+	+	.	.	II
/+	/+	.	.	.	/+	.	.	+/	.	.	/+	II
/+	.	.	/+	.	/+	.	.	.	.	.	/+	II
/+	1/	/+	1/	.	.	.	.	.	.	/+	+/	II
1	.	1	.	.	.	.	.	.	1	.	1	II
.	.	.	2/+	.	/+	.	.	.	+/+	.	/+	II
.	.	+	1	.	+	.	.	.	+	.	1	III
+	.	.	+	.	.	.	.	.	+	.	+	II
.	2	+	.	.	.	.	.	.	.	.	+	II
.	2	.	.	.	.	.	1	.	1	.	1	II
.	.	+	+	.	.	.	+	.	+	1	.	II
+	.	+	.	.	+	.	.	.	.	.	+	II
.	.	.	.	+	.	1	+	1	+	.	.	II
.	.	.	+	.	.	+	.	.	+	.	+	II
.	.	.	.	.	.	+	.	.	.	.	.	II
+	.	.	.	.	+	.	.	.	.	.	.	II
.	+	.	.	2	1	.	2	.	.	.	.	II
+	.	+	.	.	.	+	.	.	.	.	1	II
+	.	.	+	.	.	+	+	.	.	.	.	II

Sporadic species: Ch. *Festuco-Brometea*: *Acinos arvensis* 6; *Allium oleraceum* 7, 9, 18, 22; *Asperula cynanchica* 4; *Bromus inermis* 6; *Campanula glomerata* 19; *Carlina acaulis* 4, 6; *C. vulgaris* 6, 9, 11; *Erigeron acris* 5, 8, 11; *Fragaria viridis* 13,14 (3), 21(1), 22(2);

Helianthemum nummularium subsp. *obscurum* 4(1), 18, 21(1); *Melampyrum arvense* 1, 3, 10, 18(1); *Peucedanum oreoselinum* 4(1); *Phleum phleoides* 1(1), 4(1), 5, 7(1); *Plantago media* 10, 12, 14, 20; *Potentilla heptaphylla* 17, 18, 19; *P. neumanniana* 13, 22; *Ranunculus bulbosus* 10; *Thalictrum minus* 9, 17; *Thymus glabrescens* 21; *Trifolium montanum* 1, 4(1); *Vicia tenuifolia* 10, 12(3); *Vincetoxicum hirundinaria* 7, 18, 21; *Viola rupestris* 13. **Ch. Molinio-Arrhenatheretea:** *Centaurea jacea* 12; *Cerastium holosteoides* 3, 13, 22; *Crepis biennis* 1, 2(1), 5, 8; *Deschampsia caespitosa* 12; *Holcus lanatus* 9; *Lolium perenne* 1; *Pastinaca sativa* 8, 10; *Potentilla reptans* 12; *Prunella vulgaris* 13; *Tragopogon orientalis* 12, 19; *Trifolium repens* 14, 15, 19, 21; *Trisetum flavescens* 21. **Accompanying species:** *Acer platanoides* 5 c, 14 c; *A. pseudoplatanus* 5 c; *Aegopodium podagraria* 12; *Allium vineale* 11, 17; *Apera spica-venti* 1, 2; *Arenaria serpyllifolia* 13, 22; *Artemisia vulgaris* 1(1), 2(1); *Astragalus glycyphyllos* 18; *Botrychium lunaria* 6; *Calamagrostis epigejos* 6(1); *Campanula persicifolia* 1, 2; *C. rapunculoides* 1, 2, 12; *Carex flacca* 12(1), 14; *Carpinus betulus* 13 c, 17 c; *Chaerophyllum aromaticum* 2(1); *Cirsium arvense* 2, 8; *Clinopodium vulgare* 14, 20; *Corylus avellana* 22 c; *Cruciata glabra* 18; *Danthonia decumbens* 16; *Dianthus deltooides* 9; *Echium vulgare* 9; *Equisetum arvense* 5, 11, 12, 22; *Erigeron annuus* 1, 9; *Erysimum hieracifolium* 10; *Euonymus europaeus* 14c; *Euphorbia esula* 8, 12; *Geum urbanum* 5; *Hieracium umbellatum* 6; *Hypochoeris radicata* 9; *Juniperus communis* 20 b(2), c, 22 b; *Linaria vulgaris* 11; *Lupinus polyphyllus* 20; *Medicago sativa* 11; *M. ×varia* 2(2), 8, 18(1), 22; *Melandrium album* 5, 8; *Melilotus alba* 18; *Myosotis arvensis* 1, 5; *Orobancha lutea* 4; *Potentilla argentea* 5; *P. collina* 12, 15; *Primula veris* 12; *Pyrus communis* 12 b, 20 b(1); *Quercus robur* 14 c, 16 c; *Q. rubra* 14 c; *Rumex acetosella* 6, 13; *R. thyrsiflorus* 1, 2(1); *Sedum acre* 6, 7, 11, 15; *S. maximum* 5, 7; *S. sexangulare* 15; *Solidago canadensis* 1, 2(1), 21, 22; *S. virgaurea* 14, 20(1), 22; *Stellaria graminea* 21; *Trifolium campestre* 16; *T. medium* 8, 21; *Tussilago farfara* 12; *Valeriana officinalis* 2; *Vicia hirsuta* 17, 20; *V. tetrasperma* 22.

Explanations: B – Bzów, O – Okradzionów, P – Podzamcze, Rz – Rzędkowice, S – Strzyżowice, Sł – Sławków, Sm – Smoleń; f – fallow land, g – xerothermic grassland, r – roadside