ISSN 1211-3026 Čas. Slez. Muz. Opava (A), 62: 137-150, 2013
DOI: 10.2478/cszma-2013-0015

Soil seed bank in selected patches of vegetation in the beech forest of Beskid Śląski (Southern Poland)

Elżbieta Jędrzejczak

Soil seed bank in selected patches of vegetation in the beech forest of Beskid Śląski (Southern Poland). – Čas. Slez. Muz. Opava (A), 62: 137-150, 2013.

Abstract: The aim of this study was to examine the size and composition of soil seed bank in the beech forest of Beskid Śląski (southern Poland). The study was conducted in autumn 2009 on two patches of vegetation. The applied method of research was seedling germination from the soil samples. The soil was sampled to the depth of 10 cm using a 5 cm diameter cylinder. The observation of the seedling's growth was conducted in laboratory conditions for 5 months. The size of the soil seed bank was estimated at 592 seeds/m^2 (16 species) for *Dentario glandulosae-Fagetum* community and 2030 seeds/m^2 (9 species) for *Luzulo nemorosae-Fagetum* comunnity. Dominant species in the seed bank was *Juncus* sp. and *Luzula luzuloides*. In addition, the composition of the seed bank and the above-ground vegetation did not show any significant similarities and a greater number of seeds were located in the upper 5cm layer of soil.

Key words: soil seed bank, beech forest, Beskid Śląski, plant ecology

Introduction

The term soil seed bank refers to a natural storage of seeds within the soil and on its surface including seeds produced by plants that grow in the area and seeds that get there from outside. Soil seed banks can be divided into active and dormant with the bidirectional flow occurring between them. The active seed bank consists of seeds that do not have special habitat requirements and germinate shortly after reaching the soil. Sometimes seeds that are under favorable stimuli pass from a permanent seed bank into an active one. Permanent seed bank plays the role of a deposit that may make up a record of antecedents of vegetation from a given zone and the adjacent territory (Harper 1977).

Considering the importance of a soil seed bank in the dynamics of plant communities, numerous studies investigate the issue of endangered and withering plant communities for instance xerothermic turfs. Few studies examine soil seed banks of the Polish deciduous forests (ex. Jankowska-Błaszczuk 2000a, 2006). The following authors reported the results of their research on a forest growing on dry ground and a beech forest respectively: Pirożnikow (1987) and Zarzycki (1964).

The aim of this study was to examine the size and composition of soil seed bank in the beech forest of Beskid Śląski and to examine similarities between reservoirs of vivid propagules in soil and vegetation. The results allow the comparison of the composition and structure of soil seed banks from different plant communities.

Materials and methods

Research area localization: The research area is in the northeastern part of Beskid Śląski in the Department 124 of Wielka Łąka Forestry which belongs to the Bielsko Forestry Management (Nadleśnictwo Bielsko). Administratively the area is located within the borders of Bielsko-Biała (Poland).

The mountain range of Beskid Śląski is a part of the Western Carpathians, a young fold mountains great part of which is made of flysh (Alexandrowicz 1991). Soils of the Wielka Łąka Forestry consist mostly of gleysols formed in the ground hollows, tills and clay (Forestry Management report 2000). The part of Wielka Łąka Forestry where the investigation was conducted is about 530 AMSL and is considered to be moderate warm climate. The entire area of the Bielsko Forestry Management lies on a route of humid mass of air coming from the west which causes the precipitation to be much higher than in other parts of the Western Carpathians reaching an average of up to 1200 mm per year (Forestry Management report 2000).

The area of Beskid Śląski is dominated by forest communities. However, many of them are half-natural considering the over exploitation that was under way until 19th century, latter afforestation with spruce and the natural secondary succession. Nowadays, the spruce monoculture is being shaken up mostly because of the wholesale pest grading (Wilczek 2006). Wilczek (1982-1990) reported the appearance of 9 biocenoses with the most common fecund – *Dentario glandulosae-Fagetum, Luzulo nemorosae-Fagetum,* and *Abieti-Piceetum* montanum. A characteristic feature of the Wielka Łąka forest is the presence of ash *Fraxinus excelsior* and other sporadic species that may primarily be caused by the anthropogenic origin of lots of *Luzulo nemorosae-Fagetum* and *Abieti-Piceetum montanum* communities. In case of *Dentario glandulosae-Fagetum* and *Alnetum incanae* the reason might be its location the proximity to human settlements and roads in the lower mountain ranges (Wilczek 1995).

The study of seed bank**:** The most common method of seed bank examination used in this research was the observation of sprouts in the soil samples (Jankowska-Błaszczuk 2000b). The soil samples were taken using a cylinder or a drill, the sprouting of seedlings was observed in laboratory conditions. Findings obtained with this method might be slightly underestimated. This is because there were difficulties determining optimal seed growth conditions, soil stirring frequency and a very short time of observation.

The vegetation was identified using „Rośliny polskie" (Szafer, Kulczyński & Pawłowski 1988). Names were taken from „Vascular plants of Poland. A Checklist" (Mireki in. 2002) and the forest communities were described with the help of „Zespoły leśne i zaroślowe" (Medwecka-Kornaś 1977) and elaboration of diversity of those communities in the discussed region (Wilczek 1995). Seedlings were identified using "Keimlings-bestimmungsbuch der Dikotyledonen (Csapody, 1968) and "Nasiona i siewki drzew" (Gil & Kinelski 2003).

Software used for statistical analysis was Statistica and the graphs were made using Microsoft Office Excel 2007.

Sørensen index between the vegetation species structure and seed bank was estimated according to the following formula:

$S = 2z / (x+y)$

S – Sørensen index

z – number of all species

x – number of species in ground vegetation

y – number of species in soil seed bank

The coefficient may be 0 to 1 which stands for no similarity or full similarity respectively (Krebs 1996).

Experiment description**:** Two test areas measuring 10 x 15 m each and separated from each other by a 3 m high slope were set (patch I, patch II) in a beech forest in autumn 2009. Each of them was divided into 10 smaller (2 x 2 m) plots and 5 soil samples were taken from each (Fig. 1.). In that way 50 soil samples were collected. Collection of the soil samples was carried out in late October and early November 2009 after the growing season.

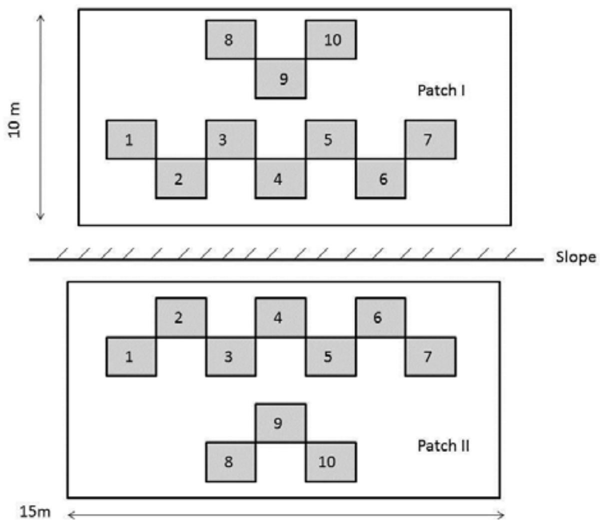

Fig 1: Location of small plots within the test areas (patches)

The soil was sampled to the depth of 10 cm using a 5 cm diameter cylinder. The rollers of soil were divided into a top and a bottom part of 5 cm each and placed separately in labeled bags. In this way 50 samples were taken from the top and the deeper soil layers for each research area which together gave 200 soil samples.

In 2010, two phytosociological relevés of 15 x 20 m plot were prepared (one relevé for each test area) using the Braun-Blanquet method (Tab. 1.). Regardless of the proximity of location, the two study areas showed differing environmental conditions. The first area (patch I) borders directly with The Barbara Stream and encloses the area of fluvial terrace which was greatly ridged. According to the species composition the community can be classified as the Carpathian beech forest community *Dentario glandulosae-Fagetum*. The tree density was estimated at 80% and the dominating species is *Fagus sylvatica*. Also single individuals of *Fraxinus excelsior* and *Sorbus aucuparia* were identified in the lighter parts of forest. Depending on the season, the dominating groundcover species was *Dantaria Dentaria glandulosa* (early spring) and *Lunaria rediviva*, *Galeobdolon luteum*, *Oxalis acetosella*, *Galium odoratum* and *Asarum europaeum* (summer). Moreover, other species characteristics of fecund Carpathian beech forests were found: *Mercurialis perennis*, *Dentaria bulbifera* and *Impatiens noli-tangere*. Density of the groundcover layer in July and August reached even 90% (Tab. 1, relevé 1.).

The second test area (patch II) lies on a meadow terrace in close neighborhood of the first research area but a steep slope of 3 m hight separates them. Vegetation of this plot represents acidophilous Carpathian beech forest *Luzulo nemorosae-Fagetum* (*Luzulo-luzuloidis Fagetum*). In comparison to the first test area the diversity was significantly smaller among the second area species. Density of treetops was estimated at 85% and 40% for groundcover. The most commonly tree found in the area was beech *Fagus sylvatica* but the presence of *Picea abies* and *Acer pseudoplatanus* was also noted. *Deschampsia flexuosa, Luzula luzuloides***,** *Athyrium filix-femina, Oxalis acetosella*, *Majantheum bifolium* dominate in the groundcover. Additionally, the presence of *Prenanthes purpurea, Rubus hirtus* and *Vaccinium myrtillus* was reported. Layers of bushes constitute 10% of coverage and compounds only of *Sorbus aucuparia* and young trees of *Picea abies* (Tab. 1, relevé 2).

In order to investigate if any differences of the soil chemical properties occur between the two areas a mixed soil sample from the depth of 20 cm was extracted from each of them. The parameters defined in the laboratory were the soil reaction (potentiometrically with a pH meter), nitrogen content (the Kjeldahl method), organic carbon content (the Tiurin method), organic compounds (carbon content times the 1,724 coefficient), available forms of nutrient elements: K_2O, P_2O_5, CaO, MgO (the Enger-Riehm method) and the content of interchangeable cations (the Kappen method). Chemical analysis showed no significant differences between the soil samples from both research areas. In both cases the soil pH was very low (Tab. 2, Tab. 3).

In the next stage, 200 plastic pots were filled with cleaned and sterilized (temp. 80^{o}C) sand to ¾ of height. A thin layer of soil taken from the research areas was placed in each pot. Fragments of underground plants such as rhizomes and small stones were removed from the soil before planting. Pots were placed in constant conditions in the Department of Plant Ecology of the Jagiellonian University's laboratory, i.e. a medium temperature was 22^{o}C (from 18^{o}C at night up to 24^{o}C in the day time), lighting 12h/day and the soil was regularly watered in order to keep the soil humidity constant. For the first 3 months (XII-II) the number of seedlings was counted and all newly come-up plants were noted. After the germination period all seedlings were collected and the soil was stirred in order to move the seeds that were located deeper in the ground to the upper side of the pot. Observations were carried out for the next two months (III-IV). Discounting grass, the seedlings were identified at least to the level of genus. The presence of ferns was also noted but by dint of the abundance of gametophytes persisting for most of the time of the experiment, the individuals were not included in the charts. Only the presence but not the number of individuals and species of ferns in a given sample was noted (letter F).

Results

Total 257 seedlings germinated from the samples, 225 of which survived to the moment when identification was possible. 50 specimens belonging to 16 species were recorded in the samples from the first patch and 175 specimens of 6 species were found and in the second patch (Tab. 4, Tab. 5). The most numerous seedlings in patch I were the seedlings of *Juncus* sp. (28%) and *Urtica dioica* (16%). Seedlings of *Juncus* sp. were also more abundant in patch II (29,1%); besides that a high amount of *Luzula luzuloides* seedlings (24%) was reported (Tab. 6).

Medium abundance of seeds in patch I was about 592 seeds/m^2 and 1,2 seedlings/sample and in patch II – 2030 seeds/m^2 and 3,9 seedlings/sample. The outcome of the Student's t-test matching against the median density in samples was 6,135 and showed essential differences in the seedlings density of both plots ($p<0,01$).

Tab 1: Relevés phytosociological. (QF) - species characteristic of classes *Querco-Fagetea*, (s) - seedlings

Date 9.07.2010r.	**Relevé 1**	**Relevé 2**
Area	100 m^2 (5 x 20 m)	100 m^2 (5 x 20 m)
Topography	Fluvial terrace	Meadow terrace
Slope	3^o	3^o
Exhibition	W	W
The height of the trees	20 m	20 m
Densely of vegetation:		
A	80%	85%
B	-	10%
C	90%	40%
D	-	-
A		
Fagus sylvatica (QF)	4.1	4.1
Quercus robur		+
Acer pseudoplatanus (QF)		1.2
Picea abies		1.2
Fraxinus excelsior (QF)	1.2	
Sorbus aucuparia	+	
B		
Sorbus aucuparia		+
Picea abies		+
C		
Calamagrostis arundinacea	1.2	1.2
Carex brizoides		2.2
Deschampsia flexuosa		2.3
Rubus hirtus		1.1
Vaccinium myrtillus	+	1.2
Betula pendula (s)		+
Fagus sylvatica (s) (QF)		+
Athyrium filix-femina	1.1	2.1
Galeobdolon luteum (QF)	2.2	1.1
Luzula luzuloides (QF)		1.3
Maiantheum bifolium		1.2
Sorbus aucuparia (s)		+
Picea abies (s)		+
Oxalis acetosella	2.3	1.3
Prenanthes purpurea (QF)		+
Sambucus nigra (s)	+	+
Viola sp.		+
Stachys slivatica (QF)	+	
Lunaria rediviva (QF)	3.2	
Galium odoratum (QF)	2.2	
Asarum europaeum (QF)	2.3	
Rubus hirtus	1.1	
Petasites albus	2.4	
Geranium robertianum	+	
Dentaria glandulosa (QF)	+	
Dentaria bulbifera (QF)	+	
Impatiens parviflora	1.2	
Impatiens noli-tangere (QF)	1.1	
Aegopodium podagraria	1.1	
Corylus avellana (s) (QF)	+	
Senecio fuchsii	1.2	
Anemone nemorosa (QF)	+	
Urtica dioica	+	
Mercurialis perennis (QF)	1.2	
Dryopteris spinulosa	+	

Tab 2: Chemical analysis of soil. The acidity and organic matter

Sample	pH in H_2O	pH in KCL	N	C org.	org. mat.	C/N
Patch I						
Level A1	4,4	3,4	0,35	5,27	9,09	15
Level B	4,6	3,6	0,16	3,02	5,21	18,4
Patch II						
Level A1	3,5	2,7	0,9	16,26	28,02	18
Level B	3,9	3	0,36	6,79	11,71	19,4

Tab 3: Chemical analysis of soil. Assimilated components and interchangeable cations

Sample	**Assimilated components**				**Exchangeable cations**			
	K_2O	P_2O_5	CaO	MgO	K+	Na+	Ca++	Mg++
	mg / 100g soil							
Patch I								
Level A1	18,2	4	61,6	3,9	12	3,8	44	2,3
Level B	11,6	0,6	53,2	2,8	8	2,6	38	1,6
Patch II								
Level A1	20,8	6,2	36,4	4	14,2	4,8	26	2,4
Levl B	14	2,5	11,2	2,2	4	1,9	8	1,3

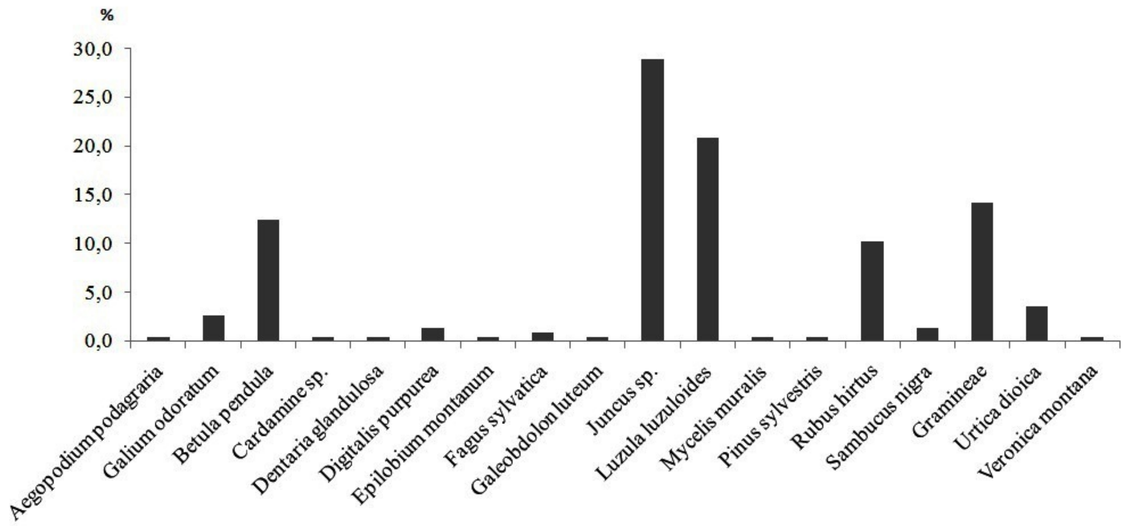

Fig 2: Share of each species found in the soil of a beech forest (total patch I and II)

Tab 4: Species that germinated from samples taken at the first test area (patch I) (ignored numbers of trials in which there was no seedling). F- sample, which grew ferns, s.- specimens

Nr samples	Species
1	F
2	F
3	Galium odoratum
5	Cardamine sp. , F
6	Gramineae
7	Dentaria glandulosa, Juncus sp.
8	F
9	F
11	Juncus sp.
12	Betula pendula 2 s., F
15	Juncus sp.
16	F
17	Urtica dioica 2 s.
19	F
20	Rubus hirtus
21	Sambucus nigra, Luzula luzuloides 2 s., Juncus sp.
22	Juncus sp. 5 s., Luzula luzuloides 2 s., Galium odoratum 2 s.
24	Juncus sp. 2 s., Gramineae, F
27	F
28	F
29	Asperula odorata
30	Galeobdolon luteum, Digitalis purpurea
31	Galium odoratum 2 s.
34	Gramineae
36	F
37	Luzula luzuloides, Urtica dioica
38	Urtica dioica
39	Veronica montana, Epilobium montanum, Juncus sp.
40	Urtica dioica, F
41	Juncus sp., F
42	Urtica dioica 2 s., Rubus hirtus
43	F
44	Sambucus nigra
46	Juncus sp.
47	Mycelis muralis, F
48	Aegopodium podagraria
50	Urtica dioica, F

Tab 5: Species that germinated from samples taken at the second test area (patch II) (ignored numbers of trials in which there was no seedling). F- sample, which grew ferns, s.- specimens

Nr samples	Species
2	Rubus hirtus,
3	Luzula luzuloides, Juncus sp. 2 s., Betula pendula
4	Betula pendula 3 s., Gramineae
5	Juncus sp. 11 s.
6	Luzula luzuloides
7	Betula pendula, Gramineae
9	Luzula luzuloides 6 s.
10	Luzula luzuloides 3 s.
11	Betula pendula
12	Betula pendula 4 s., Gramineae 2 s., Luzula luzuloides 4 s., F
13	Pinus silvestris, Rubus hirtus 2 s., Juncus sp. 7 s.
14	Juncus sp. 3 s., Betula pendula 5 s., Gramineae, Luzula luzuloides
15	Luzula luzuloides 4 s., Juncus sp. 3 s., Gramineae 2 s.
16	Luzula luzuloides, Rubus hirtus, Gramineae
17	Luzula luzuloides, Rubus hirtus, Betula pendula, F
18	Juncus sp., Gramineae, Rubus hirtus, Betula pendula 2 s.
19	Luzula luzuloides, Juncus sp.
21	Juncus sp. 5 s., Rubus hirtus
22	Gramineae 2 s., Rubus hirtus 2 s.
23	Luzula luzuloides 2 s., Rubus hirtus, Gramineae
24	Luzula luzuloides, Gramineae, F
25	Luzula luzuloides 2 s., Rubus hirtus, Gramineae 2 s., Juncus sp. 3 s.
26	Gramineae 2 s., Luzula luzuloides
27	Luzula luzulloides 3 s.
28	Juncus sp. 2 s.
28	Juncus sp. 4 s., Gramineae
29	Digitalis purpurea 2 s.
30	Rubus hirtus 2 s., Juncus sp.
30	Juncus sp.
31	Gramineae 4 s., Rubus hirtus, Betula pendula 2 s.
32	Betula pendula
33	Luzula luzuloides, Betula pendula
34	Fagus sylvatica, Luzula luzuloides, Rubus hirtus
35	Rubus hirtus, Betula pendula 2 s.
36	Juncus sp.
37	Rubus hirtus, Gramineae 2 s.
38	Sambucus nigra, Rubus hiatus
39	Gramineae 2 s., Luzula luzuloides, F
40	Betula pendula, Rubus hirtus
42	Luzula luzuloides, Juncus sp.
43	Fagus sylvatica
44	Gramineae, Rubus hirtus, Betula pendula
45	Luzula luzuloides, Juncus sp., Gramineae
46	Luzula luzuloides
47	Luzula luzuloides 3 s.
48	Luzula luzuloides
49	Graminae 2 s., Juncus sp. 3 s.
50	F

Tab 6: Number of seedlings of each species recorded during the five months of observation (XII-IV)

Species	Patch I		Patch II		Sum
	number	frequency	number	frequency	
Aegopodium podagraria	1	2			1
Asperula odorata	6	12			6
Betula pendula	2	4	26	14,9	28
Cardamine impatiens	1	2			1
Dentaria glandulosa	1	2			1
Digitalis purpurea	1	2	2	1,1	3
Epilobium montanum	1	2			1
Fagus sylvatica			2	1,1	2
Galeobdolon luteum	1	2			1
Juncus sp.	14	28	51	29,1	65
Luzula luzuloides	5	10	42	24	47
Mycelis muralis	1	2			1
Pinus sylvestris			1	0,6	1
Rubus hirtus	2	4	21	12	23
Sambucus nigra	2	4	1	0,6	3
Gramineae	3	6	29	16,6	32
Urtica dioica	8	16			8
Veronica montana	1	2			1
Sum	50	100	175	100	225

Tab 7: Depth existence of propagules

	0-5 cm		6-10 cm	
	patch I	patch II	patch I	patch II
Number of species	16	7	6	6
Sum	17		8	
Number of specimens	40	103	10	72
Sum	143		82	

In the samples taken from the 5 cm depth a higher amount of both seedlings (143) and species (16 plot I, 7 plot II) was reported. In both patches from the deeper layer (6-10 cm) only 82 seedlings represented by 6 species germinated (Tab. 7, Fig. 3). The species that occurred only in the deeper layers was *Pinus sylvestris*; *Fagus sylvatica, Veronica montana, Digitalis purpurea* and *Mycelis muralis* were found exclusively in the upper layer of the ground (Tab. 8).

In both examined plots most of the species are found only in forest vegetation, 18 species in patch I, what accounted for 51% and 14 species in patch II (58%). Species occurring only in the seed bank and only in the ground cover account for 21% up to 26%. 9 species were found in both vegetation and the seed bank in patch I whereas patch II contained only 5 such species. In the first research area 8 species were found in the seed bank exclusively, the other contained 5 such species (Fig. 4).

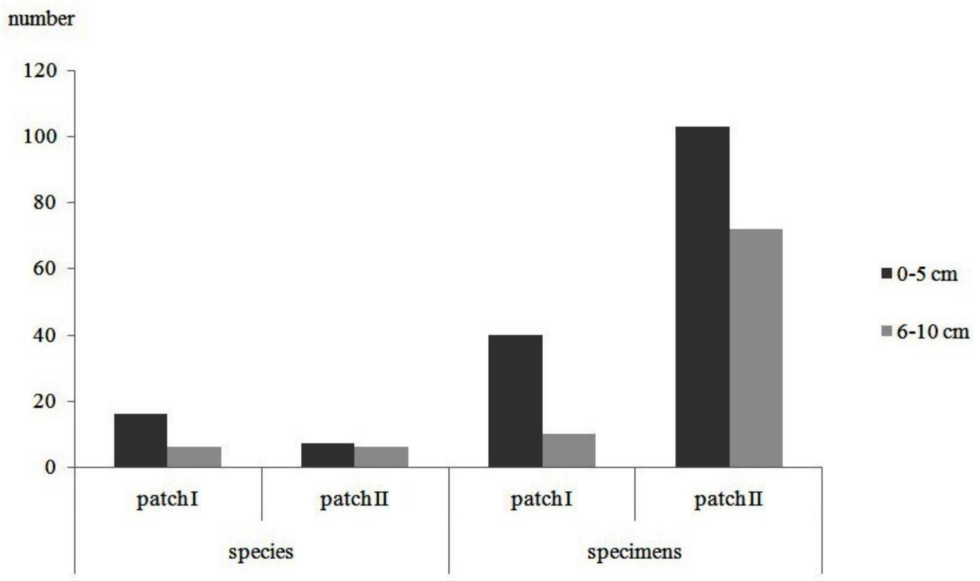

Fig 3: Relation the size of soil seed bank than depth existence

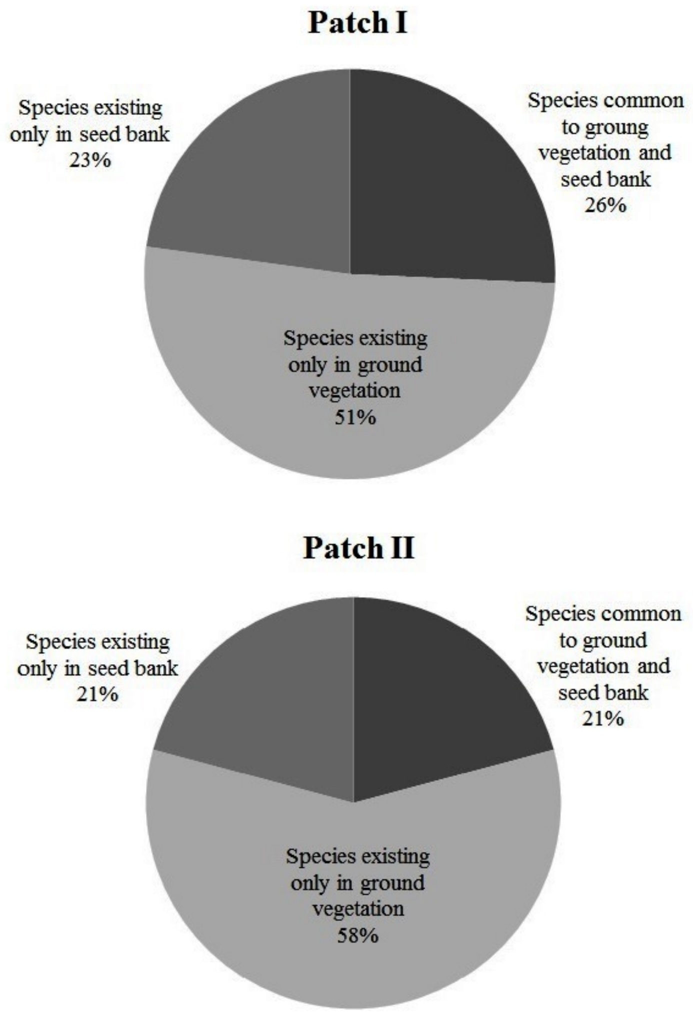

Fig 4: Share of each species found in the soil seed bank and ground vegetation (patch I and II)

Tab 8: Number of seedlings of each species recorded in samples from the shallower and deeper layers of the soil (total patch I and II)

Species	**0-5 cm**	**6-10 cm**
Aegopodium podagraria	1	
Asperula odorata	5	1
Betula pendula	21	7
Cardamine impatiens	1	
Dentaria glandulosa	1	
Digitalis purpurea	3	
Epilobium montanum	1	
Fagus sylvatica	2	
Galeobdolon luteum	1	
Juncus sp.	32	33
Luzula luzuloides	30	17
Mycelis muralis	1	
Pinus sylvestris		1
Rubus hirtus	13	10
Sambucus nigra	3	
Gramineae	21	11
Urtica dioica	6	2
Veronica montana	1	
Sum	143	82

The Sørensen index for biodiversity of the forest and soil seed bank for each of the patches is shown in Tab. 9. The highest similarity was noted between both seed banks (0,56). Patch I showed a higher Sørensen index of ground vegetation to the seed bank (0,45) than patch II. The smallest similarities were found between both ground vegetation (0,34)

Tab 9: Value of Sorensen index (in case of vegetation taking *Betula pendula* because of its presence in the immediate vicinity of both patch)

Patch I **Veget. – Seed bank**	**Patch II** **Veget. – Seed bank**	**Vegetation** **Patch I - Patch II**	**Seed bank** **Patch I - Patch II**
0,45	0,43	0,34	0,56

Some species of trees, bushes and rare herbaceous plants like *Geranium robertianum*, *Dentaria bulbifera*, *Prenanthes purpurea* were present only among the above-ground vegetation. This group also included plants with higher level of ground coverage: *Lunaria rediviva*, *Oxalis acetostella*, *Asarum europaeum* (Tab. 10).

Plants which create permanent seed banks (*Juncus* sp.) and plants that produce many diasporas (*Betula pendula*) were only found in the seed bank (Tab. 11). Graminaeae, *Luzula luzuloides* and *Rubus hirtus* were the most common plants among those occurring both above the ground and in the seed bank (Tab. 12).

Tab 10: Species existing only in ground vegetation. s - seedlings

Species	Patch I	Patch II
Fraxinus excelsior	+	
Sorbus aucuparia	+	+
Quercus robur		+
Acer pseudoplatanus		+
Picea abies		+
Corylus avellana (s)	+	
Fagus silvatica	+	
Stachys sylvatica	+	
Galeobdolon luteum		+
Oxalis acetosella	+	+
Lunaria rediviva	+	
Vaccinium myrtillus	+	+
Asarum europaeum	+	
Calamagrostis arundinacea	+	+
Geranium robertianum	+	
Petasites albus	+	
Dentaria bulbifera	+	
Senecio fuchsii	+	
Anemone nemorosa	+	
Mercurialis perennis	+	
Dryopteris spinulosa	+	
Carex brizoides		+
Deschampsia flexuosa		+
Athyrium filix-femina	+	+
Majantheum bifolium		+
Prenanthes purpurea		+
Viola sp.		+

Tab 11: Species existing only in seed bank.

Species	Patch I	Patch II
Betula pendula*	+	+
Cardamine sp.	+	
Digitalis purpurea	+	+
Epilobium montanum	+	
Juncus sp.	+	+
Mycelis muralis	+	
Pinus sylvestris		+
Veronica montana	+	
Luzula luzuloides	+	
Dryopteris spinulosa		+

* species presence in the immediate vicinity of the test areas

Tab 12: Species present in the seed bank and vegetation

Species	Patch I	Patch II
Fagus silvatica		+
Sambcus nigra (s)	+	+
Galeobdolon luteum	+	
Asperula odorata	+	
Rubus hirtus	+	+
Dentaria glandulosa	+	
Aegopodium podagraria	+	
Urtica dioica	+	
Luzula luzuloides		+
Gramineae	+	+
Dryopteris spinulosa	+	

Discussion and conclusions

The research conducted in Beskid Sląski indicated large soil seed bank differences between the two analysed beech forest communities. Lower diasporas density was recorded in the samples collected from *Dentario glandulosae Fagetum* (592 seeds/m^2) compared with the density of seeds in the samples from *Luzulo nemorosae Fagetum* (2030 seeds/m^2). The number of seeds present in the fecund Carpathian beech soil deviates strongly from the values reported for deciduous forests in Poland. Pirożnikow (1983), using the method of counting the living diasporas removed from the soil, estimated that the size of the soil seed bank in Białowieski National Park is 3989-8115 seed/m^2. Jankowska-Błaszczuk (2000a,2000b), counting seedling emergence from soil samples, gave slightly lover values for hail in Białowieża - 2142-3827 seed/m^2. Zarzycki (1964) studied the beech forests of Tatry and Bieszczady and estimated the soil seed bank to be 1700-2000 seeds/m2, on the other hand, Olano et.al. (2002) investigated birch-carpinus forests in Urkiola National Park (north Spain) and reported 7057 seeds/m2.

There are many reasons why there were differences in the amount of seed abundance in the soil of Beskid Śląski in the works of different authors. One of them is the use of different seed sampling methods (inclusion of mulch layer in the samples), others include varying observation times or diverse land topography of the examined area— e.g. floodplain terraces along mountain streams often suffer from floods which can lead to leaching the seeds out from the soil. It should be taken into consideration that the size of the soil seed bank is usually bigger than the research may suggest. Some species are known for their great production of seeds, e.g. *Deschampsia flesuosa* rarely sprouts in soil samples (Granstrom 1982). According to the studies by Zarzycki (1964) carried out in the beech forests in the Carpathian Mountains, differences in sprouting intensity between different species belonging to the same genus occurred. Forest species like *Allium ursinum* germinated worse in laboratory conditions than the non-forest species e.g. *Allium montanum*.

The quality of habitat is one of the main factors which influence the durability of soil banks. Pickett and McDonnell (1989) observed less seeds in acidic and organic soils, which is not proven by Warr et al. (1994) where more numerous seed banks (but less diverse) were observed in acidic soils. The results of the research in the Beskid Śląski also show greater variety of the soil seed bank in more fertile community *Dentario glandulosae Fagetum*, yet less propagules compaction in comparison to poorer communities *Luzulo nemorosae Fagetum*. However, the beech forest soil from covered patches is characterized by strong acidity.

A large share of *Juncus* sp. in both patches has significant importance on similarity of the two tested seed bank. As emphasized by Jankowska-Błaszczuk (2000a, 2000b) this species is frequently represented both in the soil bank of forest and meadows, and it may be an even 90% marked seeds, while this species is not absent in groundcover. Test results from the Beskid Śląski also confirmed the view that the seed banks in forests are mainly formed by species with high light requirements or species creating small seeds like *Juncus* sp., *Epilobium montanum, Betula pendula, Urtica dioica, Luzula luzuloides* and grasses. Seeds of sciophytic plants are present in the soil seed banks relatively shortly (Pickett and McDonnell, 1989). Excluding *Betula pendula* which light seeds present in the soil probably come from seeding. In studies carried out in Beskid Śląski the portion of trees was not significant. Similar outcomes were reported by Zarzycki in Karpaty (1964) and Warr et al. (1994) in south-west England and Jankowska-Błaszczuk (2002) and Pirożnikow (1983) in the Białowieża Forest.

My research has also shown that the deeper the samples were taken, the lower the number of species and seeds. 2/3 of all propagules are located in the upper layer of soil, up to 4 cm. This phenomenon had also been described by many other researchers (Picket and McDonnell, 1989). Thompson and others underline that the vertical distribution of seed banks may be related to their longevity. Therefore, seeds of plants that are not found in the undergrowth or occur there in low numbers are found in general in the deeper layer of soil and at the same time they form permanent seed banks. Similar results were obtained by Jankowska-Blaszczuk (2000b) in their studies carried out in the primary and secondary hail in Białowieski National Park. Studies carried out in Beskid Śląski do not confirm the connection between how deep the propagules lay with their potential for creating permanent seed banks. *Juncus* sp. which is considered to be the species forming permanent seed banks (Thompson and Grime, 1979) occur in shallower and deeper layers of soil in equally large amounts while *Utrica dioica* occurs more commonly in shallower layers of soil. Species which do not create permanent seed banks like *Mycelis muralis, Ageopodium podagraria, Betula pendula* and *Galeobdolon luteum* were mainly present in the upper layer of soil (up to 5 cm deep), which is consistent with the results of other studies (Piroznikow, 1983, Jankowska-Blaszczuk, 2000b).

The greatest part is constituted by plants that are present only in the groundcover of both examined plots and the similarity of groundcover to seed bank was not significant. Many authors reported major discrepancies between vegetation and the species composition of seed banks in different types of plant communities (ex. Pickett & McDonnel 1989, Kalamees & Zobel 1997). On the other hand, Jankowska-Blaszczuk (2002) proves greater compatibility between the layer of undergrowth and the seed bank. She assessed the similarity of species composition to be 0,70, however, she draws attention to the fact that a similar species composition does not reflect the composition of groundcover and the seed bank. Moreover, the similarity of the groundcover and the seed bank, as well as the size of seed bank, bumps seasonally (Jankowska-Błaszczuk 2002). In studies carried out in Beskid Śląski a definitely higher similarity of seed banks than the above-ground vegetation was estimated. The reason for those differences may be a higher pace of environmental changes on the top of the soil (Wall et al., 1994). Both study areas contained around ¼ species which were common to the undergrowth and the soil bank seed. In both cases, species which were present only in the seed bank constituted over 20%. These species originated mainly from *Dentario glandulosae Fagetum* which is a more fertile area. Unfortunately, it was not confirmed in previous studies which in turn indicate that poor environments are characterized by greater differences between the species composition and the seed banks (Jankowska-Blaszczuk 2000 follow Staaf & others 1987). Among species found exclusively in the seed bank there were those creating permanent seed banks: *Juncus* sp., *Epilobium montanum, Digitalis purpurea* and also anemochores that produce fugitive seeds: *Betula pendula* and *Mycelis muralis*. Diasporas of *Rubus hirtus* were observed more often in the soil than among the groundcover vegetation. Investigation showed a great number of species abundant in the groundcover but absent or occurring occasionally in the seed bank. Those plants are mainly geophytes: *Dentaria glandulosa, Mecurialis perennis, Galeobdolon luteum, Petasites albus, Oxalis acetosella* and hemicryptophytes: *Asarum europaeum* and *Lunaria rediviva*. Grasses and *Luzula luzuloides* were numerous in both vegetation and the seed bank. Similar outcomes were reported by Jankowska-Błaszczuk (2000a, 2000b, 2002) and Zarzycki (1964). Authors emphasize the presence of grass seeds and small-seed plants in the soil seed bank, whereas in the groundcover is dominated by species that propagate mainly vegetatively and their seeds were rare in the seed bank which is well presented by the studies carried out in Beskid Śląski.

Acknowledgments: I would like to thank Professor Stefania Loster, the supervisor of my Master's thesis, and my friend Marcin Nobis for the time spent on reviewing the manuscript and their valuable comments.

References

Aleksandrowicz S.W. (1991): Budowa geologiczna, pp. 243-245. In: Starkel L. (ed.): Geografia Polski. Środowisko przyrodnicze. PWN, Warsaw, 669 pp.

Csapody V. (1968): Keimlingsbestimmungsbuch der dikotyledonen. Akademiai Kiado, Budapest, 286 pp.

Falińska K. (2004): Ekologia roślin. PWN, Warsaw, 511 pp.

Gil W. & Kinelski S. (2003): Nasiona i siewki drzew. Multico, Warsaw, 157 pp.

Granström A. (1982): Seed banks in five boreal forest stands originating between 1810 and 1963. – Can. J. Bot. 60: 1815-1821.

Grzybowska B. & Loster S. (2009): The role of soil seed bank in maintaining calcareous grasslands in the Wyżyna Miechowska upland (S Poland), pp 208-218. In: Mirek Z. & Nikel A. (eds): Rare, relict and endangered plants and fungi in Poland. W. Szfer Institute of Botany, Polish Academy of Sciences, Krakow, 573 pp.

Harper J.L. (1977): Population biology of plants. Academic Press, London, 892 pp.

Jankowska-Błaszczuk M. (2000a): Soil seed banks in primeval deciduous forest in Białowieża, Poland. – Proc. IAVS Symp: 95-98.

– (2000b): Zróżnicowanie banków nasion w naturalnych i antropogenicznie przekształconych zbiorowiskach leśnych. – Monographiae Bot. 88: 1-147.

– (2002): Variability of soil seed banks of the natural deciduous forest. – Ecological Questions 2: 209-221.

– (2006): Seasonal diversity, light requirements and seed mass of species in the persistant soil seed bank of a shaded deciduous forest – Polish Botanical Studies 22: 261-271.

Kalamees R. & Zobel M. (1997): The seed bank in Estonian calcareous grassland: Comparison of different successional stages. – Folia Geobot. Phytotax. 32: 1-14.

Kondracki J. (1994): Geografia Polski. Mezoregiony fizyczno-geograficzne, PWN, Warsaw, 339 pp.

Krebs C.J. (1996): Ekologia. Eksperymentalna analiza rozmieszczenia i liczebności. PWN, Warsaw, 647 pp.

Medwecka-Kornaś A. (1977): Zespoły leśne i zaroślowe, pp. 383-441. In Szafer W. (ed.): Szata roślinna Polski. Tom 1. Wyd. III, PWN, Warsaw, 614 pp.

Mirek Z. (ed.) (2002): Krytyczna lista roślin naczyniowych Polski. W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow, 442 pp.

Olano J.M., Caballero J., Laskurain N.A., Loidi J. & Escudero A. (2002): Seed bank spatial pattern in a temperate secondary forest. – J. Veg. Sci. 13(6): 775-784.

Pickett S.T.A. & McDonnell M.J. (1989): Seed bank dynamics in temperate deciduous forest, pp. 123-147. In: Leck A.M. (ed.): Ecology of soil seed banks. Academic Press, San Diego, 462 pp.

Pirożnikow E. (1987): Seed bank in the soil of stabilized ecosystem of a deciduous foest (*Tilio-Carpinetum*) in the Bialowieza National Park. – Ekologia Polska 31: 145-172.

Szafer W., Kulczyński S. & Pawłowski B. (1988): Rośliny polskie. Wyd. VI, cz. II, PWN, Warsaw, 1019 pp.

Szafer W. & Zarzycki K. (eds) (1977): Szata roślinna Polski. PWN, Warszawa, 614 pp.

Thompson K. (1987): Seeds and seed banks. - New Phytol. 106: 23-34.

Thompson K., Bakker J.P. & Bekker R.M. (1997): Soil seed banks of north-west Europe: methodology, density and longevity. University Press, Cambridge, 276 pp.

Thompson K. & Grime J.P. (1979): Seasonal variation in the seed banks of herbaceous species in the contrasting habitats. – J. Ecol 67: 893-921.

Warr S.J., Kent M. & Thompson K. (1994): Seed bank composition and variability in five woodlands in south-west England. – J. Biogeogr. 21: 151-168.

Wilczek Z. (1995): Zespoły leśne Beskidu Śląskiego i zachodniej części Beskidu Żywieckiego na tle zbiorowisk leśnych Karpat Zachodnich. Wydawnictwo Uniwersytetu Śląskiego, Katowice, 129 pp.

– (2006): Fitosocjologiczne uwarunkowania ochrony przyrody Beskidu Śląskiego (Karpaty Zachodnie). Wydawnictwo Uniwersytetu Śląskiego, Katowice, 224 pp.

Zarzycki K. (1964): Biological and ecological studies in Carpatian beechwood. – Bull. Acad. Pol. Sc. 12(1): 15-21.

Author's address: Elżbieta Jędrzejczak, Institute of Botany, Jagiellonian University, Kopernika 27, 31-501 Kraków, Poland. E-mail: e.jedrzejczak@gmail.com