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PRELIMINARY FIELD STUDIES ON SURVIVAL RATE OF SEEDS OF INVASIVE TEROPHYTE *IMPATIENS GLANDULIFERA* ROYLE (BALSAMINACEAE)

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ABSTRACT. The paper presents the results of preliminary studies on the survival rate of seeds of invasive terophyte *Impatiens glandulifera* Royle (Balsaminaceae). The aim of this study was to investigate the dynamics of seeds germination on its spontaneous stands. Both, the survival rate of the seeds in the soil, and factors involved in the determination of this process were investigated. The seeds were placed in bags on the soil surface and at a depth of 5 cm in three plant communities (*Phragmitetea*, *Convolvulion sepium*, *Alnetea glutinosae*) on the four spontaneous stands of *I. glandulifera* in Poznań and its surroundings. Under optimal conditions, in the absence of flooding (*Convolvulion sepium*) the seeds longevity in the soil was only 7-8 months, and then they dynamically germinated (97.8 ±0.8%) or become deteriorated (2.1 ±0.8%) leaving no reserve for future growing seasons. Spring flooding (*Phragmitetea* and *Alnetea glutinosae*) contributed to the extension of the seed germination process, reduced the number of germinated seeds (45.5 ±14.5% and 61.9 ±2.6%), increased the number of the deteriorated seeds (49.7 ±12.9% and 36.7 ±2.5%) and the presence of a small percentage of seeds spending time (4.7 ±1.9% and 1.4 ±0.3%) which did not germinate and did not show any external signs of the deterioration. In the spring, it was found that all the seeds that were spending time became deteriorated (they underwent putrefaction and maceration). The results suggest that *I. glandulifera* do not form a persistent soil seed bank in the plant communities studied.

KEY WORDS: *Impatiens glandulifera*, Balsaminaceae, invasion ecology, seeds, terophyte, invasive species, survival rate of seeds, in the field

INTRODUCTION

Impatiens glandulifera Royle (*I. roylei* Walpers) is an impressive annual plant that under favourable conditions grows up to 3 m in height. It originates from Asia, where it occurs from northern Pakistan, through Kashmir, to India at the height of 1600-4300 m a.s.l. The introduced range covers a number of countries within the latitude of 30-70°N, where it occurs in the lowlands and in the low mountains up to 800 (900) m a.s.l. (1200 m in the Alps) (Beerling and Perrins 1993, Drescher and Prots 2000, 2003, Fischer et al. 2003, Helmisaari 2006, Hulme and Bremner 2006, Fabiszewski and Brej 2008).

In 1839, Dr. J.F. Royle sent *Impatiens glandulifera* seeds from Kashmir to the Royal Botanic Gardens at Kew (England). Soon after that, the species was cultivated in many European countries as an ornamental, honey and medicinal plant. The first spontaneous stands in England were observed in 1855 (in the Middlesex and Hertfordshire), and since 1898, it has been perceived as a weed (Lhotska and Kopecký 1966, Beerling and Perrins 1993, Drescher and Prots 2000, 2003). Within the present borders of Poland it was first observed in the Sudetes in 1890, in the following places Siodlo, Ploczki Dolne, Stepnica, Plonina (Schube 1903). Isolated stand of *I. glandulifera* appeared on the Vistula Spit around 1940. Over the next 40 years, *I. glandulifera* spread in the southern, south-eastern, central parts of the country and in Pomerania. At present, it has a status of invasive species both in Poland, and in the greater part of its secondary area (Tokarska-Guzik 2005). Unfortunately, it is still cultivated and its cultivation is rapidly getting out of control. After crossing the fence, it quickly begins colonization of anthropogenic habitats, such as built-up areas, cemeteries, garbage, waste, abandoned lots and roadside ditches. From these habitats, it enters the semi-natural and natural ones, such as thickets, banks of watercourses, valleys of large rivers, bright alder and riparian forests, their edges, and rushes. These are fertile and moist habitats, naturally exposed to periodic flooding (Drescher and Prots 2000, Kasperek 2002, Tokarska-Guzik 2005, Śliwiński 2008).

Over 150 years of the presence of *I. glandulifera* in Europe has resulted in a number of publications on its biology, ecology and the dynamics of its invasion (among others: Lhotska and Kopecký 1966, Koenies and Glavač 1979, Mumford 1988, 1990, Beerling and Perrins 1993, Pyšek and Prach 1993, 1995, Starý and Tkalců 1998, Dawson and Holland 1999, Drescher and Prots 2000, 2003, Maule et al. 2000, Chitka and

Schürkens 2001, Kasperek 2002, Willis and Hulme 2002, 2004, Hulme and Bremner 2006, Lopezaraiza-Mikel 2006, Lopezaraiza-Mikel et al. 2007, Fabiszewski and Brej 2008, Śliwiński 2008, Nienhuis and Stout 2009, Nienhuis et al. 2009, Janczak 2010). Despite numerous previous studies, there is still a need to broaden the basic knowledge about *I. glandulifera*, especially about the seed biology and their survival rate in the field.

Seeds of *I. glandulifera* (4-7 mm long, 2-4 mm wide, weight of seeds in air-dry state is 2-35 mg, 21.8 mg on average) are one of the largest seeds produced by the annual plant of the British flora (Beerling and Perrins 1993, Willis and Hulme 2004). The number of seeds produced by one individual can reach up to 2500 (Koenies and Glavač 1979), and a seed deposition may reach even 5000-6000 seeds per 1 m^2 (Beerling and Perrins 1993). The seeds of this species are exalbuminous (they do not have an endospermic tissue) (Hegi 1924, Utami and Shimizu 2005). Their humidity is about 4% in the air-dry state (Mumford 1988), and thus they may be qualified into the orthodox category (Duczmal and Tucholska 2000). Seeds of *I. glandulifera* exhibit a deep dormancy, which may be overcome by cold stratification, keeping them in a constant swollen state at 4°C. In the laboratory, the germination ability reaches 100%, and at 20°C in a swollen state, they may preserve their viability for at least three years (Mumford 1988).

The aim of the study was to investigate the dynamics of *I. glandulifera* seeds germination in various plant communities, and to answer the question, what their survival rate in the soil is and what the determining factors are.

MATERIAL AND METHODS

The study was conducted on the spontaneous stands of *I. glandulifera* in Poznań and Bnin. Four research areas in three plant communities were set up, for which phytosociological characteristics is shown in the Table 1.

Area I (N 52°13'50.0", E 17°05'32.7"), Table 1, Phot. 1

Located in a large (about 2 ha) patch of reed rushes *Phragmitetum australis* facies with *I. glandulifera* in Bnin, which formed onto the peaty silt soil (MŁt) on the undeveloped plot of land in the land depression near the Kórnickie Lake. From the east and the west the plot adjoins several properties, from which it is separated by drainage ditches. From the north it adjoins the alder grove, and from the south-east – the Kórnik-Śrem road. Long-term flooding of the research areas took place in spring in 2007 and 2008. *Impatiens glandulifera* grew scattered over the entire surface of rushes. Individuals of this species grew in low densities (1-2 per 1 m^2 on average), which allowed them to develop branched plant habit with impressive lateral shoots that grew up even in the lower part of the stem. Many of them reached the height of 3 m and a few inches in the diameter at the base of the stem. They towered over the reeds laying down.

Area II (N 52°22'36.5", E 16°51'35.3"), Table 1

Located in a patch of reed rushes *Phragmitetum australis* facies with *I. glandulifera*, which evolved onto the gyttja soil (MŁgy) on the edge of one of the ponds in Poznań-Kopanina. In spring 2007, short-term flooding occurred there and the reeds were burnt. In contrast to the above-described rushes in Bnin, *I. glandulifera* occupied a small area (about 1 are), and it grew in high density (several dozens of individuals per 1 m^2). Such a density resulted in a strong competition and a different pace of the development of *I. glandulifera* from the early stages. In high summer the vast majority of these individuals was high (2.5 m on average) and slender, having a small number of short lateral shoots, located in the upper part of the stem, whereas the lower part was smooth and deprived of leaves. The height of the remaining ones was less than 1 m, and the number of leaf whorls was by about 2-3 lower.

Area III (N 52°27'40.5", E 16°57'47.3"), Table 1, Phot. 2, 3

Located in a small (about 1 are) patch of the plant community from alliance *Convolvulion sepium* facies with *I. glandulifera*, which evolved onto the marshland surface (MRV) on the edge of the forest island and around the ditch with water at Bożywoja Str. in Poznań. It is the only one experimental stand, where there was no flooding for two research seasons. For the most of the day *I. glandulifera* stand was shaded laterally by trees from the forest island or the trees growing along the road. In late summer or early autumn the side of the road at Bożywoja Str. was mown together with the roadside belt of *I. glandulifera* stand about 2 m wide.

Area IV (2007 – N 52°13'54.2", E 17°05'27.2", 2008 – N 52°13'54.4", E 17°05'29.0")

Located in a grove of alder (plant community from class *Alnetea glutinosae*) adjacent to rush vegetation of the Kórnickie Lake. It grows on fen (Tn), and probably comes from planting (*Alnus glutinosa* height is of several meters and the diameter of the trunk reaches a few centimeters). Each year during the study, the area was flooded with water from the lake, while in the second year the flooding did not cover the research stands. *Impatiens glandulifera* occurred in drier and very bright areas, mainly on the edges of the grove. Most of the individuals of this species did not exceed the height of 1.5 m. There was a great number of individuals laying down and rooting in the nodes observed. On this stand, *I. glandulifera* featured with delicate structure and a small number of flowers and fruits.

The study was conducted from mid-September 2006 to mid-October 2008. Two-factor experiment in four blocks, and in four replicates per 100 seeds each, was set up. Blocks comprised of four patches of plants within the three plant communities (in each patch one research area has been set up, factor I – type of the community (*Phragmitetum australis* facies with *I. glandulifera*, *Calystegion sepium* facies with *I. glandulifera*, *Alnetea glutinosae*), factor II – the depth of the seeds placement: on the soil surface (0 cm) and at a depth of 5 cm. The experiment was set up in the mid-September 2006, in the time of the full fructification of the species investigated. In this study seeds of a local origin collected on

Table 1. Phytosociological characteristics of the spontaneous stands of *Impatiens glandulifera*

Consecutive number of a photograph and a name of syntaxon	1	2	3	4
Date of a photograph	05-09-2006	01-08-2006	18-07-2006	29-06-2006
Density of the tree layer (a) [%]	0	0	0	80
Density of the shrub layer (b) [%]	0	0	Zn.	5
Coverage of the herb layer (c) [%]	100	100	100	100
Coverage of the moss layer (d) [%]	0	0	0	0
Photography area [m^2]	50	25	25	100
Number of species in the photograph	10	10	20	15
D. Cl. *Alnetea glutinosae*				
Alnus glutinosa (a)	.	.	.	5.3
ChCl. *Phragmitetum communis*				
Phragmites australis	4.4	5.4	.	.
Carex acutiformis	4.4	+	.	1.3
Mentha aquatica	.	.	r	.
Berula erecta	.	.	r	.
ChCl. *Artemisietea vulgaris*				
Impatiens glandulifera	3.4	5.3	4.3	2.2
Urtica dioica	1.3	1.2	3.3	3.3
Calystegia sepium	2.2	.	3.3	.
Impatiens parviflora	.	+	2.3	5.4
Galium aparine	1.2	.	3.3	+
Geranium robertianum	.	.	.	3.3
Alliaria petiolata	.	.	.	2.3
Geum urbanum	.	.	r	1.3
Rubus caesius	.	.	1.2	+
Cirsium arvense	.	+	+	.
Eupatorium cannabinum	+.3	.	.	.
Solidago canadensis	.	r	.	.
Epilobium hirsutum	.	r	.	.
Myosoton aquaticum	.	.	r	.
ChCl. *Molinio-Arrhenatheretea*				
Poa trivialis	.	+	2.3	1.3
Deschampsia caespitosa	.	.	.	+.3
Lysimachia nummularia	.	.	+	3.3
Caltha palustris	.	.	.	2.3
Agrostis stolonifera	.	.	2.3	.
Cirsium oleraceum	.	.	1.2	.
Equisetum palustre	.	r	.	.
Arrhenatherum elatius	.	.	+	.
Companion plant species				
Sambucus nigra (b) 4/1.1, *Aegopodium podagraria* 3/1.3, *Stellaria media* 3/+, *Bromus sterilis* 3/+, *Humulus lupulus* 3/+, *Bidens frondosa* 1/r, *Echinocystis lobata* 1/+, *Symphytum officinale* 1/+.				

Explanations: 1 – area I, *Phragmitetum communis* (Bnin), 2 – area II, *Phragmitetum communis* (Poznań), 3 – area III, *Convolvulion sepium* (Poznań), 4 – area IV, *Alnetea glutinosae* (Bnin).

the same day were used. Special attention was paid to the fact that the seeds were mature and healthy. Seeds samples were mixed with a small part of the local soil and sealed in labelled bags made from a moisture- and air-permeable material (a 95% polyamide knit), covered with a wire mesh of 0.5 cm × 0.5 cm, that formed a protection against rodents. In this way, similar to the natural, yet controlled experimental conditions, were obtained. Bags were placed on the soil surface (0 cm) and at a depth of 5 cm in four replicates per 100 seeds for a given depth. Thus, there were eight bags containing seeds at every sample plot.

In the given growing season, the observations started when germination of spontaneously scattered *I. glandulifera* seeds was noticed on the research and other stands. Instead, the end of the growing season for this species was a signal to finish the observation. Observations comprised the periodic opening of bags and counting of seeds that germinated and those that become deteriorated. This enabled capturing the dynamics of their germination process. Initially, bags were opened every week, then every 2-3 weeks, until mid-October, when the end of the growing season for *I. glandulifera* on the research areas was observed. During counting, the seeds were washed out on a sieve with water from nearby watercourses. The germinated and deteriorated seeds were discarded and ungerminated, healthy ones were placed again in bags with fresh, local soil at the respective depths. Observations were resumed in the spring next year. Studies were repeated in the following year by setting up experimental stands in mid-September 2007 in the same settings and using the same method.

Soil-habitat profile of the analysed stands was examined in August 2007. In order to determine the types and subtypes of the soil in the experimental areas, a series was of additional typologic surfaces established. As a part of the field work, soil pits up were made to 60 cm in depth, which were afterwards deepened by drilling down to 150 cm. "Classification of forest soils of Poland" was the basis for soil description (Święcicki 2000). Analysis was performed in the field by specifying the granulometric composition of soils and pH of the soil levels, measured with use of Hellige acidimeter. Carbonate content was determined using 10% HCl acid.

Phytosociological characteristics was accomplished during the 2006 growing season with use of phytosociological photographs by Braun-Blanquet method. The photograph covered the research areas or their close proximity. Vascular plant nomenclature was adopted after Mirek et al. (2002), and phytosociological nomenclature was adopted after Matuszkiewicz (2002).

Statistical analysis of the results was performed with use of Statistica 6 software. The percentage values were calculated according to the C.I. Bliss Formula (Snedecor and Cochran 1976) followed by two-way analysis of variance ANOVA at the level of significance $\alpha = 0.05$. Significant differences between means were determined using the Tukey test and Excel software was used for data analysis.

Due to the fact that some of the bags containing seeds have been damaged by rodents, only complete results from the three research areas (area I, area III, area IV) in the 2007 growing season were subjected to statistical analysis, rejecting incomplete data from the area II of 2007 and data from all areas of 2008.

Statistical analysis

The average number of germinated *I. glandulifera* seeds in the 2007 growing season differed significantly between plant communities (Fig. 1).

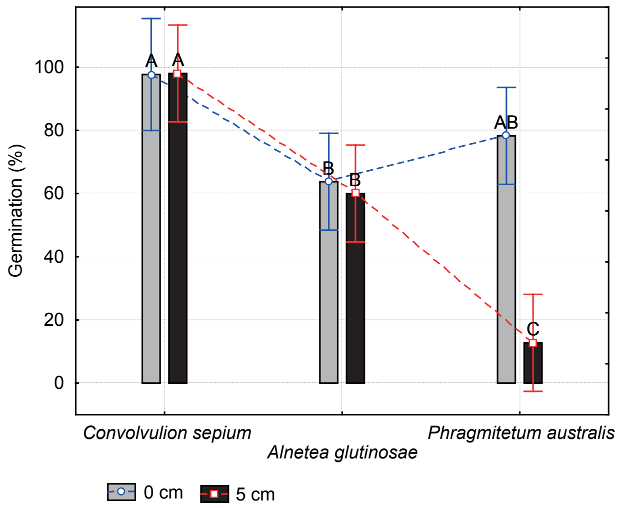

Fig. 1. Arithmetic means for the percentage of germinated seeds of *Impatiens glandulifera* depending on the type of plant community and depth of their localization in the soil. Vertical bars indicate confidence intervals of 0.95. The same letters represent values that do not differ significantly

The most of seeds germinated in herb community from alliance *Convolvulion sepium* (97.8% ±0.8), the least in the reed rushes *Phragmitetum australis* (45.5 ±14.5%), and the avarage value was recorded in the community from class *Alnetea glutinosae* (61.9 ±2.6%). The number of germinated seeds in bags placed on the soil surface and at a depth of 5 cm did not differ significantly within the herb community (97.7 ±1.8% and 98.0 ±1.4%, respectively) and the alder (63.7 ±2.5% and 60.0 ±4.7%, respectively), but there was a significant difference in the reed rushes (78.2 ±13.6% and 12.7 ±9.1%, respectively). There was a statistically significant effect on seed germination rate of both, the type of the plant community ($F = 23.71$, $p < 0001$) and the depth of their localization in the soil ($F = 12.18$, $p < 0.01$). There was also a statistically significant interaction between those two factors ($F = 10.82$, $p < 0.001$).

The average number of seeds that have deteriorated (due to the putrefaction and maceration) in the 2007 growing season, differed significantly between plant communities (Fig. 2).

Most of them were found in the rushes (49.7 ±12.9%), and the least in the herb community (2.1 ±0.8%), whereas the average value was reported for the alder (36.7 ±2.5%). The number of the deteriorated seeds in bags located on the soil surface and at a depth of 5 cm did not differ significantly within the herb community (2.3 ±1.8% and 2.0 ±0.7%, respectively) and within

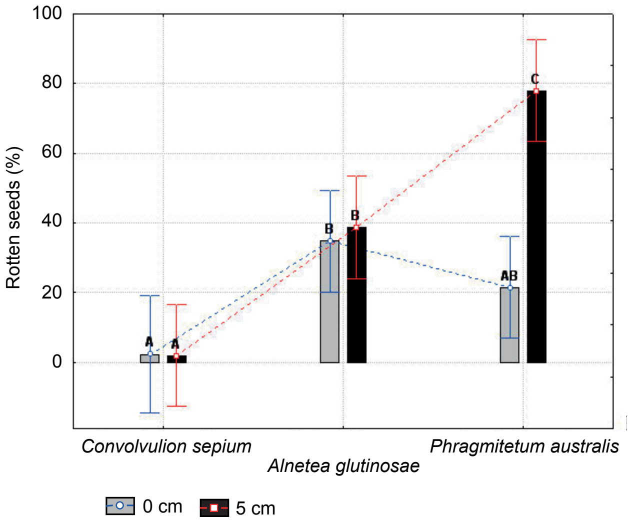

FIG. 2. Arithmetic means for the percentage of deteriorated *Impatiens glandulifera* seeds in the 2007 growing season, depending on the type of the plant community and the depth of their localization in the soil. Vertical bars indicate confidence intervals of 0.95. The same letters represent values that do not differ significantly

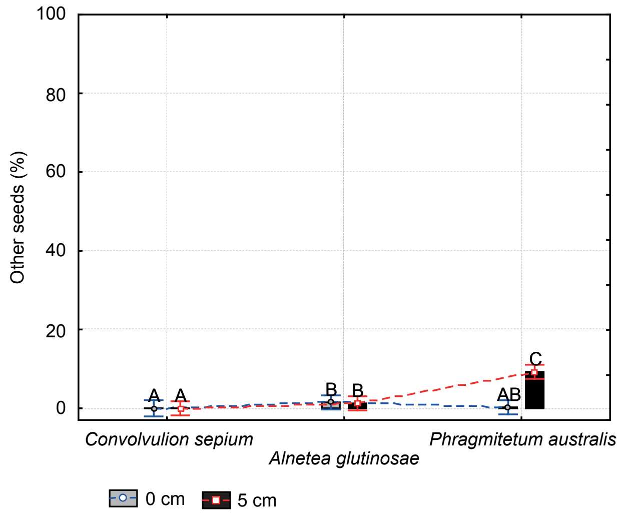

FIG. 3. Arithmetic means for the percentage of *Impatiens glandulifera* seeds that did not germinate and showed no external signs of deterioration at the end of the 2007 growing season, depending on the type of the plant community and depth of their localization in the soil.Vertical bars indicate confidence intervals of 0.95. The same letters represent values that do not differ significantly

the alder (34.7 ±2.1 % and 38.7 ±4.8%, respectively), whereas within the rushes there was a significant difference observed (21.5 ±13.6% and 78.0 ±7.7%, respectively). It was found that the process of deterioration is affected by the type of the plant community ($F = 25.57$, $p < 0.00001$), and the depth of their localization in the soil ($F = 10.21$, $p < 0.01$) as well. There was also a statistically significant interaction between those two factors ($F = 8.57$, $p < 0.01$).

The percentage of seeds that did not germinate and show no external signs of the deterioration process at the end of the 2007 growing season, was significantly different in the plant communities given (Fig. 3).

In the herb community, no such seeds were observed, as all of them germinated or became deteriorated in a small percentage, whereas the percentage of such seeds was on average 1.4 ±0.3% and 4.7 ±1.9% in the alder and in the rushes, respectively. Most of them (9.2 ±1.9%) were found in the rushes at a depth of 5 cm, and the value was significantly different from the other experimental variants. It was found that the number of seeds that did not germinate during the 2007 growing season was significantly influenced by the type of the plant community ($F = 20.78$, $p < 0.0001$) and the depth of their localization in the soil ($F = 21.00$, $p < 0.001$). A statistically significant interaction between those factors was also found ($F = 20.12$, $p < 0.0001$).

Field observations

The 2007 growing season of *I. glandulifera* began in mid-March and lasted until mid-October. The dynamics of seed germination was different at respective research plots, due to a close link to the occurrence or absence of flooding (Fig. 4).

Seed germination process started at the earliest, was the shortest and reached the highest value in the herb community (plant community from alliance *Convolvulion sepium*). It was the only site where there was no flooding. Germination process lasted only three weeks in this community, that is till April 4, wherein already on March 12, during the first observation, it was found that in bags located on the surface of the soil and in the bags at a depth of 5 cm, 97.6% and 92.5% of seeds germinated, respectively (Phot. 2, 3). Ultimately, 97.8% of the seeds germinated on this research area, and the other left deteriorated (they underwent putrefaction). Thus, there was no reservoir of seeds observed, which would constitute a potential soil seed bank for future growing seasons. Worth noting, the length of life of all seeds studied on this research stand, was less than seven months, that is, from the moment of their maturation and landing in the soil, until the germination (or deterioration) process has started.

On the other stands, the germination process started later and lasted longer. There were also bigger differences, depending on the depth at which seeds were spending time and more of them became deteriorated (Fig. 3, 5).

In the reed rushes *Phragmitetum australis* in Bnin, where from the first days of June there was a several centimeters water level maintained on some of the sites, the first germinated seeds were observed on March 28, wherein they were more abundant in bags placed on the soil surface – as much as 61.7%, as compared to 0.3% (one seed) at a depth of 5 cm. Whereas the germination process of seeds in bags placed on the soil surface ended at the end of April, in those bags that were placed at a depth of 5 cm, only then the germination began. At this research plot, the germination process was extended up to eight weeks, i.e. May 22. Since June, however, seed deterioration process became intensified, especially considering seeds that were located deeper in the soil.

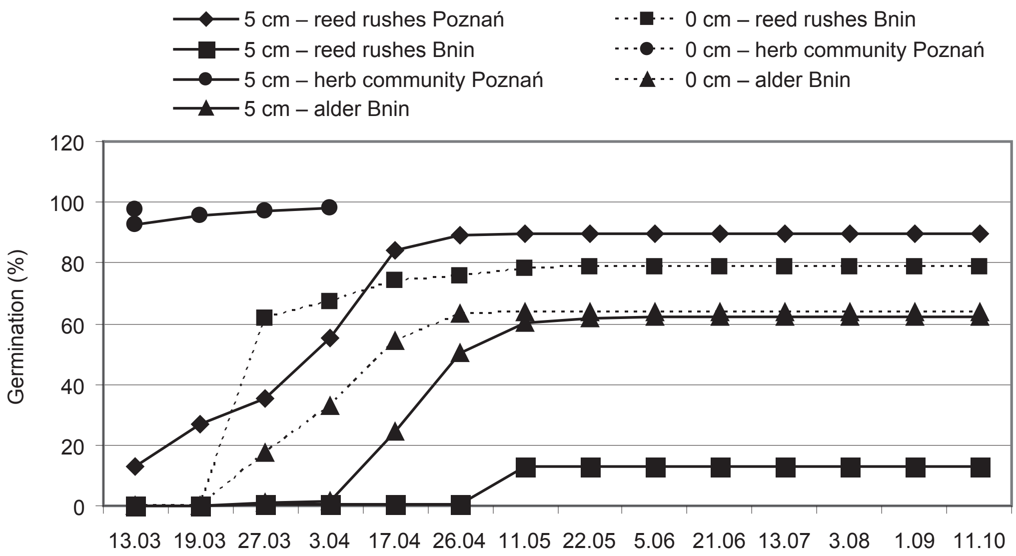

Fig. 4. Dynamics of *Impatiens glandulifera* seed germination process in the 2007 growing season, depending on the type of plant community and depth of their localization in the soil

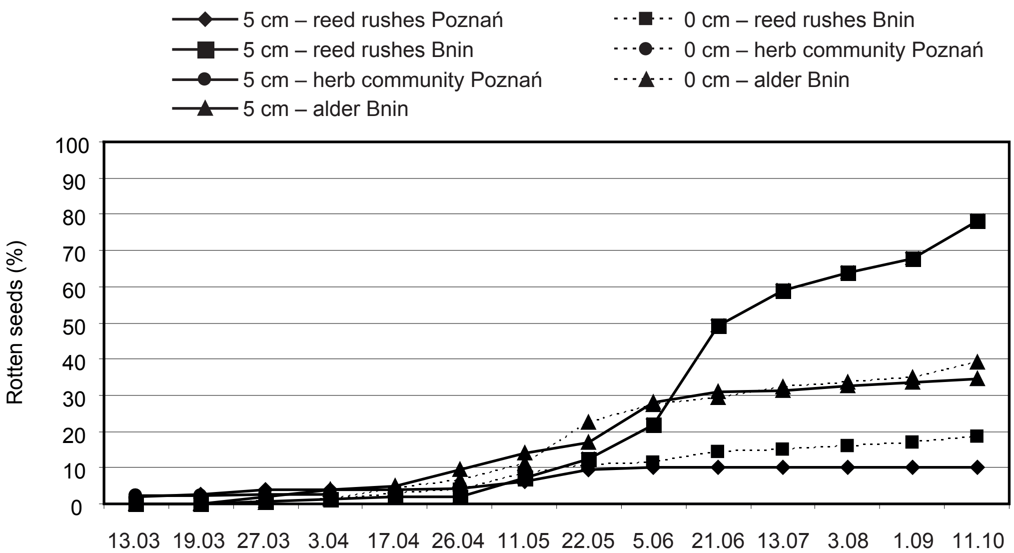

Fig. 5. Dynamics of the deterioration process of *Impatiens glandulifera* seeds in the 2007 growing season, depending on the type of plant community and depth of their localization in the soil

Of note, that at this study area and in this growing season there were no *I. glandulifera* seedlings observed. Probably, as a result of the prolonged flooding, on the surface of the reed rushes, on which thousands of specimens of this species flourished in the previous season, no specimen showed up this year. A potential source of diasporas was found, which is an assembly of *I. glandulifera,* growing on the rubble several dozens of meters away from the rushes, and a few specimens of this species, which have remained in its close proximity.

At the study area in the *Phragmitetum australis* reed rushes in Poznań-Kopanina, short-term, minor spring flooding, lasting until mid-March occured. At the beginning of the observations, on March 13, 2007, the water subsided, and the ground was muddy and wet. It turned out, that during the winter, all bags with the seeds that were placed on the soil surface were damaged and further observation was not possible. However, in bags placed at a depth of 5 cm, first sprouts were observed. In mid-March, swathes of reeds were burned out, which also covered the study plot in Kopanina. Although, the process of germination of *I. glandulifera* seeds that were located at a depth of 5 cm, was still observed, and during the observations on April 16, 2007, plenty of seedlings of this species (2 on a Braun-Blanquet scale) were noted, in close proximity of the regenerating reed, *Phragmites australis* (2), stinging nettle, *Urtica dioica* (r), the seedlings of creeping thistle, *Cirsium arvense* (+) and hairy willowherb *Epilobium* (r). At this plot, as in reed rushes in Bnin, the germination process lasted eight weeks, i.e. to May 9.

The study plot in the alder (plant community from class *Alnetea glutinosae*), located near the Kórnickie Lake in Bnin, was flooded twice in spring 2007, with the water level of several centimeters sustaining on the soil surface. The first flooding lasted until mid-April, after which the water subsided and the ground became fresh, and, here and there, moist. However, on the first days of June, the re-flooding of water from the Kórnickie Lake occurred, which lasted until mid-July. At this plot, the process of the seed germination lasted for 10 weeks (from March 28 to June 5), wherein the seeds from the bags placed on the soil surface germinated for 6 weeks (from March 28 to May 11), and those from the depth of 5 cm germinated for 10 weeks (from March 28 to June 5), but the most intensive germination lasted for 5-6 weeks (from April 3 to May 11). Since early May intensification of seed deterioration process was observed.

The research plots may be ranked from the lack of flooding to the prolonged spring flooding, which clearly corresponds with a percentage decrease of the germinated seeds and an increased contribution of the rotten seeds and others (Fig. 6, 7).

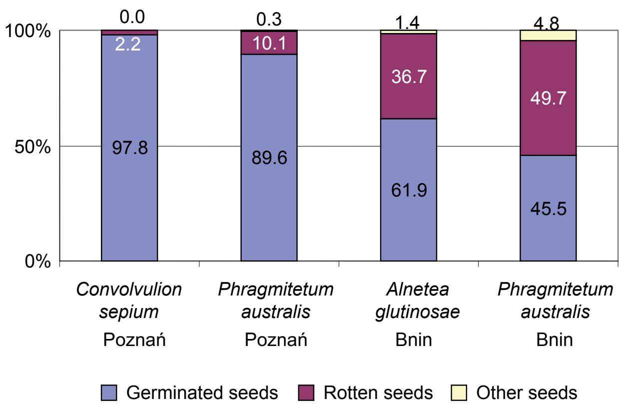

FIG. 6. Percentage of the germinated, deteriorated and other seeds (from bags placed on the soil surface and at a depth of 5 cm, on average) in the 2007 growing season, in the plant communities ranked from the absence of flooding to the long-term spring flooding (for *Phragmitetum australis* in Poznań, data correspond to the seeds from bags placed at a depth of 5 cm, as the bags located on the soil surface were damaged by rodents)

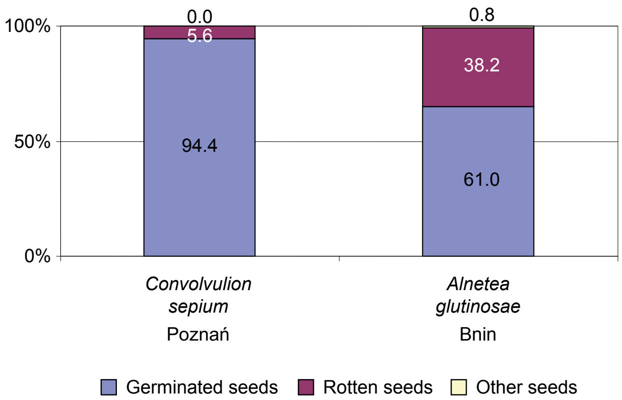

FIG. 7. Percentage of the germinated, deteriorated and other seeds (from bags placed on the soil surface and at a depth of 5 cm, on average) in the 2008 growing season, in the plant communities ranked from the absence of flooding to long-term spring flooding. The figure represents data from only two research plots, since the bags containing seeds from two others, were damaged by rodents

PHOT. 1. Deteriorated *Impatiens glandulifera* seeds on the flooded plot in the reed rushes *Phragmitetum australis* (area No. I)

PHOT. 2 and 3. Germinated *Impatiens glandulifera* seeds in bags placed on the surface of the soil (0b) and at a depth of 5 cm (5c) in the herb community from alliance *Convolvulion sepium* (area No. III)

Spending time seeds observations

As a result of observations carried out between March 2008 and March 2009, it was found that all the seeds that did not germinate in the previous growing seasons (2007 and 2008, respectively), have become deteriorated during winter (they have underwent the process of putrefaction and maceration), which means that the potential seed bank did not survived till the following spring.

DISCUSSION

Preliminary results suggest that *I. glandulifera* seeds do not form a persistent soil bank, and their survival rate is determined mainly by habitat conditions. Under favourable conditions, the seeds of this species remain in the soil only a few (7-8) months, after which they rapidly germinate in spring (almost at 100%) or deteriorate to a minor extent, leaving no reserve for the future growing seasons. According to Thompson and Grime (1979) such seeds form a "transient seed bank, type II". It is typical for species from the temperature zone and stands for a specific adaptation, by which the seeds do not germinate during winter. Due to the fact that the seeds of *I. glandulifera* prefer surface layers of the soil, the seed bank that they form, can also be specified as the active one (Falińska 2004).

The results of this study do not confirm reports that *I. glandulifera* form a persistent soil seed bank (Stroh 2005, http://www.cps-skew.ch, http://www.lwg.bayern.de/bienen) and that its seeds can survive in the soil for at least 18 months (Beerling and Perrins 1993). However, the results correspond with those of Walker et al. (2009), who reported that the species does not form a persistent soil seed bank.

In unfavourable conditions, such as the occurrence of spring flooding, a small part of the visually healthy seeds tends to spending time for several months. It is likely, that finding such seeds was a prerequisite for methodically unverified statement (Stroh 2005, http://www.cps-skew.ch, http://www.lwg.bayern.de/bienen) that *I. glandulifera* forms a persistent soil seed bank. The results of this study showed that all of the seeds "spending time" in spring deteriorated, and by definition, the seeds that meet the criteria of the soil seed bank must be viable and able to germinate (Falińska 2004).

The results of field studies on the survival rate of *I. glandulifera* seeds do not correspond with the results of laboratory tests, where the seeds of this species can survive in a swollen state, at 20°C without loss of viability for at least three years (Mumford 1988). Such a long viability of seeds in the laboratory should be regarded as the potential that will almost never be found in immeasurably different conditions in the field, due to the presence of lower temperatures in autumn and winter, as well as occurrence of flooding.

One of the factors determining the type of a seed bank is the size of seeds, whereas, their weight is a better indicator of their survival rate than the surface (Moles et al. 2003). In most studies, the seeds are considered small when their weight does not exceed 3 mg, and large seeds are those wheighing more than 3 mg (Czarnecka and Władyka 2007). *Impatiens glandulifera* seeds may be qualified to a category of large seeds. It was found (Thompson and Grime 1979, Bekker et al. 1998, Leishman and Westoby 1998, Tsuyuzaki and Goto 2001, Moles et al. 2003, Hölzel and Otte 2004, Czarnecka and Władyka 2007) that in the flora of Europe, seeds forming a transient seed bank are larger and they prefer both shallower parts and the surface layer of the soil, whereas seeds forming persistent seed bank are smaller and they prefer deeper parts of the soil. Seeds of *I. glandulifera* fit into this model. In contrast, seeds of *I. noli-tangere* form a persistent soil seed bank (Falińska 2004). Thompson and Grime (1979) reported that, even closely related species occupying the same habitat (eg. *Ranunculus bulbosus*, *R. acris* and *R. repens*) may form different types of seed bank. Studies on Australian and South-African flora have not confirmed the relationship between the size of seeds and their survival rate in the soil, or there was a positive correlation found (Australia) (Leishman and Westoby 1998, Moles et al. 2003 and references cited therein, Holmes and Newton 2004).

Bertiller and Aloia (1997) found that terophytes, in contrast to other forms of life, do not represent a uniform seed bank model. This observation was not confirmed by Moles et al. (2003), who found no correlation between the form of life and a form of growth, and the survival rate of the seeds.

CONCLUSIONS

1. The process of germination and deterioration of *Impatiens glandulifera* seeds is largely determined by habitat conditions (type of the plant community, and the depth at which seeds are spending time) and the associated hydrological conditions (absence or presence of flooding and its duration).
2. Under optimal conditions *I. glandulifera* seeds longevity in the soil is only 7-8 months, after which they germinate rapidly (almost at 100%) or deteriorate to a lesser extent, leaving no reserve for the future growing seasons.
3. The main factor limiting germination and viability *I. glandulifera* seeds is spring flooding.
4. High survival potential of *I. glandulifera* seeds observed in the laboratory, has not been observed in the field in relation to the plant communities investigated.
5. The results of this study suggest that *I. glandulifera* do not form a persistent soil seed bank in the plant communities studied.

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