Acta Biologica Hungarica 61 (Suppl.), pp. 197–205 (2010)
DOI: 10.1556/ABiol.61.2010.Suppl.19

SEED LONGEVITY AND GERMINATION CHARACTERISTICS OF SIX FEN PLANT SPECIES

S. Tatár*

PhD School of Biological Sciences, University of Pécs,
Ifjúság u. 6, H-7624 Pécs, Hungary

(Received: August 9, 2010; accepted: October 10, 2010)

Fens are among the most threatened habitats in Europe as their area has decreased considerably in the last centuries. For successful management and restoration conservationists need detailed knowledge about seed bank formation and seed longevity of plants, as these features are closely related to successional and vegetation dynamical processes. I analysed seed longevity and the germination characteristics of six fen plant species by seed burial experiments. Based on seed weight, seed bank was expected for long-term persistent for the light-seeded *Schoenus nigricans, Carex appropinquata, C. pseudocyperus, C. davalliana* and *Peucedanum palustre* and also that for the medium-seeded *Cicuta virosa.* It was proved that, the latter two species have short-term persistent seed banks, while *Carex pseudocyperus* has a transient seed bank, therefore these species may only have a limited role in restoration from seed banks. It was found that *Schoenus nigricans, Carex appropinquata* and *C. davalliana* have persistent seed banks, because some of their four-year-old seeds have emerged. Fresh seeds had low germination rate in all studied species and majority of seeds emerged after winter, except for *Carex pseudocyperus.* After the germination peak in spring, the majority of the ungerminated seeds of *Schoenus nigricans, Peucedanum palustre, Carex appropinquata*, *C. davalliana* and *Cicuta virosa* entered a secondary dormancy phase that was broken in autumn. I found the seasonal emergence of the latter three species highly similar.

Keywords: Burial experiment – *Carex appropinquata* – *Carex davalliana* – *Carex pseudocyperus* – *Cicuta virosa* – *Peucedanum palustre* – *Schoenus nigricans* – seed bank

INTRODUCTION

Only 1% of the Earth's surface is covered by fens [21]. They occupy large areas of the Holarctic boreal zone (North America, Scandinavia, Eastern Europe and Western Siberia), and they are also common in some areas of the tropical Southeast Asia, the temperate South America, and at the high elevations of New Zealand [20]. The area of fens has considerably decreased (by 62% to 187,000 km^2) in the last centuries in Europe. In most countries of Northwestern Europe more than 90% of fen ecosystems have been transformed into meadows and pastures during the last few decades. In Hungary 97% of fens has been destroyed by draining and ploughing, therefore all types of them are protected *'ex lege'* since 1997 [12]. It is mostly human impact that

* E-mail: tatarsandor@invitel.hu

causes degradation of multiple fen ecosystem services (e.g. the ability to retain or convert nutrients and to retain carbon-dioxide) [20].

As a consequence fens are among the most threatened habitats throughout Europe. The most severe problems are desiccation (caused by drainage and global warming), the abandonment of management and in some cases spread of invasive species [12, 20].

Fens form an important part of the Natura 2000 network in the European Union, but most of them are likely to be degraded in the future in the lack of proper management (e.g. rewetting, mowing, grazing). For succesful management and restoration (aiming to preserve the rare, endangered plant and animal species of these habitats) conservationists and site managers need detailed knowledge about the ecological conditions and mechanisms of fens.

Life strategy, seed banks and the seed longevity of plants need to be mentioned among the most important research topics, as are closely related to vegetation dynamical processes. Regeneration from seeds is more riskful than vegetative spread because of the vulnerability of seedlings [11], therefore seed dormancy and environmental factors of germination play a decisive role in the life strategy of plants [15]. This ecological knowledge is very important for nature conservation [1, 22].

This paper presents experimental results for the seed longevity and the germination characteristics of six fen plant species: *Carex appropinquata, C. davalliana, C. pseudocyperus, Schoenus nigricans, Cicuta virosa* and *Peucedanum palustre.*These species – except for *Carex pseudocyperus* and *Schoenus nigricans* – are protected in Hungary.

Carex species, with several long-term persistent seed bank records, may play an important role in habitat reconstruction and regeneration [14, 17, 19, 24]. According to the literatural sources, previous germination tests (either in the lab or in the field) were only carried out in *Carex pseudocyperus* [17, 19].

MATERIALS AND METHODS

Results of a five-year-long seed burial experiment are presented for four species of *Cyperaceae* and two species of *Apiaceae*. The diaspore of *Cyperaceae* (hereafter referred to as “seed”) consists of a nutlet or an achene surrounded by a perigynium (utriculus). Approximately 700–700 ripened seeds per species were collected in 2005 (Table 1). Seeds had been stored at room temperature for some weeks before being sown on the surface of a 4 cm thick soil layer sterilized at 90 °C. Between 2005 and 2009 100–100 (in the case of *Carex davalliana*, *Cicuta virosa* and *Schoenus nigricans* 50–50) seeds were sown to the surface of peat containing potting soil (see Table 1). One tray was left to unsown control which contained sterilized potting soil. The abbreviated species names of graphs are followed the paper of Dobolyi et al. [8]. Each germination shift was started in August between years 2005 and 2009 and lasted for 12 months. Time of sowing – except for *Carex davalliana* – coincided with the natural seed dispersal period. After sowing trays (sized 27 × 33 cm) were covered with

Table 1
Places and dates of seed collection

Fen plant species	Seed weight categories[1]	Date of seed collection (2005)	Place of seed collection [names of the Hungarian nature reserves (NR)]	Plant communities
Carex appropinquata	3	11th June	Veresegyházi Úszószigetek NR (in the village of Veresegyház) (Geo-coord.: N47°38’51.71”; E19°16’46.04”)	*Phragmitetum communis* (floating mires)
Carex davalliana	2[2]		Sikárosi-láp NR, part of the Veresegyházi-medence NATURA 2000 site (in the village of Mogyoród) (code: HUDI20055, Geo-coord.: N47°37’15.86”; E19°16’12.02”)	*Caricetum davallianae*
Carex pseudocyperus	3	8th July	Veresegyházi Úszószigetek NR (in the village of Veresegyház) (Geo-coord.: N47°38’51.71”; E19°16’46.04”)	*Phragmitetum communis* (floating mires)
Cicuta virosa	4	25th August		
Peucedanum palustre	3	25th August		
Schoenus nigricans	3	8th July	Kocsma-rét NR, part of the Duna és ártere NATURA 2000 site (in the village of Sződ) (code: HUDI20034, Geo-coord.: N47°43’26.58”; E19°09’55.40”)	*Junco obtusiflori–Schoenetum nigricantis*

[1] Seed weight categories; 1–8 (Csontos 2001, Csontos and Tamás 2003).
[2] Own measurement (thousand seed weight with utriculus: 0.713 g).

punched agricultural foil, and were put outdoor in a shaded place in a common garden in order to be exposed to near-natural light and temperature conditions (e.g. chilling effect in winter). The used mean monthly temperature data (derived from weather station of village Aszód, Geo-coord.: E19°28’35’’, N47°39’20’’) were kindly provided by the Hungarian Meteorological Service. Mean monthly temperature data (between July 2005 and May 2009) were calculated from daily measurements.

Seeds not sown after collection in 2005 were put into a pot filled with sterilized sand and covered by a plastic mesh, and then it was buried outside 70 cm deep in the soil. In this depth seeds enter dormancy due to the higher carbon-dioxide concentration, the lower temperature fluctuation and the lack of light [9].

Trays were watered regularly, and seedlings were counted and removed every week, several photos were taken, and a seedling herbarium was compiled, too. During the experiment the number of seedlings of each species was pooled in the middle of every month.

Seed banks were classified according to Thompson [22] also accepting recommendations of Csontos and Tamás [5]. This system consists three groups: transient (seed longevity is shorter than 1 year), short-term persistent (longevity: 1 to 5 years) and long-term persistent group (>5 years).

RESULTS

Seed longevity and germination characteristics

No seeds emerged from the sterilized potting soil (sterilised control for seed rain). Fresh seeds had a low germination rate in all studied species. No seeds of *Carex pseudocyperus* emerged after one year suggesting a transient seed bank. For *Peucedanum palustre* and *Cicuta virosa* short-term persistent seed banks were proved, as their four-year-old seeds have already lost their viability. A significant portion (ca. 30%) of four-year-old seeds of *Carex appropinquata, C. davalliana* and *Schoenus nigricans* still emerged suggesting they may have long-term persistent seed banks.

The seeds of *Carex pseudocyperus* had a low germination percentage (14.5%) and a short longevity as well. A relatively high germination rate (>65%) was only observed in the two umbellifers, *Peucedanum palustre* and *Cicuta virosa* during 2006–2007 and 2007–2008. Seasonal characteristics of germination were very similar in *Cicuta virosa, Carex appropinquata* and *C. davalliana* only small difference in average germination rates has been revealed between the latter two species (Figs 1, 2).

Effect of temperature

The majority of the seeds emerged after winter, except for *Carex pseudocyperus* (Fig. 3). During the study period (2005–2009) mean seasonal temperatures were the following: spring: 12.1 °C; summer: 21.5 °C; autumn: 11.1 °C; winter: 1.3 °C. Between September 2006 and August 2007 mean monthly temperatures were regu-

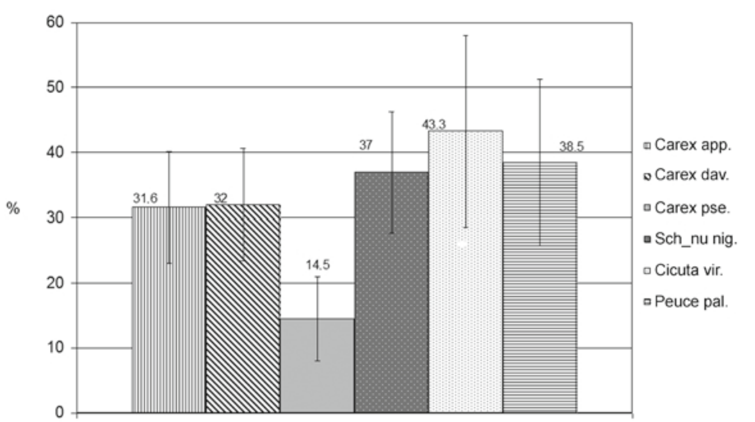

Fig. 1. Germination rates (mean ± S.D.) in studied species based on the results of the five-year-long experiment (2005–2010)

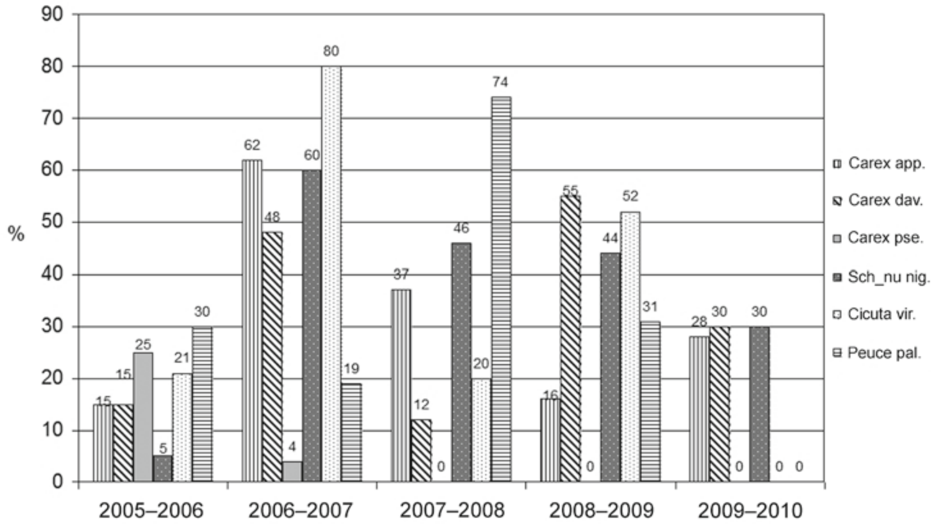

Fig. 2. The average germination rates of the different aged seeds of the six plant species studied. The age of the sowed seeds was the following: 2005 – fresh, 2006 – 1 year old, 2007 – 2 years old, etc.

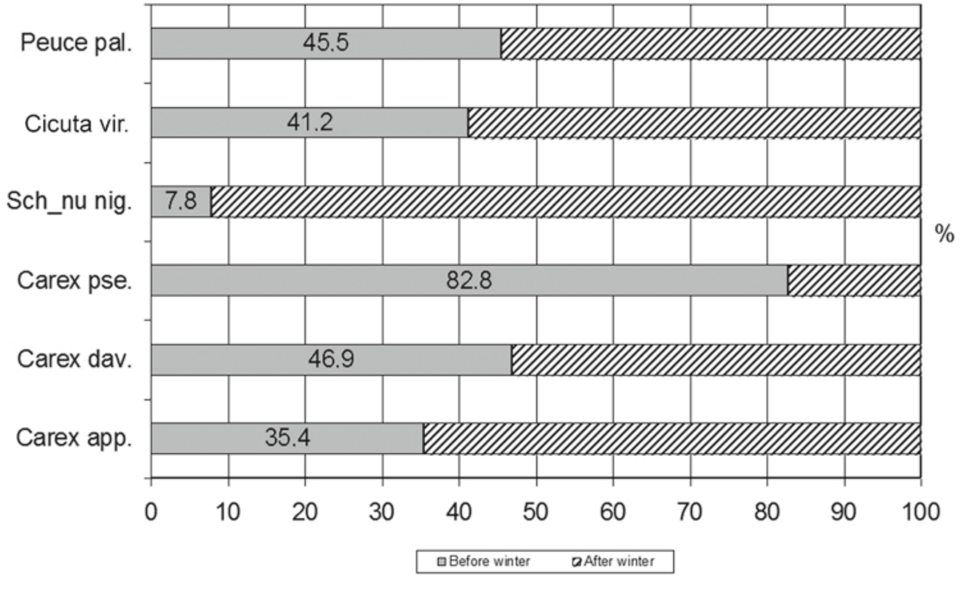

Fig. 3. The distribution of germination before and after winter/chilling effect (mean values of 2005–2010)

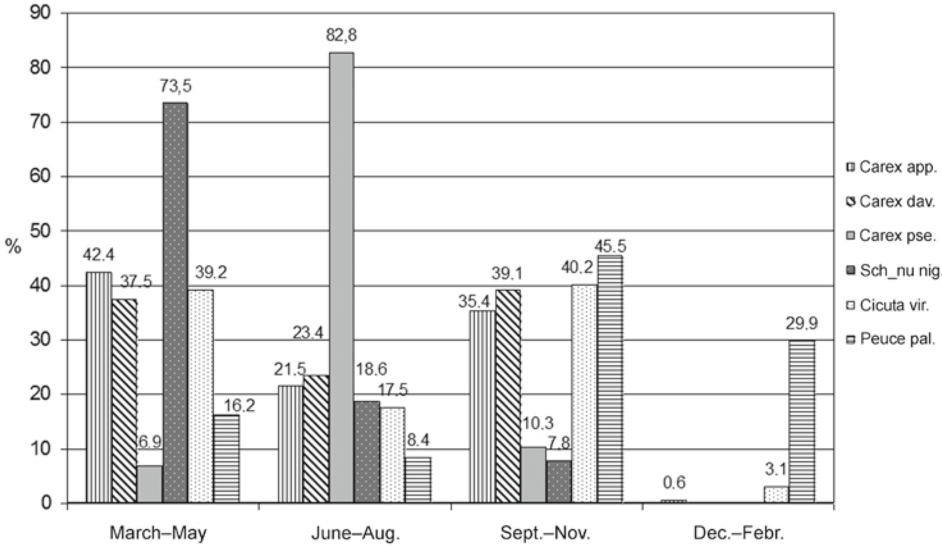

Fig. 4. Seasonal germination pattern of the studied species (mean values of 2005–2010)

larly higher than multi-year average observed with several new absolute temperature maximum records. This time the highest germination rates were observed in *Schoenus nigricans, Carex appropinquata* and *Cicuta virosa.*

After the germination peak in spring, the majority of the remained (ungerminated and viable) seeds of *Carex appropinquata*, *Carex davalliana*, *Schoenus nigricans, Peucedanum palustre* and *Cicuta virosa* entered secondary dormancy that was broken in autumn. Seasonal emergence of *Carex appropinquata*, *Carex davalliana* and *Cicuta virosa* proved highly similar (nearly equal maximum germination percentage in every season with a peak in spring and autumn). Most *Schoenus nigricans* seedlings emerged in spring (73.5%), *Carex pseudocyperus* had a summer germination peak (82.8%), while *Peucedanum palustre* (45.5%) germinated mostly in autumn.

DISCUSSION

Based on the general trend for small seeded species to form persistent seed banks [5, 22] and specific seed weight data one could expect long-term persistent seed banks in the light-seeded *Schoenus nigricans, Carex appropinquata, C. pseudocyperus, C. davalliana* and *Peucedanum palustre* and in the medium-seeded *Cicuta virosa.*

According to Thompson et al. [23], *Cicuta virosa* and *Peucedanum palustre* possess transient seed banks (based on vertical distribution of their seeds in soil and their presence in aboveground vegetation). Matus et al. [14] found that most species of the Dutch fen-meadow (*Cirsio dissecti-Molinietum*) had at most short-term persistent seed banks. They concluded that successful restoration of fens from soil seed banks without reintroduction of characteristic species is only possible in areas that had been degraded only a few years before. They recorded *Peucedanum palustre* in the vegetation, apparently missing from the seed bank, therefore classified as transient seeded [14].

I found that *Cicuta virosa* and *Peucedanum palustre* have short-term persistent seeds as they lost viability after four years only. The differences between the expected and the obtained results can be explained as follows: flattened seeds of *Peucedanum palustre* with a large surface/volume ratio, i) are less likely to get into the soil therefore ii) are more exposed to seed-predators [13]. Burial may also have increased seed longevity in *Peucedanum palustre* and *Cicuta virosa*.

In my study *Carex pseudocyperus* had a transient seed bank with an average germination rate of 14.5%, however, its seeds had still emerged in the experiment of Schütz [17] with a much higher germination rate (98.7%) after two years. Nevertheless, I would like to highlight that there were big differences between the storage conditions, the experimental treatments and the design between Schütz's test and mine. Instead of burial Schütz used a cold-wet lab stratification for six months before sowing with a fluctuating temperature (22 °C/10 °C). In another study of Schütz, covering 13 European populations of *C. pseudocyperus,* no regional pattern of dormancy had been revealed [19].

Fresh seeds had low germination rate in all studied species (see Fig. 2). This corresponds well with the observation of Baskin and Baskin [2], stating that the seeds of many species are dormant at maturity, and unable to germinate under a broad set of environmental conditions. My results showed a "risk-spreading" strategy in seed bank (after Grubb [10]) for all studied species, as majority of seeds did not germinate, although ideal conditions were provided (Fig. 1).

The effect of temperature on germination

It is already proved that the positive response to diurnally fluctuating temperatures and the requirement for a relatively high temperature for increased rate of germination is common amongst *Cyperaceae* and in the case of *Carex pseudocyperus* [17]. Schütz [19] observed the seasonal dormancy patterns of 19 *Carex* species typical for temperate climate in various – but mostly wet – habitats. All the species analysed by Schütz had dormancy cycles, and showed similar seasonal responses to temperature. Seeds came out of dormancy in late autumn or winter, and they re-entered dormancy or conditional dormancy in late spring or early summer. I found a similar dormancy cycle for *Carex appropinquata* and *C. davalliana* with germination peaks in September and April. Most of the seeds of *Schoenus nigricans* emerged in September and May. February in 2008 was extremely warm, which lead to the highest monthly germination percentage in *Peucedanum palustre* (Fig. 4). A considerable germination peak was also observed in autumn in the another umbelliferous species *(Conium maculatum)* [6].

As it was mentioned before, the majority of seeds of studied fen plants – except for *Carex pseudocyperus* – emerged after winter (see Fig. 3). According to my findings, chilling effect – especially in the case of *Schoenus nigricans* and *Carex appropinquata* – helped to break seed dormancy presumably. This finding corresponds with the results of Schütz [19], which showed the positive effect of cold stratification on *Carex* germination. Contrary, it was found that 82.8% of the seeds of *Carex pseudocyperus* germinated before winter (i.e. in summer, Fig. 4), which seems to be related to a transient seed bank. It means that short-lived seeds can exploit their short viability more efficiently due to germinating during first summer.

ACKNOWLEDGEMENTS

I would like to thank my supervisor A. Borhidi as well as G. Matus and P. Csontos for their useful advice. I also thank J. Hegyesi and G. Papp for their help.

REFERENCES

1. Bakker, J. P. (ed.) (1989) *Nature Management by Grazing and Cutting*. Geobotany 14. Kluwer Academic Publishers, Dordrecht, pp. 416.
2. Baskin, C. C., Baskin, J. M. (1989) Physiology of dormancy and germination in relation to seed bank ecology. In: Leck, M. A., Parker, V. T., Simpson, R. L. (eds) *Ecology of Soil Seed Banks*. Academic Press, San Diego, pp. 53–66.
3. Bekker, R. M., Bakker, J. P., Grandin, U., Kalamees, R., Milberg, P., Poschlod, P., Thompson, K., Willems, J. H. (1998) Seed size, shape and vertical distribution in the soil: indicators of seed longevity. *Funct. Ecol. 12,* 834–842.
4. Csontos, P. (2001) A természetes magbank kutatásának módszerei. [Methods of studying the natural seed bank.] *Synbiol. Hung. 4.* Scientia Kiadó, Budapest, pp. 1–155. (In Hungarian.)
5. Csontos, P., Tamás, J. (2003) Comparisons of soil seed bank classification systems. *Seed Sci. Res. 13,* 101–111.
6. Csontos, P. (2008) A bürök *(Conium maculatum)* terméseinek túlélése a talajban. [The survival of hemlock *(Conium maculatum)* seeds in the soil.] *Növényvédelem*, *44,* 441–443. (In Hungarian.)
7. Csontos, P., Tamás, J., Balogh, L. (2003) Thousand-seed weight records of species from the flora of Hungary, I. Monocotyledonopsida. *Studia Bot. Hung. 34,* 121–126.
8. Dobolyi, Z. K., Horváth, F., Lőkös, L., Szerdahelyi, T. (1994) Database of the Hungarian vascular plants (Hungplant). *Studia Bot. Hung. 25,* 85–90.
9. Fenner, M. (1985) *Seed Ecology*. London, Chapman and Hall, pp. 151.
10. Grubb, P. J. (1988) The uncoupling of disturbance and recruitment, two kinds of seed bank, and persistence of plant populations at the regional and local scales. *Ann. Zool. Fennici 25,* 23–26.
11. Harper, J. L. (1977) *Population Biology of Plants*. Academic Press, London, pp. 892.
12. Lájer, K. (1998) Bevezetés a magyarországi lápok vegetációökológiájába. [Introduction to the vegetation ecology of Hungarian fens.] *Tilia 6,* 84–238. (In Hungarian.)
13. Maron, J. L., Simms, E. L. (1997) Effect of seed predation on seed bank size and seedling recruitment of bush lupin *(Lupinus arboreus). Oecologia 111*, 76–83
14. Matus, G., Verhagen, R., Bekker, R. M., Grootjans, A. P. (2003) Restoration of the *Cirsio dissecti-Molinietum* in The Netherlands: Can we rely on soil seed banks? *Appl. Veget. Sci. 6,* 73–84.
15. Meyer, S. E., Monsen, S. B., McArthur, E. D. (1990) Germination response of *Artemisia tridentata (Asteraceae)* to light and chill, patterns of between-population variation. *Bot. Gazette*, *151,* 176–183.

16. Schopp-Guth, A. (1997) Diasporenpotential intensiv genutzter Niedermoorböden Nordostdeutschlands – Chancen für die Renaturierung? *Z. Ökol. Naturschutz 6,* 97–109.
17. Schütz, W. (1997) Are germination strategies important for the ability of cespitose wetland sedges *(Carex)* to grow in forests? *Can. J. Bot. 75,* 1692–1699.
18. Schütz, W., Rave, G. (1999) The effect of cold stratification and light on the seed germination of temperate sedges (*Carex*) from various habitats and implications for regenerative strategies. *Plant Ecol. 144,* 215–230.
19. Schütz, W. (2000) Ecology of seed dormancy and germination in sedges *(Carex)*. *Perspectives in Plant Ecology, Evol. Syst. 3,* 67–89.
20. Schrautzer, J., Rinker, A., Jensen, K., Müller, F., Schwartze, P., Dierßen, K. (2007) Succession and Restoration of Drained Fens: Perspectives from Northwestern Europe. In: Walker, L. R., Walker, J., Hobbs, R. J. (eds) *Linking Restoration and Ecological Succession.* Springer, New York, pp. 90–120.
21. Succow, M. (1988) *Landschaftökologische Moorkunde*. Fischer Verlag, Jena, pp. 340.
22. Thompson, K. (1993) Persistence in soil. In: Hendry, G. A. F., Grime, J. P. (eds) *Methods in Comparative Plant Ecology: A Laboratory Manual*. Chapman & Hall, London, pp. 199–202.
23. Thompson, K., Bakker, J. P., Bekker, R. M. (1997) *The Soil Seed Banks of Northwest Europe: Methodology, Density and Longevity.* Cambridge University Press, Cambridge, pp. 276.
24. Valkó, O., Török, P., Tóthmérész, B., Matus, G. (2010) Restoration potential in seed banks of acidic fen and dry-mesophilous meadows: Can restoration be based on local seed banks? *Rest. Ecol.* (in press), DOI: 10.1111/j.1526-100X.2010.00679.x.