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Soil seed bank of an alpine lichen heath in the Northwestern Caucasus: species richness

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Abstract. Soil seed bank of an alpine lichen heath was studied by sampling a whole 0.49 m^2 plot with subsamples of 10x10 cm size. Germination process continued during three years. 18 species were identified in the seed bank. The species composition was similar to our earlier findings. Species - area dependence was analysed in series of plots from 0.01 to 0.49 m^2. No significant differences were found between floristic diversity of viable seeds in the soil and floristic diversity of aboveground vegetation at the same plot sizes. Cumulative curve of species richness depending on amount of samples showed that ten to twenty samples are enough to reveal most of the species persisting in the seed bank. Differences between years of sampling as well as species richness dependence on amount of samples and total area of sampling are discussed.
Key-words: persistent seed bank; floristic diversity; species - area relationship; alpine lichen heath; Northwestern Caucasus

Introduction

Seed banks of arctic and alpine communities are known to be relatively poor in species (McGraw and Vavrek 1989). In a recent paper concerning two alpine plant communities in the Central Alps, Diemer and Prock (1993) reported rather high species richness of their seed banks; however, species richness of aboveground vegetation was much higher. Several authors have called attention to the fact that dominant species may not accumulate viable seeds in soils (Chambers 1993; Diemer and Prock 1993; Semenova and Onipchenko 1994), as well as some other species. However, little is known about the necessary area for determination of seed bank composition (Roberts 1981; Rabotnov 1982; Simpson, Leck and Parker 1989). This study addresses the following questions: How many samples are necessary to evaluate the species composition of germinable seeds in the soil of the alpine lichen heath? How large must be total area of the sampling site? Finally, how does the species richness of the seed bank correspond to the species richness of aboveground community at the same plot size?

Material and methods

Study site

Soil samples were taken from an alpine lichen heath at the permanent study site at 2,750 m a.s.l. on Mount Malaya Khatipara (43°27' N, 41°41' E). It is situated in Teberda State Reserve, a part of the Karachaevo-Cherkessian Republic in the Northwestern Caucasus, Russia. The alpine lichen heath is dominated by fruticose lichens (mostly *Cetraria islandica* (L.) Ach.). *Festuca ovina* L., *Carex umbrosa* Host, *C. sempervirens* Vill., *Campanula tridentata* Schreb., *Anemone speciosa* Adam ex G. Pritz and *Antennaria dioica* (L.) Gaertn. are the dominant vascular plant species forming more than 5% of the aboveground biomass. A more detailed description of the area, soil and vegetation is presented in Onipchenko (1994).

Sampling and germination

A plot of 70 x 70 cm was marked, divided into 49 quadrats of 10 x 10 cm size, vegetation from these quadrats was cut back to soil level. Soil was sampled to the depth of 2 cm, because it was found earlier that the upper 2 cm soil layer of this site contains 94% of all germinable seeds (Onipchenko 1987). One more sample was taken alongside in order to simplify some estimations. Thus, the total sample area was 5,000 cm^2. Samples were taken in early August 1990, before seed-shedding but after spring seed germination. Therefore, it was attempted to examine only the persistent seed bank (Thompson and Grime 1979).

The soil samples were put into cloth bags, air dried, and transported to the greenhouse of Moscow State University (Moscow). Dry samples were spread out on sterilised sand in plastic pots, placed in the greenhouse and watered. We counted germinated seedlings and removed them after identification. The germination process was allowed to occur during 3-4 months in both spring and autumn, it was discontinued during summer and winter for three years of the study. We kept the samples frozen in winter to stimulate seed germination. All soil samples were remixed at the beginning of germination process every spring and autumn in order to expose buried seeds.

Data treatment

Mean number of species per sample, standard error, and coefficient of variation were calculated for 50 samples. Cumulative number of species was plotted

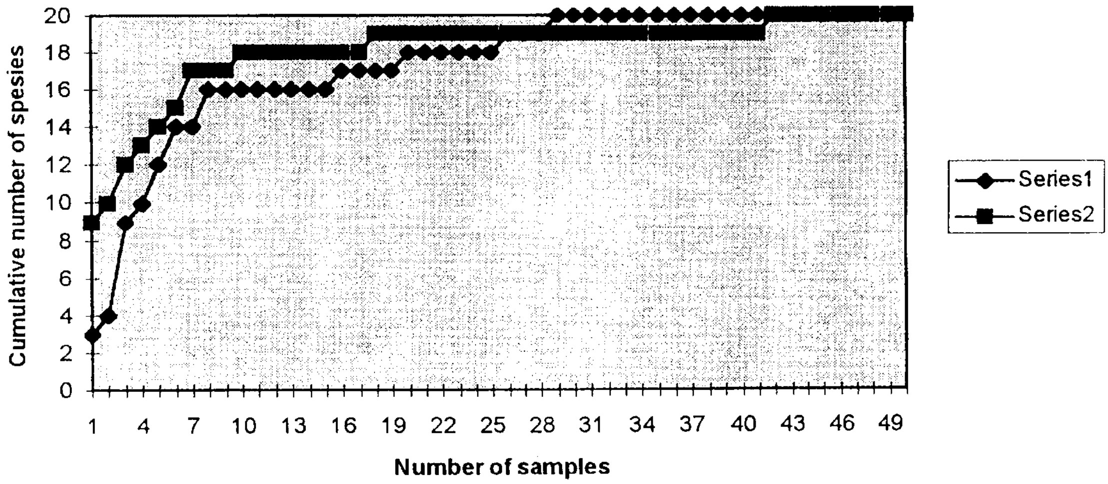

Fig. 1. Cumulative number of species identified in soil seed bank samples from an alpine lichen heath in the Northwestern Caucasus based on regular (1) and random (2) sampling.

on the basis of regular and random sampling (Fig. 1). Species-area dependence was analysed in series of square plots with sides 10, 20, 30, 40, 50, 60 (four replicates - from each corner of the sampling plot), and 70 cm (one replicate) (Fig. 2). Mean number of species per plot and standard error were calculated for all plot sizes. Two equations were fitted (cf. van der Maarel 1988):

$$S = c \cdot A^z \qquad (1)$$

$$S = a + b \cdot \ln A \qquad (2)$$

where S = number of species, A = area, a, b, c, and z - regression parameters.

Anemone speciosa Adam ex G.Pritz.	16	± 6
Campanula tridentata Schreb.	8	± 4
Carex sempervirens Vill.	10	± 5
C. umbrosa Host	10	± 4
Carum caucasicum (Bieb.) Boiss.	24	± 10
Erigeron alpinus L.	6	± 3
Eritrichium caucasicum (Albov) Grossh.	28	± 9
Euphrasia ossica Juz.	344	± 59
Festuca ovina L.	18	± 6
Gentiana pyrenaica L.	62	± 16
G. septemfida Pall.	22	± 8
Helictotrichon versicolor (Vill.) Pilger	20	± 7
Luzula spicata (L.) DC.	54	± 10
Minuartia circassica (Albov) Woronow	2	± 2
Pedicularis comosa L.	20	± 7
Primula algida Adam	198	± 23
Ranunculus oreophilus Bieb.	16	± 6
Veronica gentianoides Vahl.	142	± 26
Dicotyledons (undeterm.)	74	± 18
Monocotyledons (undeterm.)	10	± 5
Total number of seeds	1,084	± 75
Fritillaria lutea Mill. (cloves)	40	± 9
Lloidia serotina (L.) Reichenb. (cloves)	10	± 5

Table 1. The composition of the soil seed bank in an alpine lichen heah (number of seeds per m^2, mean ± standard error, n=50).

Results

Eighteen species of alpine vascular plants were identified in the seed bank of the alpine lichen heath from the samples of 1990 (Table 1). Two species germinated from dormant cloves. In the previous study (Onipchenko 1987; Semenova and Onipchenko 1994) when 10 samples with total area of 1,375 cm^2 were taken from the same study site in 1982, seedlings of seventeen species were found. These species lists slightly differ from each other: seedlings of *Arenaria lychnidea* Bieb., *Gentiana aquatica* L., *Pulsatilla albana* (Stev.) Bercht. et C.Presl, *Trifolium polyphyllum* C.A.Mey. emerged only from the samples of 1982, whereas seedlings of *Erigeron alpinus* L., *Euphrasia ossica* Juz., *Minuartia circassica* (Albov) Woronow, *Pedicularis comosa* L., *Ranunculus oreophilus* Bieb. were found in the samples of 1990. All these species but *Euphrasia ossica* were rare in investigated samples.

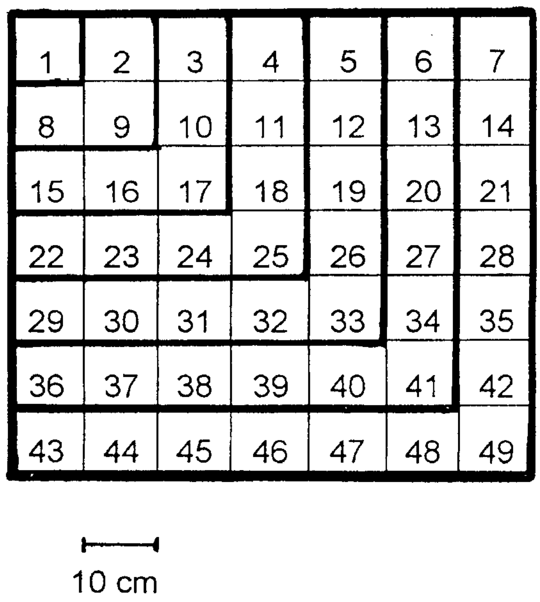

Fig.2. Sampling scheme with plots from 0.01 to 0.49 m^2

Plot size (m^2)	0.01	0.04	0.09	0.16	0.25	0.36	0.49
Seeds							
$\bar{X}$	5.0	11.3	14.5	17.0	18.0	19.5	20
SE	0.8	0.5	0.8	0.4	0.5	0.3	-
Seeds+cloves							
$\bar{X}$	5.5	12.5	16.3	18.8	19.8	21.5	22
SE	0.8	0.6	1.0	0.4	0.6	0.3	-
Aboveground vegetation							
$\bar{X}$	6.2	-	-	-	20.2	-	-
SE	0.4	-	-	-	0.7	-	-

Table 2. The number of species in the seed bank and aboveground vegetation at different plot sizes. $\bar{X}$ = average number of vascular plant species; SE = standard error. No significant differences were found in species richness of the seed bank and seed+clove bank vs. aboveground vegetation according to the t-test (p>0.05).

Cumulative number of species depending on amount of samples is shown in Fig. 1. Both curves are similar and levelled off at approximately ten samples. Of course, this levelling off can be considered an artefact - if the number of samples is plotted logarithmically (as an approximation of log area) it disappears. However, the idea is often used in practice. The numbers of species at different plot sizes were calculated both for seedlings germinated from seeds and for plants from seeds and dormant cloves (Table 2). No significant differences were found between species richness of viable seeds in the soil and the aboveground vegetation at the same plot sizes.

The species diversity per 10 x 10 cm plot calculated for 50 samples was 5.2±0.3 for seeds and 5.5±0.3 for seeds and cloves, coefficient of variation was 34% for both cases. The t-test revealed significant difference in species number for seeds vs. aboveground vegetation ($0.01<p<0.05$), while the difference between seed+clove pool and aboveground vegetation was found to be insignificant ($p>0.05$).

Regression coefficients c and a of Eqs. (1) and (2) represent the number of species per m^2, coefficients *z* and *b* show the rate of increase in species richness (Table 3). The correlation coefficient (r^2) is higher for Eq. (2) than for Eq. (1). The same was found for aboveground vegetation of alpine lichen heaths (Onipchenko and Semenova 1995).

Discussion

The seed bank of the lichen heath contained relatively high number of species. A majority of species occurring in this community appear to have at least a small seed reserve. Very few species of alpine lichen heaths are known as not persisting in seed banks (e.g. *Antennaria dioica*). Even a seedling of *Vaccinium vitis-idaea* was found in the field germination experiment (Semenova and Onipchenko 1991, 1994), whereas we did not find flowers of this species in this community during 15 years of observations.

Such species diversity of buried seeds contrasts with data obtained for different tundra communities where seed bank diversity was found to be much lower, ranging from 0 to 13 taxa (Archibold 1984; Morin and Payette 1988; Ebersole 1989; McGraw and Vavrek 1989). On the other hand, the number

	Equation (1)			Equation (2)		
	c	*z*	r^2	*a*	*b*	r^2
Seeds	29.30	0.346	0.960	23.49	3.90	0.978
Seeds+cloves	32.29	0.345	0.957	25.88	4.27	0.973
Aboveground vegetation	19.56	0.233	0.925	24.44	3.61	0.997

Table 3. Coefficients (*c, z, a, b*) of regression and correlation coefficient (r^2) for species-area regressions according to equations (1) and (2).

of taxa found in our study is comparable with data obtained for alpine plant communities in the Central Alps and Caucasus (Ziroyan 1988; Hatt 1991; Diemer and Prock 1993; Semenova and Onipchenko 1994).

The differences in species composition between seed banks sampled in 1982 and 1990 may have several explanations: (1) The species are absent in the samples by chance. It is especially probable for species with low seed density in the seed bank. (2) The differences result from year-to-year differences in seed production, seed viability, and seed storage in soil during the years before sampling. (3) The differences are due to spatial distribution of established plants in the plant community - the total sampling area in 1990 (0.5 m^2) was too small to reveal the total species composition, in spite of the big amount of samples.

Euphrasia ossica is a special case of such distribution. It was not found at all in the soil sampled in 1982. At the same time, it was the most numerous species which was found in 92% plots sampled in 1990. The seedlings of this species also emerged during the field experiment, but they were many fewer. *Euphrasia ossica* is very small annual hemiparasitic plant with ballistically dispersed seeds. Thus, its seeds can not fall far from the mother plant. The spatial distribution of *E. ossica* is rather uneven. A patch of this species could occur at the sampling plot. This may be a reason why we found such a big amount of *E. ossica* in our samples. Differences in seed production could cause the observed differences between 1982- and 1990-year samples as well; however, we should take into account that seeds of this species can remain germinable quite a long time (for instance, seedlings of *E. ossica* emerged during all three years of germination).

In most seed bank studies no attempt is made to determine whether or not sampling was sufficient (Rabotnov 1958, 1982; Roberts 1981). The simple cumulative curve (Fig. 1) shows that ten to twenty samples are enough to reveal most of the species persisting in the seed bank of the alpine lichen heath. This corresponds to the findings of Forcella (1984) for a pasture in the south-eastern Australia and Gross (1990) for an annually ploughed field in Michigan, U.S.A.

Contrary to common opinion that the floristic richness of a seed bank is considerably less then that of the corresponding plant community, these values were similar in the lichen heath at the same plot sizes. This fact can be commented upon as follows.

Species of alpine lichen heaths grow in quite stressful and unpredictable environment where the seed reserve may be of great importance for the maintenance of sexually reproductive species (Urbanska and Schütz 1986). Nevertheless, we always can find a few species in aboveground vegetation which are not known to persist in seed banks. We also can find species which do not produce seeds in such conditions. Therefore, we should expect the seed pool to be poorer. On the other hand, some mechanisms limiting a number of coexisting species in aboveground vegetation (e.g. competition) hardly play a role in a buried seed community. A dormant seed pool can include species from surrounding vegetation. These may increase species diversity, especially on small scale. However, to determine the total species composition of the seed bank we must investigate larger areas. It does not mean that the sample size must be larger or the sample number must be more. The sampling technique can be improved by subsampling several large units with very small subunits, as it was proposed by Bigwood and Inouye (1988).

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