Acta Botanica Hungarica 45 (1–2), pp. 139–151, 2003

CHANGES IN THE SPATIAL PATTERN OF THE SEED BANK IN A SEMIARID SANDY GRASSLAND

G. KEMÉNY, Z. NAGY and Z. TUBA

Dept. Botany and Plant Physiology, Fac. Agricult. Environm. Sci.
Szent István University
H–2103 Gödöllő, Páter K. út 1, Hungary
E-mail: kemenyg@mail.orfk.b-m.hu

(Received 29 January 2003)

The survey was carried out on the seed bank of several patches of an open, semiarid sandy grassland (*Festucetum vaginatae* Rapaics ex Soó 1929 (Borhidi 1996)). We chose four, approximately 20 m × 20 m large, adjacent patches, different in their species composition and total cover. Soil samples were taken in early spring and at the end of summer, in two consecutive years. We determined the seed bank of the samples with the seedling emergence method. The fact that we found the seeds of only two species that were not present in the vegetation indicates the isolated and without artificial disturbed state of the grassland. The vegetation and the seed bank of the patches showed a low degree of similarity in the same period, while the composition of the spring aspect reflected clearly in the seed bank of late summer in all four patches. Results showed that mosaic-like appearance is not only characteristic of the vegetation, but also the seed bank of the soil. Differentiation of the seed bank manifested mostly after the period of seed-fall, at the end of summer, while in early spring it was less expressed. On the basis of the differentiation of the seed bank we can conclude that not the dispersion of seeds, but natural vicinity of mother plants was decisive in forming the spatial variation of the seed bank.

Key words: mosaic structure, seed bank, semiarid sandy grassland, spatial pattern

INTRODUCTION

Mosaic structure of the vegetation is characteristic of arid and semiarid areas. The view of the landscape is composed of the mosaic-like structure of uncovered and covered patches. Significant differences can be shown in the seed amount and dynamics of open and covered patches that can be attributed to the presence or absence of the most productive, generally annual species (Nelson and Chew 1977, Kemp 1989, Ghermandi 1997, Baptista and Shumway 1998). It has been observed that the amount of seeds is lower in less covered patches than in those covered by shrubs or other perennials (Reichman 1984, Aguiar and Sala 1997). This phenomenon's primary cause is the seed dispersion into the immediate vicinity of mother plants, not excluding the dispersion by wind and animals (Pulliam and Brand 1975, Bullock 1976, Nelson and

Chew 1977, Reichman 1979, Baptista and Shumway 1998). Most of the annual species of sandy areas do not have a special apparatus for dispersion. Consequently, the principal factor in formation of the seed pattern strongly depends on the weight of the seed (Symonides 1987) and more than 70% of the seeds are in the 5–10 cm vicinity of the mother plant (Harper 1977). In case of several grass species Rabinowitz and Rapp (1981) showed within laboratory circumstances that seed dispersal by the wind was in the range of 15 to 50 cm. This can be a reason for the difference showed in the seed amount of patches, and the aggregated dispersion of seeds at a very small scale. A study carried out in the Sonoran desert in Arizona by Reichman (1984) showed, that micro reliefs (e.g. ravines, wind-furrows, natural dips, etc.) of the ground can cause the local accumulation of the seeds increasing this way the difference between the seed banks of the patches. Also clumps of grass can collect floating seeds (Bertiller 1998).

The association selected for the examination (*Festucetum vaginatae* Rapaics ex Soó 1929 (Borhidi 1996)) is situated in the central part of Hungary, between the Danube and Tisza rivers. The association is a mosaic of patches with a diameter of 10–40 metres of stands in different states of vegetation dynamics and succession. Our information on the seed bank of the grassland is rather sparse (Kincsek 1985, Halassy 2001).

Our work examined firstly the similarity of the seed banks of the adjacent, but structurally different patches of approximately 20 m × 20 m to the vegetation.

Supposing on the one hand, a limited seed-dispersion we raised as a hypothesis that seed banks of structurally different patches can be distinguished easily. On the other hand, although due to the high number of ephemeral species the existence of a general seed bank was also supposed, presumably leading to difficulties in distinguishing the seed banks of structurally different patches. Our assumptions were tested at the end of summer after the seed-fall of ephemerals and most perennials, and in early spring, in the time of the exhaustion of the seed bank (Kemény 2002) during two vegetation periods.

MATERIALS AND METHODS

The sandy grassland (*Festucetum vaginatae* Rapaics ex Soó 1929 (Borhidi 1996)) is an association widespread in the Danube-basin developed on a loose, calciferous sandy soil with semiarid features due to water shortage periods and also due to edaphic reasons (Zólyomi 1958, Fekete *et al*. 1988, 1995). The study area is situated 25 km west of Kecskemét (Kiskunság National Park, near Fülöpháza). The annual mean temperature is 10.5 °C, and the annual mean precipitation is about 550 mm, with two maxima (in May and November). The vegetation cover is 20 to 80% at highest and the total number of species is low (50 to 60).

We have chosen patches for the examinations significantly differing in their phytosociology (Kemény *et al*. 2001). The size of the patches was defined on the basis of the spatial changes in micro-reliefs.

The examined stands were (Fig. 1): Patch I: open patch situated on the top of a hillock, dominated by *Festuca vaginata, Euphorbia seguieriana, Silene otites* with a total cover of 30–40%. Patch II: a patch situated on the slope of a hillock, more open than the previous patch, dominated by *Festuca vaginata* tussocks and *Silene otites* individuals with a basal diameter of 20 to 40 cm in which other species were present only dispersedly. The vegetation cover is 20–30%. Patch III: a patch located in a hillock dip, dominated by *Festuca vaginata* and *Stipa borysthenica*. Some other grasses e.g. *Bothriochloa ischaemum, Cleistogenes serotina, Poa bulbosa* were also present with higher cover values. The cover was about 60–70% out of which 10–15% were given by moss cushion and lichen thalli. Patch IV: a patch situated on the top of a hillock, dominated by *Stipa borysthenica* and to a lesser extent by *Festuca vaginata*. The cover by a few peren-

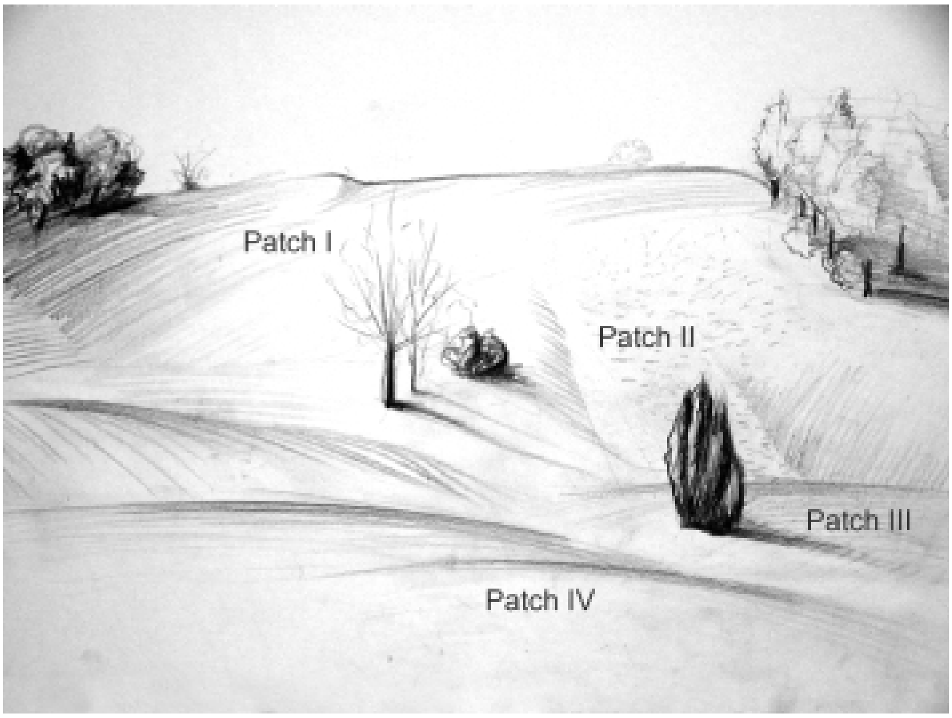

Fig. 1. Schematic drawing of the four patches of the semiarid sandy grassland

nial species (*Fumana procumbens, Poa bulbosa, Cleistogenes serotina*) was also considerable. The vegetation cover is 60–70%. Detailed coenological description of the patches has already been reported (Kemény *et al*. 2001).

For the seed bank examinations an area of 20 m × 20 m was selected in each patch from which 20 samples were taken to 5 cm depth in August 1992, March and August 1993, and March 1994. The total surface area of the samples was 0.76 m^2 per patch. The soil samples were air-dried at room temperature and kept at a cool place for one month. Vegetative plant parts were removed from the samples by sieving. The cores were transferred to a plant growth chamber (14 h day length, 300 µmol/m^2/s light intensity, 23/15 °C day/night temperatures) and spread in 3 cm layers on trays. Seedlings were identified, counted and removed after four successive germination periods in five months by mixing and spreading the soil again after each counting procedure (Thompson *et al*. 1997). No new individuals have been detected in the 40 days after the fourth counting procedure. Species were identified after Csapody (1968) and using germinated seeds of species collected in the area. Species nomenclature follows Horváth *et al*. (1995).

The composition of the vegetation and that of the soil seed bank were compared by the Sørensen's similarity index (Greig-Smith 1983). Classification of soil samples were done by using the SYN-TAX programs (Podani 1993). Distances were calculated by using the Sørensen-index for binary data, for clustering the average-link method was used.

RESULTS

We found 59 species in the four mosaic patches with different coenological structures. Seeds of 39 species emerged from the soil samples at least one occasion. (19 (76%) from the 25 annual species, and 20 (59%) from the 34 perennial species.) Only two species were found (*Chenopodium album,* and *Hieracium* sp.) to appear in the seed bank of the soil, but not in the above ground vegetation.

We examined the similarity of the composition of the vegetation and the seed bank in the patches with the Sørensen-index. We found that in the same period (e.g. early spring vegetation – early spring seed bank) there is no strict correlation between the vegetation and the seed bank (Table 1). The autumn seed bank, however – which contains the seeds of ephemeral species and also seeds of frequent perennials – shows a high degree of similarity with early spring vegetation (Table 2). Between the early spring seed bank and autumn vegetation there was no such similarity that can be mostly explained by the absence of seeds of perennial species.

Table 1
Similarity between the composition of the seed bank and above ground vegetation (Sørensen-index)

Sørensen's similarity index	Late summer vegetation *vs* l.s. seed bank (1992)	Early spring vegetation *vs* e.s. seed bank (1993)	Late summer vegetation *vs* l.s. seed bank (1993)	Early spring vegetation *vs* e.s. seed bank (1994)
Patch I	0.38	0.54	0.51	0.42
Patch II	0.44	0.44	0.33	0.37
Patch III	0.55	0.38	0.45	0.38
Patch IV	0.44	0.33	0.48	0.25

In the cluster analysis of the samples taken at the end of the first summer (Aug. 1992) three larger groups were detected (Fig. 2). The first group is formed by samples from Patch I (white square), in the second the samples of Patch III (black triangle) and Patch IV (white circle) and into the third group the samples of Patch II (black rhombus) fall. In the second larger group, a further four units (at y-axis value of 0.65) can be distinguished. Most of the samples of Patch III (black triangle) belong to the first unit. Into the second, third and fourth units, the samples of Patch IV (white circle) fall.

In the cluster analysis of the samples taken at the end of summer of the following year (1993) two larger groups and a unit containing two samples can be observed (Fig. 3). Samples of Patch I (white square) and Patch II (black rhombus) are in the first group. A sharp difference between the two patches cannot be observed now, but on level 0.55 samples of Patch II (black rhombus) separate into smaller units. To the second large group (on level 0.8) the samples of Patch III (black triangle) and Patch IV (white circles) belong. The difference of the few samples from Patch III (black triangle) can be probably attributed to the absence of *Erophila verna*. Also a third group can be seen (on level 0.8) where there are two samples from Patch II (black rhombus). From these

Table 2
Similarity between the composition of the seed bank and above ground vegetation (Sørensen index)

Sørensen's similarity index	Late summer seed bank ('92) *vs* spring veg. (1993)	Early spring seed bank ('93) *vs* autumn veg. (1993)	Late summer seed bank ('93) *vs* spring veg. (1994)	Early spring seed bank ('94) *vs* autumn veg. (1994)
Patch I	0.88	0.80	0.86	0.64
Patch II	0.76	0.48	0.81	0.50
Patch III	0.74	0.38	0.66	0.41
Patch IV	0.63	0.44	0.65	0.39

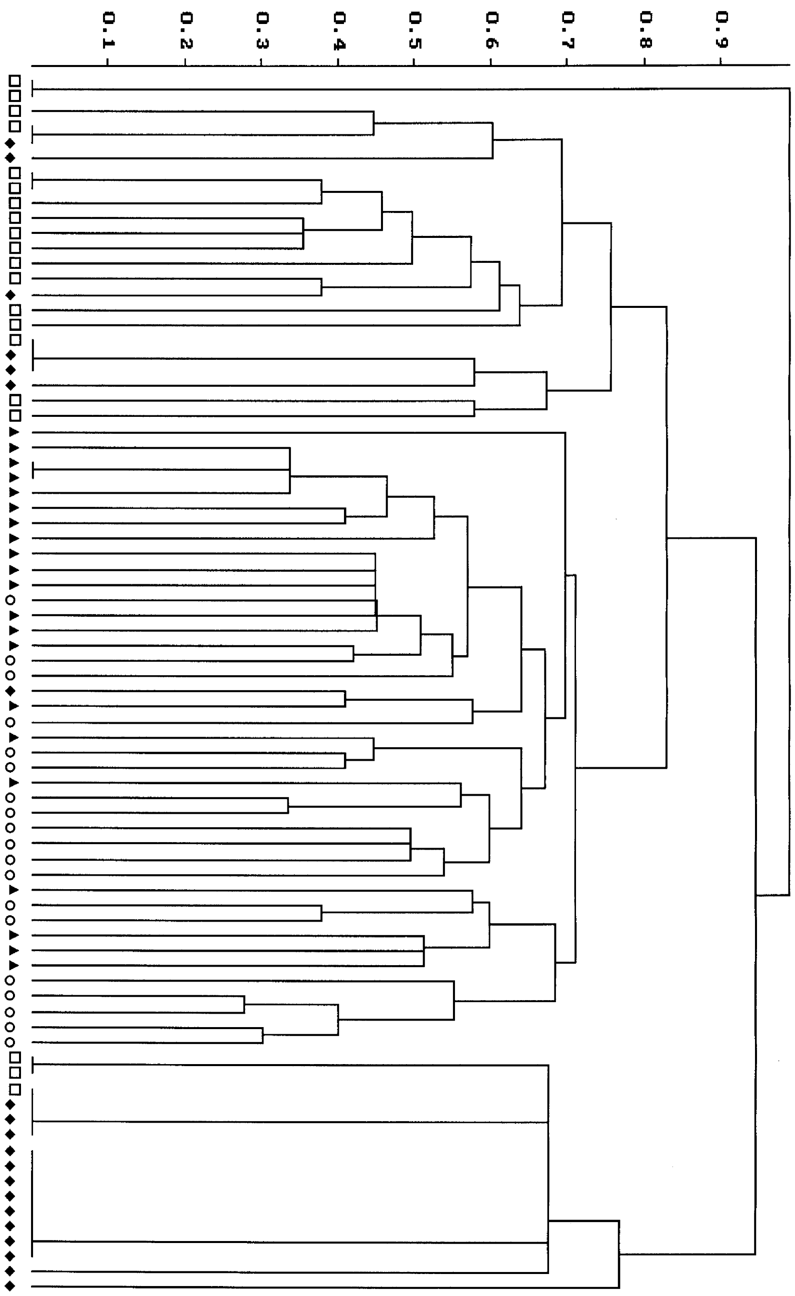

Fig. 2. Classification of soil samples in late summer, in 1992. Distances were calculated by using the Sørensen-index for binary data, for clustering the average-link method was used (Podani 1993). Y axis: fusion dissimilarity. X axis: soil samples of the 4 patches. White square: soil samples of Patch I; Black rhombus: soil samples of Patch II; Black triangles: soil samples of Patch III; White circle: soil samples of Patch IV

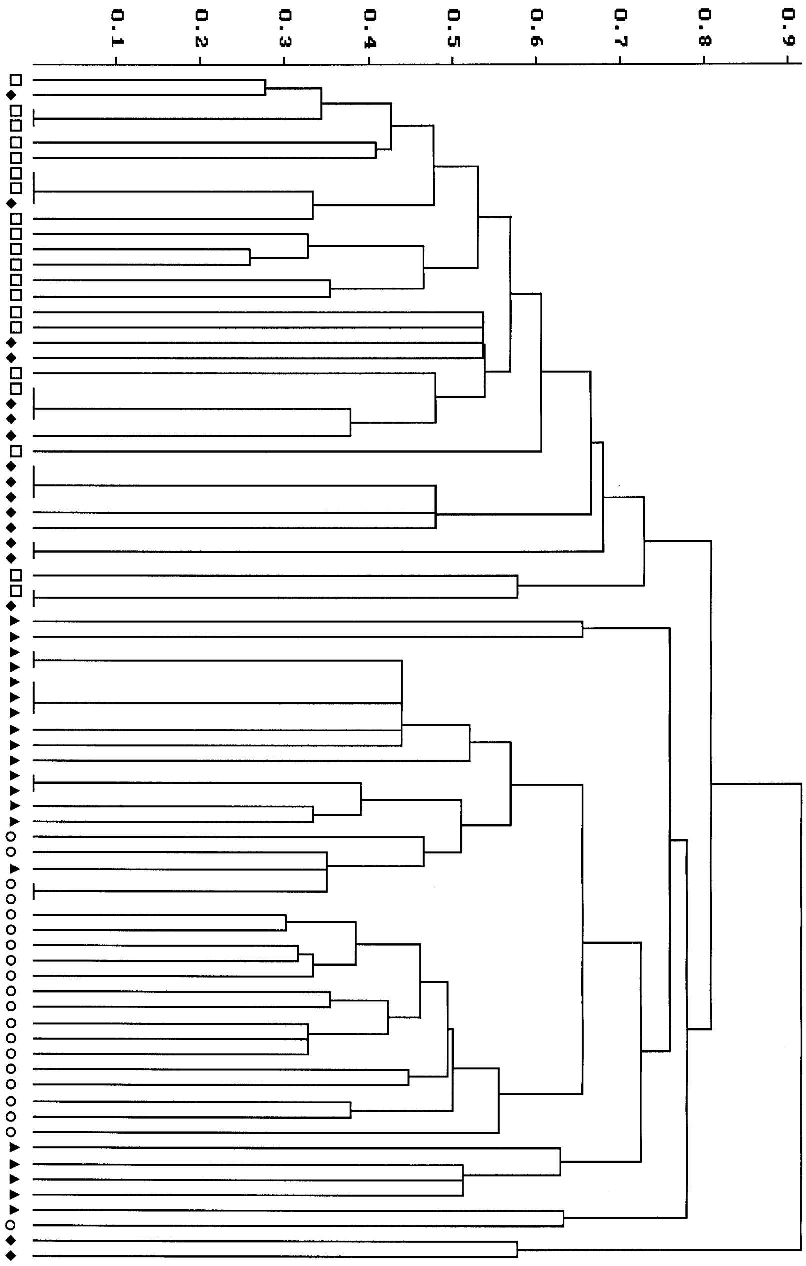

Fig. 3. Classification of soil samples in late summer, in 1993. Distances were calculated by using the Sørensen-index for binary data, for clustering the average-link method was used (Podani 1993). Y axis: fusion dissimilarity. X axis: soil samples of the 4 patches. White square: soil samples of Patch I; Black rhombus: soil samples of Patch II; Black triangles: soil samples of Patch III; White circle: soil samples of Patch IV

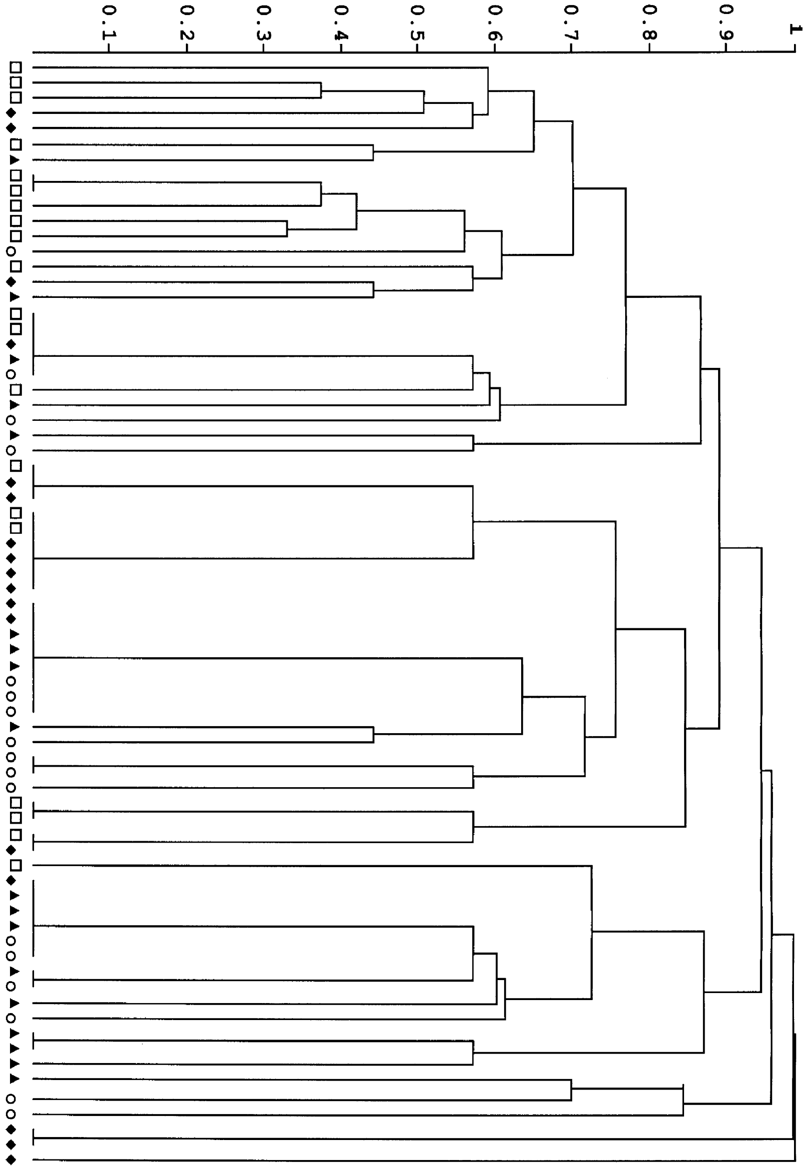

Fig. 4. Classification of soil samples in early spring, in 1993. Distances were calculated by using the Sørensen-index for binary data, for clustering the average-link method was used (Podani 1993). Y axis: fusion dissimilarity. X axis: soil samples of the 4 patches. White square: soil samples of Patch I; Black rhombus: soil samples of Patch II; Black triangles: soil samples of Patch III; White circle: soil samples of Patch IV

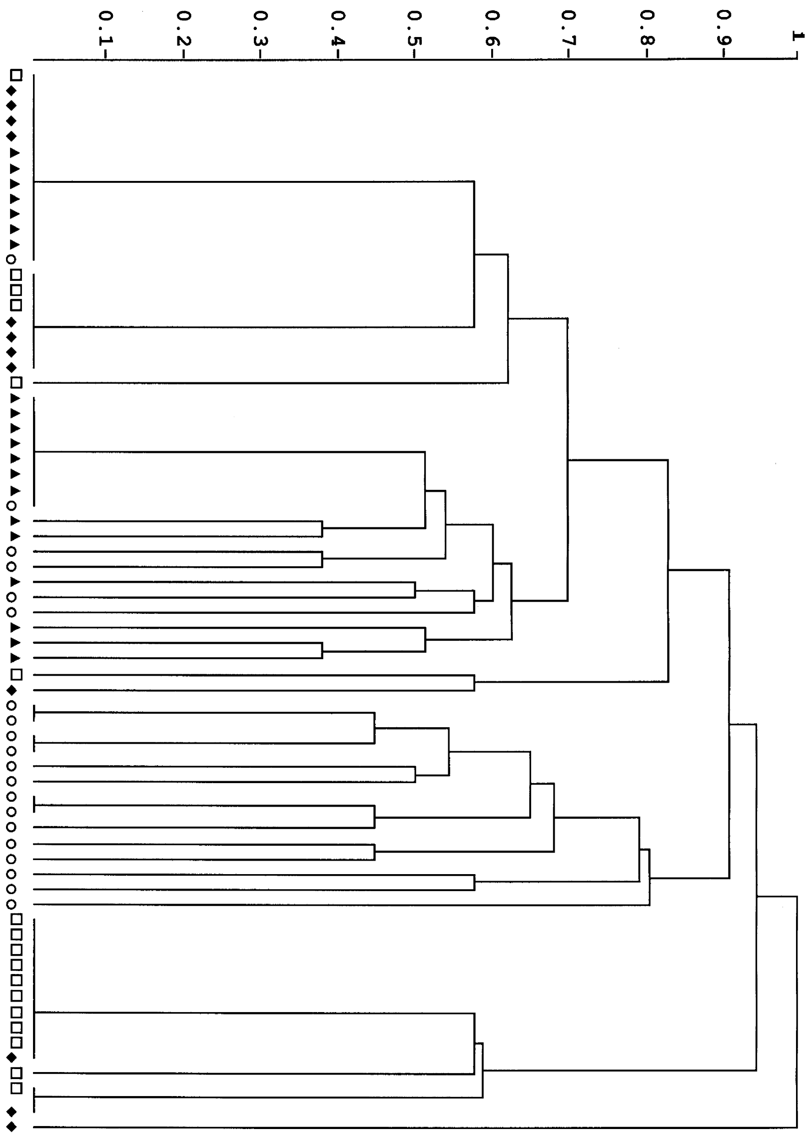

Fig. 5. Classification of soil samples in early spring, in 1994. Distances were calculated by using the Sørensen-index for binary data, for clustering the average-link method was used (Podani 1993). Y axis: fusion dissimilarity. X axis: soil samples of the 4 patches. White square: soil samples of Patch I; Black rhombus: soil samples of Patch II; Black triangles: soil samples of Patch III; White circle: soil samples of Patch IV

samples two dominant species (*Silene otites*, and *Erophila verna)* of the patch were absent.

The groups segregating in the cluster analysis of samples taken on the first date of early spring (March 1993) cannot be linked with the patches (Fig. 4).

In the analysis of spring samples of the following year (March 1994) (Fig. 5) three large groups and a unit containing a unique sample segregate (on level 0.9). Samples of Patch II (black rhombus) and Patch III (black triangle) belong to the first large group, samples of Patch IV (white circle) belong to the second and most of the samples from Patch I (white square) fall into the third group.

DISCUSSION

During the two vegetation periods we found only seeds of two species (*Hieracium* sp., and *Chenopodium album*) that were not present in the vegetation. This shows the isolated, intact state of the grassland, without artificial disturbance. It is also justified by the results from a study by Halassy (2001), who found several – mainly weed – species present only in the seed bank when the grassland was previously exposed to artificial disturbance. It is a general observation for grasslands that in relatively undisturbed, old grasslands the number of seeds is fairly low and there is no close connection between the composition of species above the ground and that in the soil (Hayashi and Numata 1971, Thompson and Grime 1979, Bigwood and Inouye 1988, Bakker 1989, Coffin and Laurenroth 1989, Perez *et al*. 1998). A considerable similarity was shown in a desert short-grass community by Henderson *et al*. (1988). There is not a general consensus as at what time the comparison of the composition of the seed bank and the vegetation should be made. We have not found high correlation between the vegetation and the actual seed bank of the given vegetation period. The pool of viable seeds and actual vegetation are dynamically – temporally – linked. Based on the late summer seed bank the vegetation of early spring could be predicted, and we have found a high degree of similarity. In this period of the year, spring ephemeral species can be already found in the seed bank (Kárpáti and Kárpáti 1954). In addition, most of the perennial species can be found in the late summer seed bank. According to Moore (1980), this close correlation in case of plant communities under extreme environmental conditions can exist because the repeated disturbances limit the composition of the association to early succession species securing the survival of the population by an extensive seed production and a persistent seed bank. The *Festucetum vaginatae* association, showing semiarid features, is characterised by a frequent and unpredictable environmental disturbance regime (Zólyomi 1958, Fekete *et al*. 1995), and therefore the proportion of annual species is high, approximately 40%. The seed bank in early spring shows a lower degree of similarity with the autumn vegetation, as the seed bank becomes exhausted by this time, and contains ephemeral species predominantly (Kemény 2002), and these are absent in the autumn vegetation.

Studies carried out on arid and semiarid grasslands firstly examined the differences in the seed amount of patch types, and viewed the mosaic character of the seed bank also from quantitative aspects (Nelson and Chew 1977, Reichman 1979, 1984). In the examined grassland the late summer seed bank of physiognomically different, but adjacent patches segregated sharply on the basis of the composition in both years, in spite of 49% of the species is wind dispersed (Csontos *et al*. 2002). This result also justifies the earlier observations reporting on limited seed-dispersion (Harper 1977, Rabinowitz and Rapp 1981, Symonides 1987). In spring, when the seed bank becomes poorer, the segregation of the seed banks of the patches is less expressed. This pattern of temporal variability of the seed bank show that majority of seeds have a short-term persistence in the soil (Thompson and Grime 1979).

CONCLUSION

The results show that both of initial assumptions were right, when considering the temporal dynamics of the seed bank. In late summer, when seed-fall of most ephemeral and perennial species have already terminated, seed banks of the patches were different. In early spring, when the seed bank is poorer, the “borders” of the seed banks of the patches merges.

*

Acknowledgements – The authors wish to thank dr László Körmöczi for revising on previous version of the manuscript. The present study was supported by the Hungarian Scientific Research Fund (OTKA F 013226, T 1545, T 22723) and MEGARICH (EU) granted to Z. Tuba.

REFERENCES

Aguiar, M. R. and Sala, O. E. (1997): Seed distribution constrains the dynamics of the Patagonian steppe. – *Ecology* **78**: 93–100.
Bakker, J. P. (1989): Nature management by grazing and cutting. – *Geobotany* **14**.
Baptista, T. L. and Shumway, S. W. (1998): A comparison of the seed banks of sand dunes with different disturbance histories on Cape Cod National Seashore. – *Rhodora* **100** (903): 298–313.

Bertiller, M. B. (1998): Spatial patterns of the germinable soil seed bank in northern Patagonia. – *Seed Sci. Res.* **8**: 39–45.

Bigwood, D. W. and Inouye, D. W. (1988): Spatial pattern analysis of seed banks: an improved method and optimized sampling. – *Ecology* **69**: 497–507.

Borhidi, A. (1996): *An annotated checklist of the Hungarian plant communities, I. The non-forest vegetation*. – In: Borhidi, A. (ed.): Critical revision of the Hungarian plant communities. Janus Pannonius University, Pécs, pp. 43–94.

Bullock, S. H. (1976): Comparison of the distribution of seed and parent-plant populations. – *Southw. Naturalist* **21**: 383–389.

Coffin, D. P. and Lauenroth, W. K. (1989): Spatial and temporal variation in the seed bank of a semiarid grassland. – *Am. J. Bot.* **76**(1): 53–58.

Csapody, V. (1968): *Keimlingsbestimmungsbuch der Dicotyledonen*. – Akadémiai Kiadó, Budapest.

Csontos, P., Tamás, J. and Tobisch, T. (2002): *A magyar flóra magterjesztési-mód adatbázisának bemutatása elemzési példákkal: a szociális magatartási típusok értékelése. A 70. éves Borhidi Attila köszöntése*. (Presentation of the database on the methods of seed-dispersion in the Hungarian flora, with analytical examples: evaluation of social behaviour types). – In: Salamonné Albert, É. (ed.): Magyar Botanikai Kutatások az ezredfordulón. Pécs, pp. 557–571.

Fekete, G., Tuba, Z. and Melkó, E. (1988): Background processes at the population level during succession in grasslands on sand. – *Vegetatio* **77**: 33–41.

Fekete, G., Tuba, Z. and Précsényi, I. (1995): Application of three approaches to evaluate abundance and rarity in a sand grassland community. – *Coenoses* **10**: 29–38.

Ghermandi, L. (1997): Sesonal patterns in the seed bank of a grassland in north-western Patagonia. – *J. Arid Envi.* **35**: 215–224.

Greig-Smith, P. (1983): *Quantitative plant ecology*. – Blackwell Scientific Publications, Oxford, UK.

Halassy, M. (2001): Possible role of the seed bank in the restoration of open sand grassland in old fields. – *Community Ecol.* **2**(1): 101–108.

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

Hayashi, I. and Numata, M. (1971): Viable buried-seed population in the Miscanthus- and Zoysia type grasslands in Japan. Ecological studies on the buried-seed population in the soil related to plant succession VI. – *Jap. J. Ecol.* **20**(6): 243–252.

Henderson, C. B., Petersen, K. E. and Redak, R. A. (1988): Spatial and temporal patterns in the seed bank and vegetation of a desert grassland community. – *J. Ecol.* **76**: 717–728.

Horváth, F., Dobolyi, Z. K., Morschauser, T., Lőkös, L., Karas, L. and Szerdahelyi, T. (1995): *Flóra adatbázis 1.2. Taxon-lista és attribútum-állomány*. (Flora database 1.2. List of taxa and attributes.) – Vácrátót, Hungary.

Kárpáti, I. and Kárpáti, V. (1954): The aspects of the calciphilous turf (Festucetum vaginatae danubialae) in the environs of Vácrátót in 1952. – *Acta Bot. Acad. Sci. Hung.* **1**: 129–159.

Kemény, G. (2002): Talajmagkészlet vizsgálatok egy mészkedvelő homokpusztagyepben. (Soil seed bank study in a semiarid sandy grassland in Hungary.) – PhD thesis, SzIE, Gödöllő, Hungary.

Kemény, G., Penksza, K., Nagy, Z. and Tuba, Z. (2001): Coenological data on temperate semidesert sandy grasslands in Hungary. – *Acta Bot. Hung.* **43**(3–4): 333–348.

Kemp, P. R. (1989): *Seed banks and vegetation processes in deserts*. – In: Leck, M. A., Parker, V. T. and Simpson, R. L. (eds): Ecology of soil seeds banks. – Academic Press INC, pp. 257–281.

Kincsek, I. (1985): Magdiszperzió vizsgálata homoki gyepcönózisokban. (Examination of seed dispersal in sandy grassland.) – Juhász Gyula Tan. Főisk. Tud. Közlem. **1985**: 41–53.

Moore, P. D. (1980): Soil seed bank. – *Nature* **284**: 123–124.

Nelson, J. F. and Chew, R. M. (1977): Factors affecting seed reserves in the soil of a Nojave Desert ecosystem, Rock Valley, Nye Country, Nevada. – *Am. Midl. Natur*. **97**: 300–320.

Perez, C. J., Waller, S. S., Moser, L. W., Stubbendieck, J. L. and Steuter, A. A. (1998): Seedbank characteristics of a Nebraska sandhills prairie. – *J. Range Manag*. **51**(1): 55–62.

Podani, J. (1993): Syn-tax 5.0: Computer programs for multivariate data analysis in ecology and systematics. – *Abstracta Bot*. **17**: 289–302.

Pulliam, H. R. and Brand, M. R. (1975): The production and utilization of seeds in planins grasslands of southeastern Arizona. – *Ecology* **56**: 1158–1166.

Rabinowitz, D. and Rapp, J. K. (1981): Dispersal abilities of seven sparse and common grasses from a Missouri prairie. – *Am. J. Bot*. **68**: 616–624.

Reichman, O. J. (1979): Desert granivore foraging and its impact on seed densities and distributions. – *Ecology* **60**: 1085–1092.

Reichman, O. J. (1984): Spatial and temporal variation of seed distributions in Sonoran Desert soils. – *J. Biogeog*. **11**: 1–11.

Symonides, E. (1987): *Population dynamics of annual plants*. – In: Davy, A. J., Hutchings, M. J. and Watkinson, A. R. (eds): Plant population ecology. – Blackwell Scientific Publication, Oxford, pp. 221–248.

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

Thompson, K., Bakker, J. P. and Bekker, R. M. (1997): *The soil seed banks of North West Europe: methodology, density and longevity*. – Cambridge University Press, Cambridge.

Zólyomi, B. (1958): *Budapest és környékének természetes növénytakarója*. (The natural vegetation of Budapest and its surroundings.) – In: Pécsi, M. (ed.): Budapest természeti képe. – Akadémiai Kiadó, Budapest, pp. 511–642.