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Viable plant diaspores in the guts of earthworms

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SUMMARY

The presence of viable diaspores in the guts of free living earthworms was investigated. The earthworms were collected in two chalk grasslands, a fertilized pasture and a wood, all in South Limburg, The Netherlands. Phanerogams as well as ferns emerged in low numbers. Bryophytes (eight species) emerged frequently in some of the samples. The plants originated probably mainly from spores. The low presence of bryophyte species regenerating from tubers suggests a high mortality of vegetative diaspores in the digestive canal of the earthworms.

Key-words: bryophytes, diaspore bank, earthworms, ferns, seed bank.

INTRODUCTION

Despite much research on all stages of the population biology of plant species (Harper 1977) it is still largely unknown to what extent the persistent seed bank (cf. Thompson & Grime 1979) is involved in the yearly recruitment of seedlings. Probably most buried seeds will die in the soil (Sagar & Mortimer 1976). The same is probably true for the buried diaspores of ferns and bryophytes (During & Ter Horst 1983; During 1987).

Light transmission into the soil is a few centimetres at most (Bliss & Smith 1985) and germination of the seeds of plant species is sometimes light-dependent (Bewley & Black 1982). Hence, light-sensitive buried seeds only germinate when transported to the upper soil layers again. This may happen by, for example, erosion, rain, frost, trampling of grazing animals, or by accidental disturbance of the soil. In many ecosystems animal activity in the soil will be the most important factor for downward and upward transport of seeds. Besides the activity of moles, voles or ants also the activities of earthworms may be important in this respect.

Since Darwin recognized the capacity of earthworms to transport diaspores (see Satchell 1983), this has been investigated in several ways. Grant (1983) showed transport of seeds by analysis both of gut contents and of worm casts. The presence of diaspores of bryophytes in worm casts has been reported, too (During *et al.* 1987). Transport of seeds occurs in an upward as well as in a downward direction (Hurka & Haase 1982). In general, the seeds passing the digestive canal of the earthworms do not lose viability (McRill & Sagar 1973; Hurka & Haase 1982; Grant 1983). The intake of seeds mostly occurs passively but McRill & Sagar (1973) have demonstrated that active and selective intake also occurs.

In this paper we report the presence of viable diaspores of phanerogams, ferns and bryophytes in the guts of earthworms collected in several habitats. Special attention is given to the ability of vegetative diaspores of bryophytes to withstand the scarification, gizzard contraction and enzyme activity in the guts of earthworms.

The results are compared with data on the presence of diaspores of bryophytes and ferns in soil samples from the same habitats.

MATERIAL AND METHODS

Earthworms were collected on 12th August 1987 at five sites: the chalk grasslands Gerendal and Wrakelberg (open microsites), and a wood and two sites in a fertilized pasture, both close to the Gerendal site, all in South Limburg (The Netherlands). The vegetation of the chalk grasslands, both nature reserves, belongs to the Mesobromion (Willems 1982). Details about these sites can be found in During & Ter Horst (1983). The grazed pasture can be classified as a Poo–Lolietum vegetation, the wood as a Querco–Carpinetum vegetation.

The earthworms, 25–30 at each site, were mainly *Allobophora caliginosa* Savigny and some individuals of *A. chlorotica* Savigny and *Lumbricus terrestris* L. Their egested gut content was collected and spread out on sterilized river sand in boxes and kept at a thermoperiod of each 12 h at 20/12°C. The light intensity in the growth cabinet was *c.* 200 $\mu mol\ m^{-2}\ s^{-1}\ nm^{-1}$ PAR. The emerging seedlings, prothallia of ferns, and bryophyte plants were estimated for a period of 4 months and identified as far as possible. Within most bryophyte species many gametophytes may originate from one protonema. Hence, the number of diaspores can only be roughly estimated from the number of emerging plants.

Soil samples of *c.* 5 cm from 0–1 cm were collected in the wood on the same day as the earthworms. They were spread out on sterilized river sand in boxes, too, and received the same treatment as mentioned above for the gut contents.

The nomenclature of the bryophytes follows Margadant & During (1982).

RESULTS

Some seeds of phanerogams were recovered only from the guts of the earthworms collected on the pasture (Table 1). Even there, their number was very low and only two species were found: *Lolium perenne* L. and *Stellaria media* (L.) Vill.

Diaspores of ferns proved to be present in all habitats. Only in the wood, however, were they found in some quantities. We were unable to identify the prothallia of the ferns. At least two species were found to be present.

In the gut contents of the worms from the pasture, the number of diaspores of bryophytes was relatively high, although only one species was present in fair amounts, *Pottia/Phascum* spec. This was also the most abundantly emerging bryophyte species in samples from the chalk grasslands (Table 1). Altogether, eight bryophyte species were found in the earthworm samples.

Unfortunately, it is not possible to identify laboratory-cultivated vegetative plants of the genera *Pottia/Phascum* and *Weissia*. In view of the results of earlier diaspore bank studies in the chalk grasslands the most important species are probably *Phascum cuspidatum*, *Pottia davalliana*, *Weissia controversa* and *W. longifolia*.

In the soil samples from the wood *Bryum klinggraeffii* was the most abundant species (Table 1). Most of the fresh shoots of *Eurhynchium hians* in these samples probably originated from stems that were still present in the soil. Some of the emerging species, e.g. *Pottia* spec. and *Weissia* spec., and also *Bryum klinggraeffii*, do not occur in the neighbourhood of the place where the samples were collected.

DISCUSSION

Grant (1983) has found seedlings emerging from the gut contents of *c.* 25% of the earthworms collected in a meadow, which is much more than in our experiments. This is

Table 1. Germination of diaspores from samples of the gut contents of earthworms collected on the Wrakelberg, the chalk grassland, the wood and the pasture (1 and 2) in the Gerendal, all in South Limburg (The Netherlands) on 12th August 1987 and the main bryophyte species in soil samples of the same habitats

	Wrakelberg		Gerendal		Wood		Pasture	
	A*	B†	A	B	A	B	A1	A2
Festuca rubra								4
Stellaria media							1	2
Ferns	+	68	+	68	++	100	+	+
Pottia spec. I (s)	++		++		+	40	+++	+++
Pottia spec. II (s)							+	+
Pottia lanceolata (s)		71						
Pottia spec. (s)		19		24		10		
Weissia spec. I (s)	++				+	30		
Weissia spec. II (s)	+							
Weissia longifolia (s)		90						
Weissia controversa (s)		?						
Anisothecium schreb. (v)		3	++	83	+	70	++	++
Ephemerum recurvifol. (s)	+	10						
Bryum klinggraeffii (v)		100	+	98		100	++	++
Bryum rubens (v)		81		94		90		++
Barbula unguiculata		47						
Barbula fallax (s)		47		6				
Fissidens taxifolius (sv)		92		71		70		
Brachythecium rutab. (v)		15		51				
Plagiomnium rostratum (v)		3		62				
Barbula convoluta (s)				92				
Eurhynchium hians (v)				43		80		
Eurh. cf. *striatum* (v)						50		
Eurhynchium praelongum						10		
Bryum spec. (?)						30		
Tortula subulata						20		
Amblystegium serpens (v)						20		
Leptobryum pyriforme (s)						10		

*A = species emerging from diaspores in gut contents; + = 1–3 exx, + + = 4–25; + + + = > 25 exx.

†B = frequency (%) of the most common emerging bryophyte species in soil samples of the Wrakelberg (only open microsites) and the Gerendal chalk grassland (data of both slopes from During & Ter Horst 1983), and of all emerging bryophyte species in soil samples of the wood.

Based on field observations on the occurrence of sporophytes and/or vegetative propagules, we indicate for each species whether regeneration mainly occurs from spores (s) or from vegetative propagules (v).

probably due to a difference in the seed content of the soil occurring in these vegetations. Also, the seeds of many species occurring in the chalk grasslands need a chilling period before germination is possible (Grime *et al.* 1981). Hence, these seeds did not germinate in our experiments. Close inspection of the egested soil revealed no additional seeds, however.

The absence of seeds in the gut contents of the worms of the wood was not surprising since its buried seed bank is probably very small because almost only perennial species with poor seed production occur. Of course, the small amount of seeds in the samples will also be due to the obvious relationship between the size of diaspores in the guts and the earthworm size.

In most diaspore bank investigations many spores of ferns are present (During & Ter Horst 1983; Leck & Simpson 1987), as was also recorded in our investigations. Their relatively high numbers in the samples of the wood reflects, probably, the large abundance of ferns in this habitat. Generally, most bryophytes present in the diaspore bank of chalk grasslands or woodlands are presumed to originate from vegetative diaspores, whereas *Pottia* spec. and *Weissia* spec., the most abundant species in the worm samples, are presumed to originate from spores (During & Ter Horst 1983; During *et al.* 1987).

This can be illustrated by the behaviour of *Bryum rubens*. In research on the diaspore bank of bryophytes in chalk grasslands (Table 1; unpublished data), *Bryum rubens* is found to be one of the most common species, even though the species occurs only very sparsely above ground. *B. rubens* never produces sporophytes in these ecosystems and reproduces exclusively via tubers in the soil. In our worm samples *B. rubens* was very rare, which suggests that vegetative diaspores suffer high mortality in the guts of earthworms, probably due to the mechanical and chemical processes.

Grant (1983) has suggested that worm activity is an important factor in plant population dynamics, much more so than the activity of rabbits, moles etc. In chalk grasslands, however, the number of worms seems to be much lower than in the pasture and also the number of wormcasts in the field is low (personal observation). Perhaps even more important is that earthworms are not able to transport large seeds and that vegetative diaspores suffer high mortality when transported by earthworms.

Probably, worm activities provide opportunities for some species to re-establish after an above ground 'catastrophe'. Also, recruitment after their transport of diaspores may contribute to the genetic diversity of the populations involved. In chalk grasslands, however, and probably in most ecosystems, their activities will never be able to buffer large fluctuations in the population dynamics, or to maintain plant species' diversity in the aboveground populations.

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