Microarthropods and nutrient transfer from pasture litter

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Summary. The flux of minerals from plant litter to the underlying soil is an important component of the nutrient cycle in grazed pastures. Soil and litter microarthropods can increase the rate at which nutrients are released from pasture litters by between 16 and 50 per cent per year and their presence is responsive to pasture management. Synergistic interactions of microarthropods with microbial decomposers enhance nutrient release and mechanisms for these processes are discussed. Sustaining such biological activity which enhances nutrient cycling is vital to the long-term mineral economy of grazed pastures and could reduce dependence on fertiliser.

Introduction

Different groups of decomposer invertebrates may predominate in the various climatic regions of Australia. Earthworms, protozoa, and nematodes are important decomposers in moist pastures, termites are numerous in the arid zones, while dung beetles and microarthropods are useful in most regions. Microarthropods can be prominent in temperate pastures and they respond strongly to fertilisers and sown pasture species (9). They mainly inhabit the litter layer and top 5 cm of soil. Microarthropods consist of two groups; Collembola (insects) and Acari (mites). Both groups of fauna are ubiquitous in soil and litter, occurring from the Antarctic continent to hot deserts. Although of small size, microarthropods are metabolically very active and are present in large numbers in improved temperate pastures. Their numbers may exceed 100,000/m^2 but an average presence would be 25,000/m^2 (10). High microarthropod numbers are strongly associated with litter of high nutrient content (9), which in turn depends on the presence of pasture species which contain high levels of these minerals. The role of microarthropods in the transfer of phosphorus from the litter of four pasture species will be reported in this paper. This work shows the value of taking all biological processes into account in research on sustainable agriculture.

Methods

Transfer of nutrients from litter of four pasture species, *Poa sieberana, Themeda australis, Phalaris aquatica* and white clover, *Trifolium repens,* was studied under two treatments of microarthropods; litter with a full complement of microarthropods present (control) and litter in which the microarthropod populations had been heavily reduced (by up to 80 per cent) with repeated applications of the insecticide, Methiocarb. The plant species were chosen to represent major litter sources on natural and improved pasture sites at the CSIRO, Pastoral Research Laboratory, Armidale, NSW. New litter of known nutrient content, was enclosed in 1 mm mesh which allowed entry of microarthropods but excluded larger invertebrates such as earthworms. A new meshed system was developed to overcome biases that can arise from the conventional litter bag construction which confines the residue within a meshed envelope, compacting the residue and altering its wetting and drying regime. The sample of new litter was placed on 1 mm mesh attached to a plastic ring frame, 13.5 cm diameter. This was positioned over the existing litter mat . The sample ring was covered with a similar but larger (15 cm diam.) meshed ring which allowed the sample ring to slowly drop down onto the soil surface as the old litter, beneath, decomposed. This arrangement removed the compaction effect and conserved the litter profile beneath the sample. Field measurements of temperature and moisture in confined and unconfined litter indicated that the microenvironment was unaffected by the apparatus (9). Methiocarb had no consistent effects on either the respiratory activity or biovolume of important, non-target decomposer micro-organisms such as litter bacteria and fungi (9).The length of the study was 18 months for clover and two years for *Phalaris, Poa* and *Themeda.* Litter samples were retrieved at specified time intervals, microarthropods were extracted and the litter sample analysed for phosphorus (P), sulphur (S) and nitrogen (N) (12,11,4).

Results and discussion

Nutrient concentrations in new litter at the beginning of the experiment and the ratios of P, S and N to carbon (C) are shown in Table 1. P, S and N can all be limiting for microbial growth and the ratios of C to these macroelements are commonly used to express the potential of organic residues to decompose. The range of values for ratios of C to P, S and N varied from 5 to 8 fold over the four pastures litters (Table 1).

Table 1. Concentration of P, S and N, as percentage of dry matter in new litter, together with the ratios of C to P, S and N of the starting material.

	P (%)	S (%)	N (%)	C:P	C:S	C:N
White clover	0.38	0.29	4.74	140	170	10
Phalaris	0.11	0.12	1.10	470	410	50
Poa	0.07	0.07	0.84	750	710	60
Themeda	0.07	0.06	0.65	750	860	80

The amount of P remaining in the litter from each species during the period of study is shown in Figure 1, with the P present at time zero scaled to 100 per cent. Micro-organisms, especially fungi, can reach into the litter and soil outside the sample in the ring and draw in and accumulate nutrients from this outside source. Hence, the amount of nutrient in the litter sample can increase to levels which are above those in the original sample, particularly if that sample is decomposing Dnly very slowly. Changes in S and N were similar and will be reported elsewhere. Analysis of variance showed that over the study period, significant (P<0.001) differences occurred in amounts of P in litter between microarthropod treatments in all litters. Over time, the P remaining in the sample was lower in control treatments than in the reduced microarthropod treatment. Significant microarthopod effects became apparent from 77 days in clover, 55 days in *Phalaris,* 225 days forPoa and 352 days for *Themeda.* In general, the higher the microarthropod numbers in the litter, the earlier the occurrence of the significant effects. Early in the study period, clover litter had very high populations of microarthropods of over 600,000/m^2 while numbers in *Themeda* were 22,000/m2.

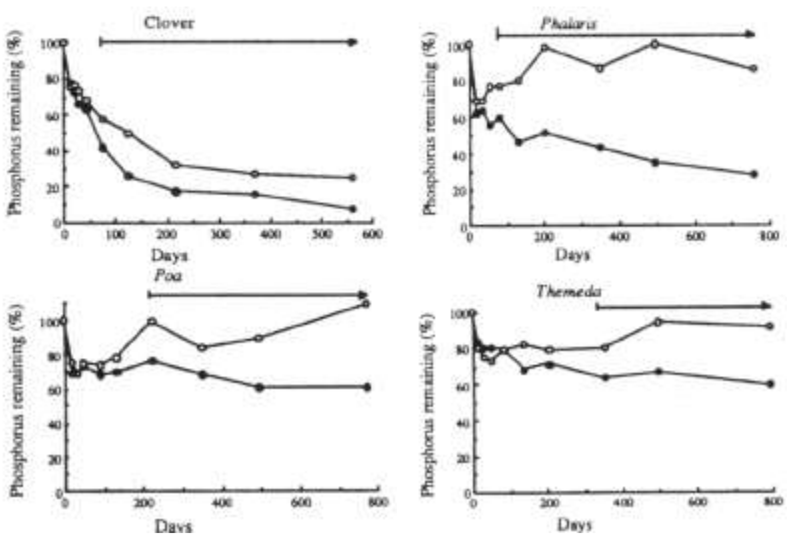

Figure 1. Changes in P in litter samples through time are expressed as a percentage (%) of the weight of P present at time zero (-•- Control; -o- Reduced microarthropods). The arrowed lines indicate where significant (P<0.05) microarthropod effects existed.

Berg and Staaf (5) proposed a conceptual model for the net transfer of minerals from forest litter with reduced numbers of invertebrates. Quality of litter is determined by the ratios of C to a limiting clement (E). Changes in the amount of nutrient in litter during decomposition are shown in Figure 2 for both litter of high and low quality. The net changes for low quality litter (high C:E) comprise three phases. The leaching phase (I) involves a rapid loss of inorganic nutrients during the first few weeks in the field. Phase IT represents a period of accumulation or immobilisation of nutrients where elements may be translocated from the surrounding substrate into the litter sample. This can occur *via* fungal hyphae or when elements are added to litter in particulate throughfall and canopy leachates. Hence, as can be seen in Figure 2, nutrients can increase to levels greater than those in the original litter sample. Nutrients are sequestered by micro-organisms in the litter/microbial substrate with no net release because nutrient levels are limiting for microbial growth. Phase II ends when the C:E ratios falls to the critical level for microbial growth beyond which there will be a net release of nutrients in Phase III. In residues of high quality with a low C:E ratio, elements are present in sufficient amounts and are not limiting to microbial growth, so that net release of elements occurs from the start and there is no accumulation phase. The model was used to interpret time trends in net transfers of P from the pasture litters in the present study.

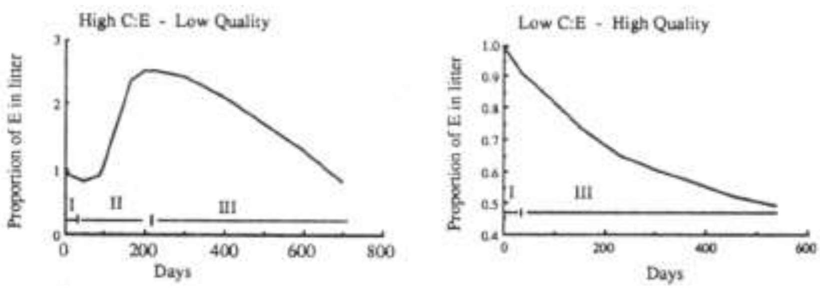

Figure 2. Conceptual model for element (E) transfers, as a proportion of the initial amount, in litter during decomposition presented by Berg and Staaf (5) for low invertebrate presence. Three phases are shown for a residue of low quality with a high C:E ratio and two phases for a high-quality litter with a low C:E ratio.

In the present study, the patterns of nutrient transfer were different in the four litter species and the two microarthropods treatments (Fig. 1). For clover, there was a net release of P from the outset in both faunal treatments. Taking the mineral transfers in the reduced microarthropod treatment of the three grass litters first, *Phalaris* reached a critical C:P ratio of 240 at approximately 472 days before net release of P followed; *Poa* and *Themeda* litter generally remained in the immobilisation phase for P throughout the study. However, when the control treatments were considered, the pattern of mineral transfer was changed significantly with a more rapid release of P in all litters. Thus, the immobilisation period proposed by the Berg and Staaf model, in the absence of invertebrates, was significantly disrupted by the activities of microarthropods in litter of lower quality. Microarthropods had the greatest effect on *Phalaris* litter.

There are various mechanisms by which microarthropods increase nutrient transfers in litter. Among these are fragmentation of litter causing increased leaching and microbial colonisation, dispersal of microbial propagules and stimulation of microbial respiration. Interactions between microarthropods and micro-organisms mainly involve feeding activities of microarthropods as they are often fungivorous and fungi predominate in the litter. Fungi concentrate nutrients during the immobilisation phase of nutrient transfer, and some microarthropods can selectively feed on fungi rather than litter (1) even preferring fungal parts of higher nutritive value, such as spores, to other parts of lower nutritive value such as hyphae (7). Hence, one way of disrupting mineral immobilisation in the litter/microbe complex, is for the microarthropods to selectively graze food of higher nutritive content such as fungi.

Some evidence for selective grazing of microarthropods can be seen in this experiment when a comparison is made between the total weight of P and C lost in the control treatment and that immobilised in the reduced microarthropods treatment. For example, in *Phalaris,* an additional 2.8 mg of P and 166 mg of C is lost per sample in the control treatment. This represents a C:P ratio of 60 . Fungi growing on a soil extract medium contain 0.7 per cent P with a similar C:P ratio (3). Thus it would appear that microarthropods grazing *Phalaris* litter are highly selective and could be mainly fungivorous. Similar calculations for the *Poa* and *Themeda* litters support this conclusion. However, in the high quality clover litter, with microarthropods present in large numbers, a C:P ratio of 200 was calculated for the additional elements removed by the animals. In this case they were probably eating a mixture of clover litter and fungi. Microarthropods increased mineral release from 16 to 50 per cent per year with all litters showing responses related to the total numbers of microarthropods present. Greater rates of mineral release were recorded for clover and *Phalaris* than for the native grasses. It is likely that selective grazing of fungi by microarthropods is a major mechanism leading to the faster release rates of P.

Large invertebrates, earthworms and dung beetles, have engaged the interest of production scientists. However the smaller, more abundant and metabolically active fauna, the microarthropods, soil nematodes and protozoa, have been virtually ignored, despite established functional roles in nutrient cycling (2). In planning ahead we should recognise that the loss of biological function, as well as physical structure, in a pasture soil could well be just as an important, although a less visible source, of production decline (8). The recommendations for future research made by the Ecologically Sustainable Development Working Group on agriculture emphasised (6) the need for interdisciplinary research if we are to develop a sustainable agriculture.

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References

1. Aitchison, C.W. 1983. Pedobiologia 25, 27-36.

2. Anderson, R.V., Coleman, D.C. and Cole, C.V. 1981. In: Terrestrial Nitrogen Cycles. (Eds F.E. Clark and T. Rosswall) Ecol. Bull. (Stockholm) 33, 201-217.

3. Baath, E. and Soderstrom, B. 1979. Rev. Ecol. **Biol.** Sol. 16, 477-489.

4. Beitz, J.A. 1974. Analytical Chemistry 46, 1617-1618.

5. Berg, B. and Staaf, H. 1981. In: Terrestrial Nitrogen Cycles. (Eds F.E. Clark and T. Rosswall) Ecol. Bull. (Stockholm) 33, 163-178.

6. Green, R. 1991. Ecologically Sustainable Development Working Groups. Draft Report -Agriculture. (Australian Government Printing Service: Canberra).

7. Hagvar, S. and Kjondal, B.R. 1981. Pedobiologia 22, 385-408.

8. Hutchinson, K.J. 1991. Sustainable Grazing Systems: Report to Working Group on Ecologically Sustainable Development in Agriculture. 33 pp.

9. King, K.L. 1989. PhD Thesis, University of New England, Armidale.

10. King, K.L. and Hutchinson, K.J. 1976. J. Appl. Ecol. 13, 41-55.

11. Rocks, R.L., Lutton, J.J. and McCabe, T.P. 1973. Proceedings of ANZAAS Conference on Science and Technology. Abstracts. (ANZAAS-SA Inc.: Adelaide). pp. 13-14.

12. Williams, C.H. and Twine, J.R. 1967. CSIRO Division of Plant Industry Technical Paper No. 24. (CSIRO: Melbourne).