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Soil fauna in sheep-grazed hill pastures under organic and conventional livestock management and in an adjacent ungrazed pasture

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ABSTRACT

Organic pasture management includes a focus on mixed livestock grazing, restrictions on nutrient inputs and livestock pest control. These are all factors which influence the environment of soil invertebrates. In this study, soil macrofauna, mesofauna and microfauna were collected from duplicate 11 and 20 year old organic and conventional legume-based sheep-grazed pasture systems. Pastures in both systems had received the same annual input of reactive phosphate rock and elemental sulphur and were stocked with the same numbers of sheep. The major difference between the two systems was absence of the chemical control of livestock pests on the organic system, resulting in lower sheep liveweights. Two ungrazed pastures which had not received any nutrient inputs for 20+ years were also sampled as part of the study to provide an additional contrast.

No significant differences in either the diversity or abundance of the soil invertebrate community were found between the organic and conventional systems, despite the use of chemicals in the conventional system. The lack of difference suggests that many of the observed and reported responses to organic management reflect altered nutrient inputs and grazing management (which were the same in the current study), rather than the cessation of chemical controls in the organic system. In contrast, the invertebrate community in the unfertilised, ungrazed pasture was distinctly different from both the grazed systems. The ungrazed pasture had a higher diversity with more New Zealand endemic species than the grazed pasture. This included twice as many large Oribatida as soil pore size increased. The lower litter quality from the lack of nutrient inputs in the ungrazed pasture was reflected in both lower earthworm abundance and the Nematode Channel Ratio (indicative of a higher proportion of fungal- than bacterial-feeding nematodes), than the grazed pasture.

We conclude that organic management when limited to a comparison of livestock pest control is not beneficial to soil invertebrates. Management practices such as stocking rates and fertiliser regime, by altering the soil physical environment and food resources, are more important in influencing invertebrate populations in this soil. Some would argue these altered management practices are an integral part of an organic production system.

Introduction

There is an increasing concern about the long-term sustainability of intensive pastoral systems (Doran and Zeiss 2000; Mackay 2008). Issues of concern include declining physical properties of the soil (Greenwood and McKenzie 2001; Sparling and Schipper 2004), loss of soil carbon (Bellamy et al. 2005; Schipper et al. 2007), increased nitrogen leaching (Ledgard 2001), and the loss of soil biodiversity (Wardle 1999; Schon et al. 2008). But there is a growing recognition that there is a limit to continued intensification of pastoral systems (Parfitt et al. 2008).

Organic agriculture continues to be advanced as a viable and sustainable alternative to conventional agriculture, reducing the environmental impacts of agricultural practices, and providing "clean green" produce to the population. As in many countries, currently only a very small percentage of New Zealand's agricultural land is under organic management (Willer and Yussefi 2007), yet interest remains high in the potential economic and environmental benefits of expanding certified organic production from the pastoral industry. Organic pastoral production systems emphasise legume-based pasture production, mixed livestock and grazing management practices, and are characterised by strict limits on plant nutrient inputs, imported feed supplements, and the use of

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Table 1
Treatment properties in hill-country pastures under ungrazed, organic, and conventional management in Manawatu, New Zealand.

Management	Ungrazed	Organic	Conventional
Stocking rate (stock unit ha^{-1})	0	12	12
Live-weight (kg ha^{-1})[a]	0	660	720
Treading pressure of single sheep (kPa)[b]	0	65	71
Farmlet size (ha) (each farmlet)		18	18
Inputs			
Phosphorus (reactive phosphate rock) (kg P ha^{-1} yr^{-1})	0	33	33
Other management inputs	–	–	Ivermectin and vaccinations
Pasture parameters (kg DM ha^{-1} yr^{-1} with kg N ha^{-1} yr^{-1} in parentheses[c])			
Pasture production[d]	n.d	8800	9590
Pasture intake[e]	n.d	6600	7190
DM from litter[f]	14 500 (348)	12 400 (397)	10 800 (346)
DM from dung[g]	0 (0)	2100 (44)	2300 (48)
DM from roots[f]	2500 (60)	4000 (128)	4000 (128)
Total DM	17 000 (408)	18 500 (569)	17 100 (522)

[a] Standard sheep at organic 55 kg live-weight and at conventional 60 kg (Mackay et al., 2006).
[b] Following Greenwood and McKenzie (2001).
[c] *N*% in herbage from Parfitt et al. (2009) and dung from Lovell and Jarvis (1996).
[d] Assuming one stock unit consumes 550 kg DM yr^{-1}. DM = Dry matter. Pasture production at low slope 46% and medium slope 31% of these values (Lambert et al., 1983).
[e] 0.75× pasture production.
[f] Calculated from Parsons et al. (1983).
[g] 0.35× of animal intake (Takahashi et al., 2007). Dung to low slopes = 60%, and medium slopes = 30% (Saggar et al., 1990).

agrochemicals in the control of pests and weeds. Organic practices are believed to be beneficial to soil invertebrates, by influencing the soils physical and chemical environment and food resources (Hassink et al. 1993; Wardle et al. 1998; Hole et al. 2005; Nielsen et al. 2008). With enhanced activity of soil invertebrates, such as earthworms, mesofauna and nematodes, benefits to soil services such as nutrient cycling have been measured (Bardgett and Chan 1999; Cole et al. 2004; Fonte et al. 2007). A number of studies have found soil fauna to be positively influenced by organic management in permanent pastures (Yeates et al. 1997; Mulder et al. 2003). In both mentioned studies the organic production systems had lower ruminant stocking rates than the conventional systems. A study by Parfitt et al. (2005) struggled to show any measurable benefits of organic management for soil fauna. In their study, organic systems had the same stocking rate and the same animal type as conventional systems, but different levels of soil fertility and nutrient inputs, highlighting one of the challenges in comparing organic and conventional pastoral systems – the control of stocking rate and fertiliser use. Controlling grazing and fertiliser regimes when assessing organic systems, offers the opportunity to explore more closely the underlying impact of a cessation in the chemical control of livestock pests on the soil invertebrate community, avoiding the compounding effects of management.

In this study we compared the influence of an organic and conventional sheep production system on the soil invertebrate community, under conditions where the stocking rate and nutrient inputs were the same in both systems. The major difference between the two systems was the use of chemicals in livestock pest control on the conventional system. One replicate of the two production systems was established in 1987 and the other in 1997. Adjacent areas in pasture that had not been fertilised or grazed for over 20 years were included in the study, to provide an indication of the soil fauna present under conditions where there had been no defoliation, livestock treading pressure and no nutrient inputs. Organic management is generally believed to be "better" for the soil and the environment and expected to positively influence soil invertebrates, including encouraging a fungal-based decomposition pathway.

Materials and methods

Study sites

The study was carried out at the AgResearch Hill Country Research Station, Ballantrae, Manawatu region, New Zealand (40°18′S 175°50′E). The Research Station is located 300 m above sea level, with an average air temperature of 12 °C and an annual rainfall of 1270 mm. Temperature and rainfall were above average in the year preceding sampling. The soils are classified as Luvisol (FAO) (NZSC = Pallic, Ngamoka silt loam) (Hewitt 1992), with silt-loam texture (42% sand, 40% silt and 18% clay). Pastures are dominated by the low fertility grass species *Agrostis capillaris* (browntop) and *Anthoxanthum odoratum* (sweet vernal), with grazed pastures also containing a small percentage of *Lolium perenne* (ryegrass) and *Trifolium repens* (white clover) (Nie et al. 1997; Mackay et al. 2006).

Four self-contained, grazed experimental farmlets (each approximately 18 ha fenced into approximately 30 paddocks) were sampled. Two farmlets were established in 1987, one under organic and the other under conventional management. In 1996, another pair of organic and conventional farmlets was established, creating a replicated farming systems comparison. Within each farmlet, there were areas fenced off (~0.1 ha), that had received no fertiliser inputs since 1987 and had not been grazed by domestic animals since that time.

The organic farmlets were registered and managed to meet the organic production standards of BioGro New Zealand (BioGro 2001). The standards of BioGro limits nutrient inputs, imported feed and prohibits the routine use of drenches, vaccines and antibiotics. History of the organic and conventional farm systems sampled in this study are described in detail by Mackay et al. (2006) and summarised in Table 1. Briefly, the organic and conventional farmlets received the same fertiliser inputs, reactive phosphate rock (33 kg P ha^{-1} yr^{-1} as RPR, a water insoluble fertiliser) and elemental sulphur (26 kg S ha^{-1} yr^{-1}), and were stocked at the same rate (12 stock units ha^{-1}) by sheep. A 'stock unit' is a 'standard sheep' which consumes 550 kg dry matter per year. The major difference between the organic and conventional farmlets was that on the conventional farmlets, prior to lambing, sheep received a 100-