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# Influence of organic and mineral amendments on microbial soil properties and processes

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## Abstract

Microbial diversity in soils is considered important for maintaining sustainability of agricultural production systems. However, the links between microbial diversity and ecosystem processes are not well understood. This study was designed to gain better understanding of the effects of short-term management practices on the microbial community and how changes in the microbial community affect key soil processes. The effects of different forms of nitrogen (N) on soil biology and N dynamics was determined in two soils with organic and conventional management histories that varied in soil microbial properties but had the same fertility. The soils were amended with equal amounts of N (100 kg ha$^{-1}$) in organic (lupin, *Lupinus angustifolius* L.) and mineral form (urea), respectively. Over a 91-day period, microbial biomass C and N, dehydrogenase enzyme activity, community structure of pseudomondas (*sensu stricto*), actinomycetes and α proteobacteria (by denaturing gradient gel electrophoresis (DGGE) following PCR amplification of 16S rDNA fragments) and N mineralisation were measured. Lupin amendment resulted in a two- to five-fold increase in microbial biomass and enzyme activity, while these parameters did not differ significantly between the urea and control treatments. The PCR–DGGE analysis showed that the addition of mineral and organic compounds had an influence on the microbial community composition in the short term (up to 10 days) but the effects were not sustained over the 91-day incubation period. Microbial community structure was strongly influenced by the presence or lack of substrate, while the type of amendment (organic or mineral) had an effect on microbial biomass size and activity. These findings show that the addition of green manures improved soil biology by increasing microbial biomass and activity irrespective of management history, that no direct relationship existed among microbial structure, enzyme activity and N mineralisation, and that microbial community structure (by PCR–DGGE) was more strongly influenced by inherent soil and environmental factors than by short-term management practices.


*Keywords:* Microbial community structure; DGGE; Nitrogen mineralisation; Organic and conventional farming practices; Lupin (*Lupinus angustifolius* L.) green manure; Urea

## 1. Introduction

Farming practices commonly associated with organic farming have a positive effect on the soil microbial diversity and, consequently, soil processes (Girvan et al., 2003; Hole et al., 2005). In comparison, there is little evidence in the literature of direct negative effects of mineral fertiliser and pesticide use on the soil microbial community in arable farming (e.g. Fraser et al., 1988; Fauci and Dick, 1994). It is noted that such practices may have different impacts on other parts of the farm system (Kirchmann and Thorvaldsson, 2000; Stolze et al., 2000).

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As observed by Bossio et al. (1998), this strongly suggests that the soil microbial community does not benefit from a particular management system (such as organic or conventional), but from specific farming techniques (e.g. green manuring, use of catch crops, crop rotations, crop residue management). Leguminous plants are often part of crop rotations, either as components of the pasture phase (e.g. clover) or as green manure crops (e.g. lupin), which add labile organic matter to the soil after incorporation. Legumes are an important source of N for most organic systems, especially in New Zealand, where crops under organic management rely almost exclusively on N released from soil organic matter via mineralisation. This highlights the importance of green manure crops and the dependence on biological processes to supply sufficient amounts of N to crops in organic farming systems. However, including green manures in crop rotations is considered good management practice in any agricultural production system because of their many positive effects on soil fertility and quality (Doran et al., 1988; Shepherd et al., 2000; Watson et al., 2002). As these practices are commonly linked to organic farming systems, soils cultivated under contrasting management regimes should show differences in biological soil properties and application of certain farming practices, such as green manure amendment, should be reflected in the composition of the microbial community and in related soil processes (Gunapala and Scow, 1998; Lundquist et al., 1999).

Interpretation of experiments examining *in situ* responses of soil microorganisms should be made with caution as incubation studies represent model systems under optimum conditions that rarely occur in the field. However, assessing soil properties under constant conditions allows variables such as soil moisture levels, temperature, microbial-plant interactions and soil type, to be studied individually. An incubation experiment was conducted to study interactions of soil microbial properties and soil processes by determining the effects of farm management history and short-term management practices on the microbial community and how changes in the microbial community affect N mineralisation. Soils with different farming histories were amended with the same amounts but different forms of N substrate (mineral as urea, organic as lupin) to study the effects on the microbial community and on key soil processes. The objectives of this study were to determine what links exist between microbial community composition and soil processes and how microbial biomass size and activity, gross N mineralisation and the community structure of selected microbial groups were influenced (a) by farm management history as opposed to short-term management practices, and (b) by the addition of different forms of N.

## 2. Materials and methods

### 2.1. Site description and experimental design

Top soil samples (0–15 cm) were collected from two sites under the same environmental conditions (approximately 2 km apart) within the cropping farm at Lincoln University, Canterbury, New Zealand (43°38′S; 172°27′E). The sites had been farmed under contrasting organic and conventional management systems for a substantial period of time. The organic site (ORG) was established in 1976, while the conventional site (CON) had been maintained under intensive mixed cropping for over 100 years. The soil at both sites was a Wakanui silt loam (free draining to 75 cm) (Mottled Immature Pallic Soil, NZ classification; Udic Ustochrept, USDA) with broadly comparable chemical and physical soil properties (Table 1).

The samples were air dried and sieved (2 mm) and, of each soil, 1.5 kg dry weight equivalent were placed in each of nine 2 l plastic containers with aeration provided by two 5 mm diameter holes in the lid. Initially and throughout the course of the experiment (every 4 days), soil moisture was adjusted to 70% water holding capacity based on weight loss by adding deionised water as a fine spray. The soils were incubated in the laboratory at a constant temperature of 20 °C. Three treatments were applied to both soils after 3 weeks of pre-incubation. Nitrogen (equivalent to 100 kg $ha^{-1}$) was added to the soils in mineral form as urea (46% N, 20% C) and organic form as ground

Table 1
Chemical and physical soil properties of ORG and CON topsoil samples (0–15 cm)

| Soil property | ORG | CON |
|---|---|---|
| C ($\mu g\ g^{-1}$) | 0.27 | 0.29 |
| N ($\mu g\ g^{-1}$) | 0.0024 | 0.0024 |
| C:N ratio | 11.4 | 12.1 |
| S ($\mu g\ g^{-1}$) | 260 | 300 |
| pH | 6.1 | 5.7 |
| Soil resin P ($\mu g\ g^{-1}$) | 45 | 37 |
| Total P ($\mu g\ g^{-1}$) | 813 | 771 |
| CEC ($cmol_c\ kg^{-1}$) | 14 | 14 |
| Ca ($cmol_c\ kg^{-1}$) | 7.3 | 7.0 |
| Mg ($cmol_c\ kg^{-1}$) | 0.79 | 0.56 |
| K ($cmol_c\ kg^{-1}$) | 0.76 | 0.39 |
| Na ($cmol_c\ kg^{-1}$) | 0.17 | 0.19 |
| Water holding capacity (%) (w/w) | 27.2 | 31.6 |
| Bulk density ($g\ cm^{-3}$) | 1.44 | 1.38 |