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Characterisation of the soil microbial community of cultivated and uncultivated vertisol in Australia under several management regimes

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ABSTRACT

Soil management is known to affect microbial populations relevant to nutrient cycling and plant health. We investigated the effects of several cropping management practices on a Central Queensland vertisol, including the application of liquid biological inoculums, green manuring and conventional chemical fertiliser. Soil microbial load and diversity was indexed using soil respiration, Biolog Ecoplate and FF microplates and PCR-DGGE. Compared to cultivated soil, uncultivated vertisol, represented by virgin brigalow soil, possessed 87% higher soil nitrate than cultivated soils, and significantly higher microbial catabolic potential, as observed in Biolog substrate utilisation patterns. In cultivated soil, there was little difference between treatments in these substrate utilisation patterns, but large changes associated with season. However, the results of 16S rDNA and Internal Transcribed Spacer region based DGGE profiles were consistent with an increase in bacterial diversity and a decrease in fungal diversity in amended cultivated soils relative to the unfertilised cultivated treatment.

1. Introduction

Ecosystem health has been traditionally assessed in terms of the 'macro' components of the ecosystem such as land forms, vegetation and macrofauna with attention now being focused on soil microbiota. Soil quality is usually characterised by its abiotic factors (e.g. cation exchange capacity/water holding capacity), but increasing recognition is now being given to biotic factors–the 'health' of the soil (Doran and Safley, 1997; Pankhurst et al., 1997). Microorganisms (biotic factors) are important indicators of soil quality because of their critical roles in biogeochemical cycles and maintenance of soil structure (Robertson et al., 1994; Sparling, 1997; Lalande et al., 2000; Anderson, 2003).

The measure of soil microbiota is however, fraught with difficulty and much work remains to establish a common range of tests and indices. Measures such as soil respiration rate and the FDA assay provide some understanding of total microbial activity, but are silent on microbial diversity. Culture based methods such as Biolog™ neglect the presence of non-culturable microorganisms, and as such are not absolute guides to the microbial composition of samples (Widmer et al., 2001). This limitation is likely to result in under-representation of slow growing organisms and organisms inhabiting different ecological niches to that tested in the Biolog procedure (e.g. obligate anaerobes). However, the trend observed in Biolog analysis can be validated by molecular tools. For example, microbial communities in activated sludge samples were studied using Biolog GN plates and DGGE and TGGE techniques (Smalla et al., 1998).

Accelerated and intensified use of agricultural soils can have negative impacts on 'soil health' (Ovreas et al., 1998; Nusslein and Tiedje, 1999; McCaig et al., 2001) with up to 40% of the world's agricultural land estimated as being seriously degraded (Woods, 1983; Mabbutt, 1992; Sample, 2007). Intensive farming practices (tillage and biomass removal) can result in increased mineralisation and depletion of soil organic matter (Dalal and Mayer, 1986; Oldeman et al., 1990; Lemenih et al., 2005). Lower proportions of microbial communities (e.g. Proteobacteria, Actinobacteria) have been observed in soils subjected to long-term cultivation practices compared to undisturbed soils (Buckley and Schmidt, 2001). Variations in microbial communities are also associated with different cultivation practices such as fertiliser application, tillage frequency, grazing, irrigation and herbicide application (Steenwerth et al., 2003). The central Queensland vertisols have been effectively continuously cropped, predominately with summer sorghum,

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mungbean or chickpea and winter wheat since the original brigalow (*Acacia harpophylla*) vegetation was cleared in the 1970s. Decline in soil organic matter, N status and grain yield has been documented by Collard and Zammit (2006).

The addition of biological materials (e.g. farm yard manure) can result in an increase in soil organic matter and improvement in soil structure (Pulleman et al., 2003) and soil biodiversity (Widmer et al., 2006; Tu et al., 2006). For example, application of dairy manure was shown to increase soil organic C, microbial biomass and enhance the community of typical gram-negative bacteria compared to the control and ammonium nitrate fertilised treatments (Peacock et al., 2001). Indeed, techniques such as mulching, crop rotation, green manuring, use of compost and application of liquid biological fertilisers such as microbially enhanced compost extracts ('compost tea') are commonly used to restore degraded soils (Omay et al., 1998; Garcia-Gil et al., 2000; Hernandez et al., 2007).

'Compost extract' may impact on soil microbial population as indexed by gross measures such as respiration rate in the following ways: (i) an increase in soil microbial population due to extract application in high volume, or in a localised manner (e.g. with seed), or following multiplication in the soil; (iii) increase in native/indigenous soil microbial population due to addition of substrate; (ii) no change in overall population, but impact on soil functions if the applied microbiota play key roles in nutrient cycling or in protecting plants from pathogens; or (iii) no change. For example, addition of a single species of rhizobia to soil enhances the performance of a matched legume crop while not altering the soil microbial load or causing a measurable increase in diversity.

The effect of organic and microbial amendment of soil is expected to be greater in moist soil than in dry soils. Indeed, the soil microbial population are expected to vary dramatically with soil moisture conditions. The central Queensland vertisol cropping

Table 1
Details of annual treatments of a field trial (commenced in 2007) conducted in Baralaba, Qld. Treatments were applied to a sorghum crop in late 2007, a wheat crop in 2008 and a mungbean crop in 2009.

Treatments	Fertility program	Application rate
Control (CONT)	Sodium Molybdenate (kg ha^{-1})	0.01
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Best-bet biology (BBB)	Compost extract (L ha^{-1})	30.0
	CalSap (L ha^{-1})	3.00
	Liquid N (L ha^{-1})	2.00
	Sodium molybdenate (kg ha^{-1})	0.05
	Fish hydrolysate (L ha^{-1})	2.00
	Humic acid (L ha^{-1})	0.50
	Sea minerals (L ha^{-1})	1.00
	Inoculant (Twin-N) (kg ha^{-1})	0.10
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Biology direct injection (BDI)	Compost extract (L ha^{-1})	30.0
	CalSap (L ha^{-1})	3.00
	Liquid N (L ha^{-1})	2.00
	Sodium molybdenate (kg ha^{-1})	0.05
	Fish hydrolysate (L ha^{-1})	2.00
	Humic acid (L ha^{-1})	0.50
	Sea minerals (L ha^{-1})	1.00
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Best-bet conventional (BBC)	Starter Z (kg ha^{-1})	10.0
	Sodium molybdenate (kg ha^{-1})	0.01
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Biology boom spray (BBS)	CalSap (L ha^{-1})	3.00
	Liquid N (L ha^{-1})	2.00
	Sodium molybdenate (kg ha^{-1})	0.05
	Sea minerals (L ha^{-1})	1.00
	Inoculant (Twin-N) (kg ha^{-1})	0.10
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Green manure (GM)	Panorama millet seed (kg ha^{-1})	4
	Cowpea seed (kg ha^{-1})	4
	Lab lab seed (kg ha^{-1})	4
	Forage sorghum seed (kg ha^{-1})	4
	CalSap (L ha^{-1})	3.00
	Liquid N (L ha^{-1})	2.00
	Sodium molybdenate (kg ha^{-1})	0.05
	Sea minerals (L ha^{-1})	1.00
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10
Feather-top Rhodes (FTR)	Panorama millet seed (kg ha^{-1})	4
	Cowpea seed (kg ha^{-1})	4
	Lab lab seed (kg ha^{-1})	4
	Forage sorghum seed (kg ha^{-1})	4
	CalSap (L ha^{-1})	3.00
	Liquid N (L ha^{-1})	2.00
	Sodium molybdenate (kg ha^{-1})	0.05
	Sea minerals (L ha^{-1})	1.00
	Peat inoculant (Nodulaid) (kg ha^{-1})	0.10