Nutrient supply from soil organic matter under different farming practices in the Central West of NSW

Dr Bhupinder Pal Singh, **Jharna R Sarker**, **Yunying Fang**, **Satvinder Singh Bawa** and **Dr Warwick Dougherty** NSW DPI, Menangle; **Dr Warwick Badgery** NSW DPI, Orange; **Dr Annette Cowie** NSW DPI, Armidale

Key findings

- Conventional tillage enhances soil organic carbon (SOC) turnover with the potential to simultaneously increase plant available nutrients [nitrogen (N), phosphorus (P), sulfur (S)] in the soil compared with no-till and perennial pasture.
- Across farming management practices and under ideal soil moisture, soil organic matter (SOM) could have supplied up to 45 kg N, 16 kg P and 19 kg S/ha in the absence of plant carbon (C) input.
- Over a longer period (126 days), particularly if there is a lack of plant C input (e.g. a normal fallow period), any P or S released via native SOM turnover over a shorter period (e.g. over 30 days) would have been immobilised by microorganisms and/or adsorbed to soil minerals, hence decreasing P and S availability for crop uptake.

Introduction

Soil organic matter is an important source of nutrients, including nitrogen, phosphorus and sulfur, for plants and a key indicator of soil quality. However, decomposition of SOM and its nutrient supply potential could vary with farming management practices. It is important to understand the supply of nutrients under different farming practices to optimise grain cropping systems productivity and profitability.

The aim of this study was to examine the impact of long-term farming practices on SOM decomposition and N, P and S net release in soil, thus evaluating the nutrient supply value of SOM in grain cropping systems.

Site description and methodology

Location	Condobolin Agricultural Research and Advisory Station NSW
Coordinates	33°05'19"S and 147°08'58"E, (195 m above sea level)
History	Established in 1998, (16-year-old farming systems trial)
Climate	Hot, semi-arid climate
Soil	Red chromosol, 27% clay (sandy clay loam)
Total C (0–10 cm)	1.2%–1.4%
Total N (0–10 cm)	0.10%–0.12%
pH (water)	5.5–6.3

Farming practices

The site has four farming practices (see http://cwfs.org.au/2015/12/10/cwfs-aog-soil-carbon-results-summary for more information (sighted 22-02-2016)).

The selected rotation treatments in each of the farming practices in May 2014 (i.e. at end of the fallow period) were:

- CT (Pa_LFW) = conventional tillage (pasture in 2013, long fallow wheat in 2014)
- CT (SFWus_Pa) = CT (short fallow wheat/ undersown pasture in 2013, pasture in 2014)
- RT (Pa_LFW) = reduced tillage (pasture in 2013, long fallow wheat in 2014)
- RT (LFWus_Pa) = RT (long fallow wheat/ undersown pasture in 2013, pasture in 2014)
- NT (Ba_Pu) = no-till (barley in 2013, pulse in 2014)
- PP = perennial pasture

Soil samples were collected (0–10 cm) from each plot, sieved (6.5 mm sieve), air dried and stored at 4 °C for various analyses (Table 1).

Table 1: Basic properties of soil (0–10 cm). Values in brackets are ± standard errors.

Treatment	Total C (%)	Total N (%)	Before incubation (day zero)		
			Mineral N	Mineral P	Mineral S
CT (Pa_LFW)	1.4 (±0.1)	0.12 (±0.00)	18.5 (±4.1)	17.3 (±3.9)	1.4 (±0.8)
CT (SFWus_Pa)	1.3 (±0.1)	0.11 (±0.00)	3.2 (±0.8)	22.2 (±3.6)	9.7 (±0.5)
RT (Pa_LFW)	1.2 (±0.1)	0.11 (±0.01)	22.0 (±3.4)	11.9 (±1.9)	0.1 (±0.1)
RT (LFWus_Pa)	1.4 (±0.1)	0.12 (±0.00)	1.7 (±0.5)	30.6 (±2.5)	2.3 (±1.5)
NT (Ba_Pu)	1.3 (±0.0)	0.11 (±0.00)	12.5 (±1.3)	14.6 (±0.4)	16.2 (±0.7)
PP	1.4 (±0.1)	0.12 (±0.01)	3.2 (±0.8)	7.3 (±1.3)	1.4 (±0.8)

Laboratory incubation and analyses

Soil samples (35 g) were weighed into 70 mL plastic vials with their moisture content adjusted to 60% of WHC. The soils were incubated in a sealed, one litre bucket at 22 ± 0.5 °C for 18 weeks. Soil-respired CO_2-C (mineralisable C), 2 M KCl-extractable mineral N (NH_4^+-N and NO_3^--N), 0.016 M KH_2PO_4-extractable SO_4^{2-}-S, and 0.5 M $NaHCO_3$-extractable PO_4-P (standard Colwell-P) were periodically measured. Net nutrient availability for N, P or S following the simultaneous mineralisation (organic to inorganic forms), immobilisation (inorganic to organic forms) and fixation (adsorption on soil minerals and/or precipitation with metal cations) processes during SOM turnover over 30 or 126 days was quantified using the following equations:

1. Net mineralisable N = extractable mineral $N_{\text{day30 or day126}}$ – extractable mineral N_{day0}

2. Net mineralisable S = extractable mineral $S_{\text{day30 or day126}}$ – extractable mineral S_{day0}

3. Net available P = Colwell $P_{\text{day30 or day126}}$ – Colwell P_{day0}

Results

Soil organic carbon turnover

Over 126 days of incubation, 185–370 mg CO_2-C/kg soil was released across different farming practices (Figure 1). There was a greater turnover of SOC under conventional tillage, whether rotational phases transitioning to pasture [CT (SFWus_Pa)] or wheat [CT (Pa_LFW)] than the PP, NT or RT (Pa_LFW) treatments. Less soil disturbance in the PP, NT and RT (Pa_LFW) treatments might have enhanced SOM soil aggregation and decreased decomposability to microbial attack compared with the CT treatments. Changes in organic chemical compounds might have also contributed to differences in SOC turnover across the farming practices.

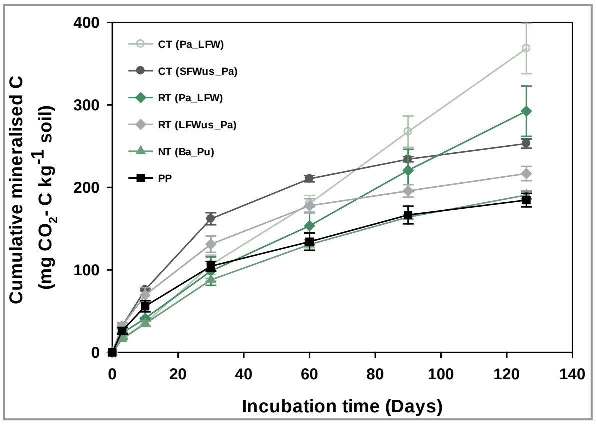

Figure 1. Cumulative SOC mineralised under different farming practices over 126 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

Nutrient supply potential of SOM

Net mineralisable N was 8–22 mg/kg soil over 30 days (Figure 2) and 11–40 mg/kg soil over 126 days of incubation (Figure 3). Consistent with SOC turnover, net mineralisable N was higher in the CT treatments, particularly in CT (Pa_LFW), than the other farming practices.

Net available P was 3–16 mg/kg soil over 30 days of incubation across all the treatments except in CT (Pa_LFW) where there was a decrease in available P (–5 mg/kg soil). However, over 126 days of incubation, net available P was negative, ranging between 3 and –23 mg/kg soil, with the RT having the greatest decrease and PP the lowest, relative to the other treatments (Figure 3). This could be due to microbial immobilisation and/or fixation of inorganic P by clay minerals and metal cations.

Consistent with the dynamics of net available P, there was a net release of mineral S (4–20 mg S/kg soil) over 30 days of incubation across the farming treatments. Thereafter (over 126 days), there was a net S immobilisation of up to 11 mg/kg soil (Figure 3), which might be due to S microbial immobilisation.

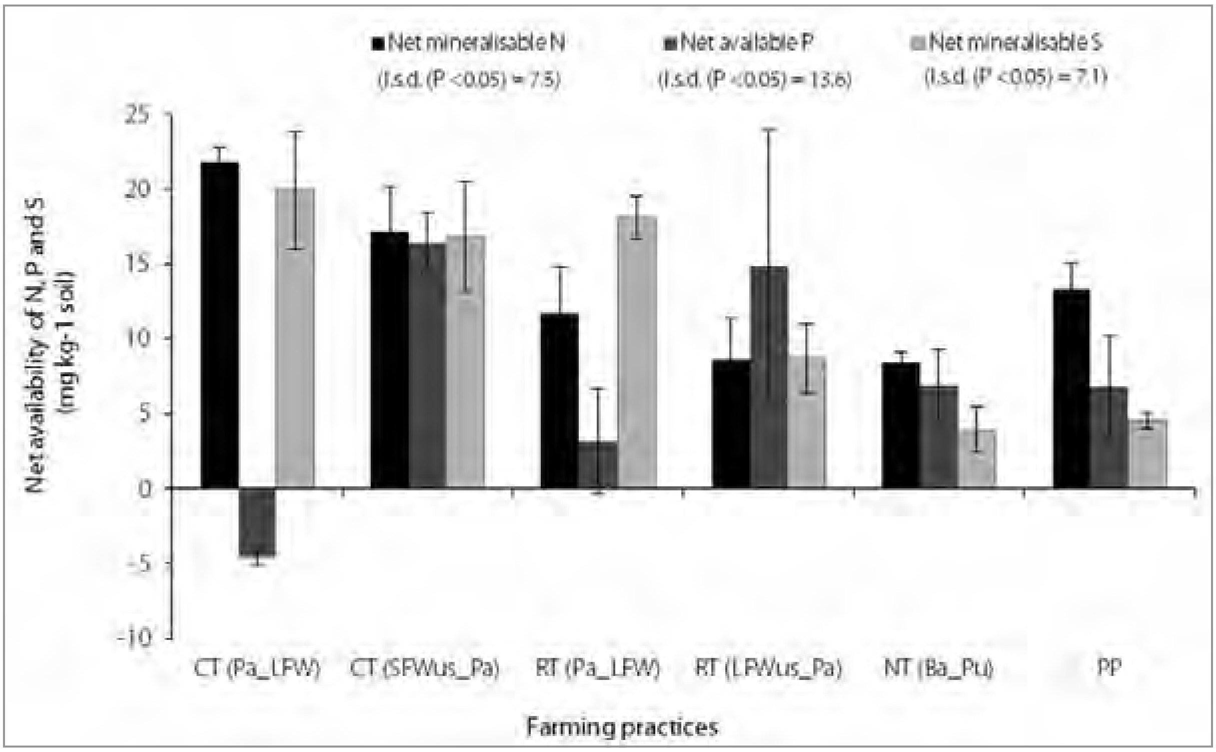

Figure 2. Effect of farming practices on net nutrient availability in soil over 30 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

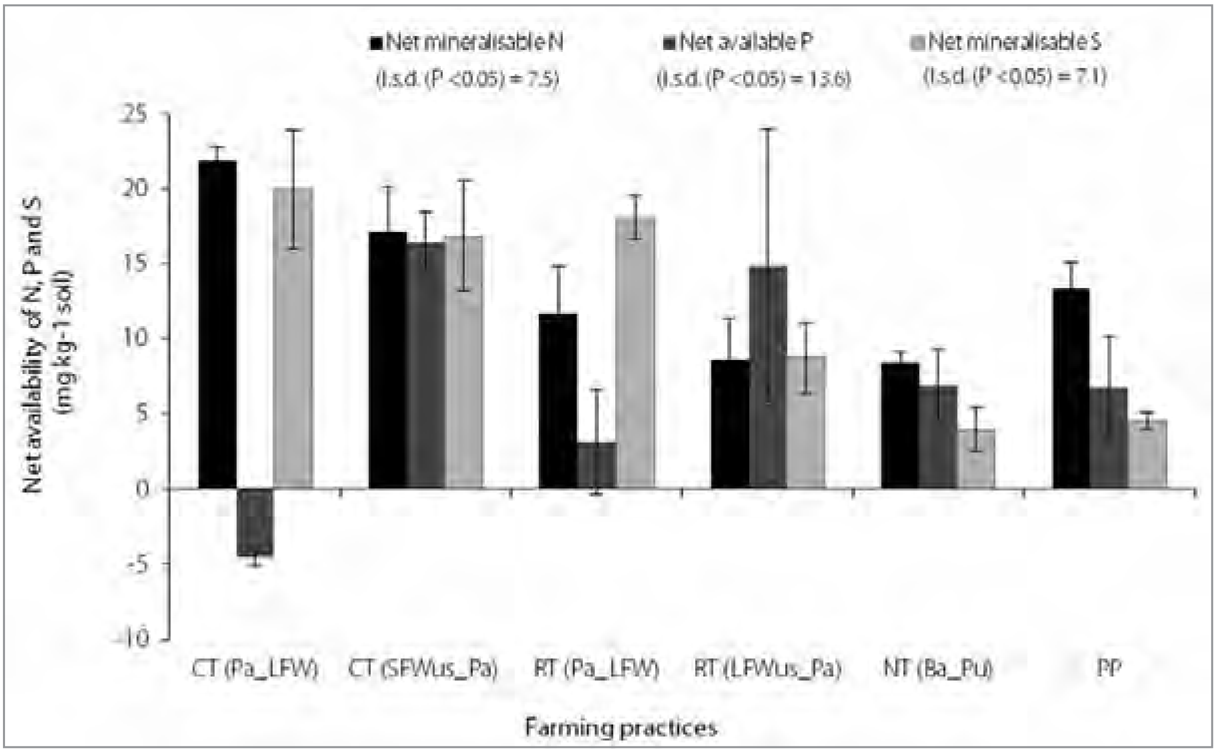

Figure 3. Effect of farming practices on net nutrient availability in soil over 126 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

Nutrient value of SOM

This study suggests that SOM can slowly release mineral N over a four-month period, while mineral P and S could also be released over a one-month period under ideal soil moisture conditions. Considering the soil bulk density of 1.3 t/m^3 (0–10 cm depth), our study suggests that SOM could supply 13–52 kg N, 4–21 kg P and 5–26 kg S per hectare. Our data also suggest that any short-term released mineral P and S could be locked up in soil over the longer term (126 days). Thus, these essential nutrients need to be supplied to counteract the nutrient locking effect, for example via microbial immobilisation or adsorption on minerals in soil.

Summary

NSW DPI data indicate that native SOM has a fertiliser value in terms of N, P and S supply to support crop productivity. However, after the initial nutrients release from SOM, mineral P and S in particular could be locked up by microorganisms and/or minerals in the soil. Hence, additional supply of these nutrients (including N as required) is needed to meet crop demand. The results on the effect of farming practices suggest that the conventional tillage increased SOC turnover and net nutrient release from SOM relative to no till or long-term perennial pasture. There is a trade-off between enhancing SOC turnover via conventional tillage that disrupts soil aggregates and exposes SOM for microbial attack versus slowing SOC loss and nutrient turnover while improving soil structure via no-till or including long-term pasture phases.

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