Cumulative effect of the application of N and P Fertilizers on soil total and labile concentrations after 12 cereal crops on a black vertosol.

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ABSTRACT

Soil organic carbon is commonly used as a key indicator of sustainability of farming systems due to effects on nutrient availability, structural stability and its central role in soil biotic processes. Trends in total carbon content (CT) and lability of carbon (CL) in soil have been measured in a long-term nitrogen (N) x phosphorus (P) fertiliser experiment in continuous cereal cropping to assess the effect of increasing crop nutrient supply on soil carbon accretion and partitioning. Increasing N supply in each crop by 80 kg/ha or more was effective in creating significantly different total and labile carbon content.

KEY WORDS

Soil organic matter, $KMnO_4$ oxidation.

INTRODUCTION

Soil organic matter is one of the key components of sustainable agricultural systems. The significance and rate of loss of soil organic carbon from soils under grain production systems on vertosols and other major cropping soils in north eastern Australia has been studied and reported (2). Associated with soil organic carbon decline is reduced soil fertility and declining grain yields and quality (3).

Several research programs examining soil fertility restoration have been undertaken focussing either on the use of zero or minimum tillage to retain stubble, or of grain legume or ley pasture systems (4, 5). The effect of N fertiliser application in arresting the decline has been limited and the role of P fertiliser has not been described.

Many related research programs have focussed on winter cereals alone and were of a short duration (3 – 7 years), this limited the extent of assessment that can be attributed to a management change. However, experiments of a longer duration provide greater opportunity for investigation of effects.

This study investigates the cumulative effects of N and P Fertilizers on soil total and labile carbon after a 12 crop sequence of summer and winter cereals on a vertosol of the Darling Downs.

METHODS AND MATERIALS

Soil was collected from Incitec Fertilizers long-term N x P experiment at "Colonsay" in the Formartin district of the central Darling Downs, Qld. Soils in this district were first cropped in the 1930s. The experiment was established in 1985.

Soil was collected after 12 crops (wheat, barley and sorghum), each of which had received a factorial combination of 0, 40, 80 or 120 kg/ha of N per crop at 0, 10, 15 or 20 kg/ha of P per crop). N is applied as urea (46% N), P as triple superphosphate (20.7% P). Treatments were laid out in a randomised block design with 3 replicates. The soil is a black vertosol, Mywybilla clay, pH (1:5 soil/0.01 M $CaCl_2$) 7.8, and CEC (cmol+/kg) 57.

Soil samples were collected from each N rate at 0, 10 and 20 kg/ha P rate, from each of 3 replicates, from 0-10 cm depth. These were air-dried at 40 ^{o}C, and ground to < 0.5 mm prior to analysis.

Total carbon (CT) was determined using 0.2 g combusted at 1300 ^{o}C in a Leco CNS 2000 Dumas combustion system. Carbon lability (CL) was determined using the permanganate oxidation technique (1) using 333 ?M $KMnO_4$.

Results

Cumulative grain yield of the 12 crops increased with N rate (Table 1). The cumulative total of grain yield is from each crop at an N rate averaged over P rates. Grain yields frequently respond to P (data not shown), the mean increase in yield is about 400 kg grain/ha.

Table 1. Effect of N rate on cumulative grain yield (kg/ha) from 1985 - 2000.

N rate (kg/ha/crop)	0	40	80	120
Total grain yield (kg/ha)	37200	45000	48700	49500

There was a significant increase ($P < 0.02$) in soil CT with increasing N application rate (Table 2). P application and the N x P interaction did not significantly influence CT.

Table 2. Soil total carbon after multiple applications of 4 N rates to 12 cereal crops at "Colonsay", 1985 to 2000.

N rate (kg/ha/crop)	0	40	80	120	l.s.d. 5 %
CT, mg/g	13.19	13.27	13.86	13.98	0.60

Soil CL significantly increased ($P < 0.02$) with increasing N application rate (Table 3). P application and the N x P interaction did not significantly influence CL.

Table 3. Soil labile carbon after multiple applications of 4 N rates to 12 cereal crops at "Colonsay", 1985 to 2000, and ratio of labile to total carbon.

N rate (kg/ha/crop)	0	40	80	120	l.s.d 5 %
CL, mg/g	1.46	1.61	1.72	1.65	0.16
CL:CT %	11.0	12.1	12.4	11.8	

DISCUSSION

Application of N fertiliser into continuous cereal cropping systems, can increase the dry matter production, and hence grain yield. Plots receiving nil N per crop were lower in CT and CL than those plots where 80 kg N/ha/crop is applied.

Dalal and Mayer (1) estimate 0.5 t C/ha/year for a Waco, and 1.8 t C/ha/year is required for a Cecilvale soil to maintain organic matter equilibrium. The Mywybilla soil is of the same series as Waco, and is adjacent to Cecilvale. Annual crop yields range from 3.3 ? 1.7 t/ha grain in nil N plots, to 4.6 ? 1.4 t/ha grain in 120 kg N/ha/crop plots. Assuming a harvest index of 50% for all years, the weight of stubble residue approximates grain yield. The C input can then be estimated at 1.3 ? 0.7 t/ha C at nil N, increasing to 1.8 ? 0.5 t/ha C at 120 kg N/ha/crop, assuming 40% C in stubble.

The CL results provide a qualitative indication of the C forms. The relatively small contribution of CL to CT (Table 3), indicates a high proportion of the total carbon is in forms that are not oxidised by the mild oxidising agent, neutral $KMnO_4$. Future studies will attempt to further characterise the soil C fractions.

CONCLUSIONS

Application of sufficient N to ensure maximum conversion of soil water to plant yield is critical in maintaining organic C status in continuously cropped soils. Soil management strategies to maximise capture of fallow rainfall events, and application of optimal N and P to ensure efficient use of moisture should produce sufficient C for equilibrium to be at least maintained at current levels.

ACKNOWLEDGMENTS

Chemical analysis has been conducted by QDNR Indooroopilly, and QDPI Leslie Research Centre.

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