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USE OF LABELLED PLANT RESIDUES TO STUDY THE IMPACT OF RESIDUE INCORPORATION ON SOIL CARBON AND AGGREGATION

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Soil structural and soil organic matter decline is a world wide problem and the return of plant residues to the soil is being used in many areas to attempt to increase soil C, which can lead to an improvement in soil structure. Studying the impact of residue incorporation on soil C can be difficult because of the large background of residual C in the soil. The use of isotope labelled plant material allows for the investigation of the effects of newly incorporated residue plant material on the C dynamics within the soil. An experiment was conducted to evaluate the effect of plant residues with differing breakdown rates, incubated at different temperatures and for different time periods on the incorporation of C into the soil and the stability of the soil aggregates to wetting. No increase in Total C within the soil aggregates was found, however there were large increases in soil aggregate stability. The rate of incorporation of the C from the added residues differed between plant materials.

Introduction:

Grain production is of major agricultural importance in Australia where much of the land has been developed from forest or natural grassland. Agricultural development of native lands has lead to a marked decline in soil organic matter (SOM) throughout the world. This contributes both to global warming via CO_2 evolution from the soil as the SOM mineralizes and to a decline in both physical and chemical fertility of the soil.

A survey carried out by the Soil Conservation Service of NSW in 1987-88 showed that 18.3% of the state of NSW, Australia suffered from soil structural decline [1]. Soil structural decline and aggregate breakdown can result in surface sealing, hardsetting, compaction, reduced water infiltration and increased surface runoff and soil erosion. Plant growth can be affected by structural decline. The most obvious effect is on root growth. If the soil is compacted, with few pores for roots to pass through, root growth can be severely reduced. The development of surface seals through aggregate breakdown can pose considerable mechanical impedance to seedling emergence. Improvement in soil structure can result in increased yields through improved plant growth, better soil water relations, higher infiltration and reduced run-off and erosion risk. This has the potential to reduce the possibility of pesticide and herbicide residues and soil and nutrients leaving the farm and entering waterways and thus lessening the environmental impact of agriculture. This is becoming increasingly important in today's society.

Materials and Methods:

Plant material, which was grown in an atmosphere enriched in carbon isotopes ($^{13}C/^{14}C$) and which received ^{15}N enriched fertiliser was incorporated into an Aquic haplustalf soil at the rate of 5 t/ha. Plant residues with a range of breakdown rates (flemingia (*Flemingia macrophylla*), medic (*Medicago trunculata*) and rice (*Oryza sativa*) straw), along with no residue return control, were used.

Prior to the commencement of this study the soil was incubated at field capacity for 20 days at 25 °C day (18 hours) and 15 °C night (6 hours). The soil was then mixed and sub-sampled into vials and incubated at a moisture content of 75% of field capacity, at temperatures resembling tropical

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(30°C day/20°C night (12 hours)) and temperate (20°C day/10°C night (12 hours)) conditions for up to six months. Sample vials were removed from the incubation chambers at 3 and 6 months and the soil air-dried. At each sampling time and at the commencement of this study Total C (C_T) and N and ^{13}C and ^{15}N were determined on an Automated Carbon and Nitrogen Analyser/Mass Spectrometer. A wet sieving technique was used to determine aggregate stability (expressed as mean weight diameter, MWD). The soil was gently crushed by rolling to pass through a 4 mm sieve before determination of aggregate stability. Prior to all C measurements and determination of aggregate stability all visible plant material not within soil aggregates was removed. Preliminary investigations were conducted using a Secondary Ion Mass Spectrometry (SIMS) to locate the ^{13}C labelled organic matter within the soil aggregates. In addition to the SIMS, an autoradiography technique and an Electron Microprobe are being used to determine the position of the ^{14}C labelled organic matter within the same soil aggregates.

Results and Discussion:

Neither temperature nor residue had any significant effect on soil aggregate C_T over the 6 month period. However during this time the amount of soil aggregate C_T derived from the added residues increased by 8% with flemingia, and 6% with rice and decreased by 28% with medic.

Mean weight diameter (MWD) increased by 73.1 %, 48.6 % and 27.4% respectively for the medic, rice and flemingia treatments and there was a decrease of 11.6 % in the control, when compared to the MWD of the soil prior to the first incubation period. MWD (meaned over all residues and the control) increased by 42.1 % at the higher temperature compared to an increase of 26.6% at the lower temperature.

Preliminary results from the SIMS scans showed the presence of ^{13}C within the soil aggregates in the medic and rice treatments. No ^{13}C was detected in the flemingia treatment

The decline in the amount of C_T derived from the medic residue relates to the fast breakdown rate of this plant material [2] which most likely resulted in the release of more labile C compounds, which improved the stability of soil aggregates [3] by providing important binding agents. Following wet sieving of the flemingia treatment a large amount of leaf material was visible on the top sieve, compared to the medic and rice treatments, even though all visible material had been removed prior to wet sieving. This indicated that there was a considerable amount of undecomposed leaf material in the aggregates, which became apparent when they slaked during sieving. This undecomposed material would not be involved in the binding of the aggregates against the forces of the water. However over a longer time this may decompose and become effective in stabilising the soil aggregates.

The correct management and incorporation of plant residues can improve aggregate stability and assist in reducing the decline in soil structure. Residues with fast breakdown rates provide short-term responses in stabilising soil aggregates but over the longer term residues with slower breakdown rates may be necessary to provide continued improvement in soil structure. To develop sustainable agricultural systems and to reduce the decline in soil structure it is necessary to incorporate plant residues with breakdown rates, which suit the environment and provide both short and long-term stabilisation of soil aggregates.

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