

SHORT COMMUNICATION

**BURNING, TRASHING AND FERTILISATION:
EFFECTS ON CARBON POOL PROPORTIONS?**

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Abstract

It is widely known that land management practices affect soil organic matter (SOM) levels, and thus the different carbon pool proportions. However, the degree to which each pool is affected is uncertain. Understanding the effect of burning, trashing and fertilisation on SOM levels and subsequently the labile and non-labile proportions of the sugar industry's soils is vital because the different carbon portions perform different functions. Labile carbon is accepted as the main contributor of available nutrients (from organic matter) for plant growth and microbial activity, whereas non-labile carbon is more important as a structural component of the soil. The objective of this work was to explore the effects of burning, trashing and fertilisation on total and labile carbon in soils. Soil samples were collected for four different treatments from the BT1 trial at Mount Edgecombe, South Africa: (i) burnt, no tops, no fertiliser (B₀F₀), (ii) burnt, no tops, with fertiliser (B₀F), (iii) trashed, no fertiliser (TF₀) and (iv) trashed, with fertiliser (TF). Each of the samples was analysed for labile and total carbon. Results showed that the addition of organic amendments (trash and/or tops, after harvest), in combination with the use of fertilisers, led to the greatest increase in SOM. The addition of organic amendments alone proved to be valuable for increasing the labile carbon content of the soil, while fertilisation tended to increase the labile carbon pool by encouraging a more extensive root system.

Keywords: sugarcane, carbon pools, labile carbon, microbial biomass, trashing, burning, fertiliser

Introduction

Simplistically, soil organic matter (SOM) is comprised of two major carbon proportions: decomposable (labile) carbon and inert carbon (non-labile). Non-labile carbon is dependent on climate and soil type and correlates particularly well with fine silt and clay content of soil, whereas labile carbon is largely influenced by management strategies (Schulz *et al.*, 2002). The labile portion can be determined using the hot water extractable carbon (HWEC) method. Despite not being well defined, the HWEC portion is known to contain microbial biomass and simple organic compounds. Furthermore, it represents the very easily decomposable part of soil (Tirol-Padre *et al.*, 2007).

The long- and short-term effects that the addition of organic matter has on soil properties have been reported on numerous occasions (Graham *et al.*, 2002; Mills and Fey, 2004; Tirol-Padre *et al.*, 2007). Christensen (1996) concluded that SOM turnover, to a large extent, determines the fate of mineral fertilisers, animal manures, crop residues and other organic wastes that are supplied to the soil.

Research such as that conducted by Körschens *et al.* (1998) has noted that labile carbon increases as mineralisation rate decreases, and that the non-labile carbon content increases with clay content. It was thus suggested that changing the physical properties, via the addition of organic carbon, can increase the labile carbon portion of the soil.

Thus, the main objective of this paper was to investigate the effect of different land management practices on the proportions of different carbon pools in the soil, as well as to determine the relationships, if any, that exist between these pools.

Materials and Methods

Soil samples were collected at depths of 0-10 cm from the long-term BT1 trial, established in 1939 at the South African Sugarcane Research Institute (SASRI) at Mount Edgecombe. The average annual rainfall in the area is 950 mm and average yearly temperature is 20.5°C. The sugarcane is grown under dryland conditions on a cracking, vertic Arcadia form soil (van Antwerpen and Meyer, 1998). Two sets of samples, March 2007 and June 2008, were taken from B_{t0}F₀ (burnt, cane tops removed, no fertiliser applied), B_{t0}F (burnt, cane tops removed, fertiliser applied), TF₀ (trashed, no fertiliser applied) and TF (trashed, fertiliser applied) treatments. Textural variation between treatments was minimal and was therefore ignored during data analysis.

The samples were analysed for total organic carbon by automated dry combustion (TOC_{dc}), using a Leco analyser (TOC_{dc}), and for labile carbon using the HWEC method (Shulz, 1990). HWEC is a chemical extraction method in which 20 g of air-dried soil is boiled in 100 ml of distilled water under reflux for one hour. The carbon (C) content of the samples is determined using a Shimadzu C/N analyser after the samples have been centrifuged and filtered. From the HWEC results, the labile carbon fraction (C_L) can be calculated using Equation 1 (Körschens *et al.*, 1998):

$$C_L = 15 \cdot HWC \quad \text{Eq 1}$$

It is important to note here that this equation was derived from long-term data in Germany, under their climatic conditions, which are much cooler than those of South Africa. Therefore, if a similar equation were developed for South Africa, it is assumed that the constant factor (15), by which the HWEC value is multiplied, will be different.

Treatments were compared to determine the effect of the different management strategies on the labile and total organic matter status of the soil. Furthermore, microbial biomass data, analysed using fumigation extraction (Banger *et al.*, 1990), and the microbial quotient, calculated as described by Haynes and Graham (2004), were studied to investigate whether any relationships existed between them and the carbon portions.

Results and Discussion

The results in Table 1 show that a combination of fertiliser and organic amendments resulted in the highest overall increase in SOM (see TOC_{dc}) levels in the soil. In this short communication, 'organic amendments' refer to trash and/or tops that were removed during harvest and then returned to the soil as a trash blanket.

Table 1. Results for total organic carbon (TOC_{dc}), labile carbon (C_L), hot water extractable carbon (HWEC), microbial biomass (MB), microbial quotient, HWEC/TOC_{dc}, C_L/TOC_{dc}, HWEC/MB and HWEC/microbial quotient from four different treatments in the long-term BT1 trial at Mount Edgecombe, South Africa.

Treatment	TOC _{dc} (%)	*C _L (%)	HWEC (%)	MB (µg C/g soil)	Microbial quotient	HWEC/TOC _{dc} (%)	C _L /TOC (%)	HWEC/MB (%)	HWEC/Micro- bial quotient (%)
Mar-07	B _{t0} F ₀	3.903	0.041	205.9	0.528	1.05	15.8	0.0199	7.8
	B _{t0} F	4.203	0.075	141.19	0.336	1.78	26.8	0.0531	22.3
	TF ₀	4.243	1.26	178.07	0.420	1.98	29.7	0.0472	20.0
	TF	5.17	2.33	275.13	0.532	3.00	45.0	0.0563	29.1
Jun-08	B _{t0} F ₀	1.1	0.036	145.53	1.323	3.27	49.1	0.0247	2.7
	B _{t0} F	1.12	0.037	109.38	0.977	3.30	49.6	0.0338	3.8
	TF ₀	2.03	1.25	153.13	0.754	4.09	61.3	0.0542	11.0
	TF	2.56	1.62	225.97	0.883	4.22	63.3	0.0478	12.2

* C_L = 15·HWEC

The addition of organic amendments increased the quantity of labile carbon (Table 1) and therefore supports the findings of Körschens *et al.* (1998). As expected, the TOC_{dc} was also increased by the addition of organic amendments. Thus, the continuous addition of organic matter over 70 years has led to increased total organic carbon and labile carbon levels in the soil in the BT1 trial.

The application of fertiliser alone was able to increase the labile carbon of the SOM. An explanation for this is that the presence of fertilisers encourages a more extensive root system, which in turn results in higher organic matter levels in the soil (i.e. > t root material/ha). There is consequently higher microbial activity in the soil (van Antwerpen, 1999).

The presence of organic matter influenced the effect of fertilisers on the carbon proportions of the soil. Labile carbon contents tended to be higher when fertiliser was used in combination with organic amendments.

A comparison of the two sampling dates (Table 1) showed that the values for March 2007 were higher than those for June 2008. Dick and Gregorich (2004) listed a number of possible reasons to explain the differences in organic matter quantities: climate, landscape, texture, inputs and disturbance, all of which alter the microbial colonies in the soil. Of these, however, it is only climate that did not remain constant from one sampling event to the next. During March 2007 the average daily temperature was 23.3°C and the average rainfall for the month was 5.5 mm. June 2008, on the other hand, was much cooler and drier, experiencing average daily temperatures of 17.5°C and average monthly rainfall of 1.3 mm, creating conditions that were less favourable for soil microbes. Data were supplied by the Mount Edgecombe weather station at SASRI.

Furthermore, samples taken in June 2008 were frozen prior to HWEC analysis, while those for March 2007 were not. Although it has been reported that soils can be frozen prior to HWEC analysis (Lee *et al.*, 2007), data at SASRI show that this practice alters the carbon content of the soil (unpublished data¹). It is thus not recommended that comparisons be made between samples that have been frozen and those that have not.

For all treatments, microbial biomass was higher for March 2007 than for June 2008. However, it was not evident why the microbial biomass for the BT_0F_0 treatment was higher than those of the Bt_0F and TF_0 treatments. Data from another BT1 investigation (Graham, 2003), shows microbial biomass values for BT_0F_0 to be lower than those of all other treatments. This data also confirms the microbial biomass trend for the other treatments, i.e. microbial biomass increases linearly from $\text{Bt}_0\text{F} < \text{TF}_0 < \text{TF}$.

Although the levels of total carbon, HWEC and labile carbon fractions in the soil were increased, the ratio between them changed with treatments. The ratio between HWEC and TOC_{dc} showed an increase from $\text{Bt}_0\text{F}_0 < \text{Bt}_0\text{F} < \text{TF}_0 < \text{TF}$ for both March 2007 and June 2008. A similar trend was observed for the HWEC/CL ratio. These ratios indicate that HWEC and TOC_{dc} both increase with addition organic amendments and/or fertiliser. Furthermore, no trend exists for the HWEC/MB and $\text{HWEC}/\text{Microbial quotient}$ ratios.

¹ A Weigel, 2009. SASRI project 07RE02 – Investigating the hot water-extractable carbon fraction and its use as a soil health indicator. Final project report available from the South African Sugarcane Research Institute, Mount Edgecombe, 4300, South Africa.

Conclusions

- The addition of organic amendments increased HWEC, C_L and TOC_{dc} compared to treatments with no organic amendments.
- The addition of fertilisers increased HWEC, C_L and TOC_{dc} due to the development of a more extensive root system.
- A combination of organic amendments and fertiliser resulted in the highest increase in HWEC, C_L and TOC_{dc} .
- The addition of organic amendments is able to increase the stable carbon content over the long term.
- $\frac{HWEC}{TOC_{dc}}$ and $\frac{HWEC}{C_L}$ ratios increased with treatments $Bt_0F_0 < Bt_0F < TF_0 < TF$.
- $\frac{HWEC}{MB}$ and $\frac{HWEC}{Microbial\ quotient}$ ratios showed no trend between treatments.

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REFERENCES

- Banger KC, Kapoor KK and Mishra MM (1990). Soil microbial biomass: Its measurement and as a nutrient source. *Indian Journal of Microbiology* 30: 263-278.
- Christensen BT (1996). Carbon in Primary and Secondary Organomineral Complexes. pp 97-165 In: MR Carter and BA Stewart (Eds), *Advances in Soil Science: Structure and Organic Matter Storage in Agricultural Soils*. CRC Press.
- Dick WA and Gregorich EG (2004). Developing and maintaining soil organic matter levels. pp 103-120 In: P Schjønning, S Elmholt and BT Christensen (Eds), *Managing Soil Quality: Challenges in Modern Agriculture*. CAB International.
- Graham MH (2003). The effect of various crop residue management practices under sugarcane production on soil quality. PhD Thesis, University of Natal, South Africa.
- Graham MH, Haynes RJ and Meyer JH (2002). Changes in soil chemistry and aggregate stability induced by fertiliser applications, burning and trash retention on a long-term sugarcane experiment in South Africa. *European Journal of Soil Science* 53: 589-598.
- Haynes RJ and Graham MH (2004). Soil biology and biochemistry – a new direction for South African soil science? *South African Journal of Plant and Soil* 21(5): 330-343.
- Körschens M, Weigel A and Schulz E (1998). Turnover of soil organic matter (SOM) and long-term balances – Tools for evaluating sustainable productivity of soils. *Zeitschrift für Pflanzenernährung und Bodenkunde* 161: 409-424.
- Lee YB, Lorenz N, Dick LK and Dick RP (2007). Cold storage and pretreatment incubation effects on soil microbial properties. *Soil Science Society of America Journal* 71: 1299-1305.
- Mills AJ and Fey MV (2004). Declining soil quality in South Africa: Effects of land use on soil organic matter and surface crusting. *South African Journal of Plant and Soil* 21: 388-398.
- Schulz E (1990). Die Heißwasserextrahierbare C fraction als kenngröße zur einschätzung des versorgungszustandes der böden mit organischer substanz (OS) (The hot water extractable C-fraction as an indicator for the status of soil organic matter). *Tag Ber Akad Landwirtsch-Wiss Berlin* 295: 269-275.

- Schulz E, Travnikova LS, Titova NA, Kogut BM and Körschens M (2002). Influence of soil type and fertilisation on accumulation and stabilisation of organic carbon in different SOM fractions. Proc 12th ISCO Conference, Beijing, China. pp 304-308.
- Tirol-Padre A, Ladha JK, Regmi AP, Bhandari AL and Inubushi K (2007). Organic amendments affect soil parameters in two long-term rice-wheat experiments. *Soil Science Society of America Journal* 71: 442-452.
- van Antwerpen R (1999). Sugarcane root growth and relationships to aboveground biomass. *Proc S Afr Sug Technol Ass* 73: 89-95.
- van Antwerpen R and Meyer JH (1998). Soil degradation – II: Effect of trash and inorganic fertiliser application on soil strength. *Proc S Afr Sug Technol Ass* 72: 152-158.