SHORT NON-REFEREED PAPER

EFFECT OF SUGARCANE RESIDUE RETENTION AND FERTILISER APPLICATION ON SOIL MICROBIAL ABUNDANCE AND COMMUNITY STRUCTURE

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Introduction

The size, activity, structure and diversity of soil microbial communities in sugarcane producing soils are strongly affected by crop harvesting methods (i.e. green cane vs. burning) as they influence soil organic matter (SOM) content and quality (Haynes and Graham, 2004). Traditionally, sugarcane is burned prior to harvest to remove brown leaves but this is detrimental to soil microorganisms due to the loss of SOM and nutrients through particulate dispersal or volatilisation (Mthimkhulu *et al*., 2016). An alternative to pre-harvest burning is green cane harvesting, whereby brown and green leaves are retained on the soil surface as a mulch to increase SOM and nutrient content (Graham and Haynes, 2005). Numerous studies have shown a significant increase in the size and catabolic diversity of soil microbial community in green harvested compared to burned sugarcane plots (Graham and Haynes, 2005; Graham and Haynes, 2006; Rachid *et al*., 2013). Previously, Thompson (1966), Graham *et al*. (2002) and Mthimkhulu *et al*. (2016), in a long-term sugarcane trial (BT1), found a steady increase in soil acidity in green harvested compared to burned treatments under fertilised plots. These findings were attributed to nutrient mining by the sugarcane crop (due to higher crop yields), decomposition of SOM and nitrification process. Since soil acidification can lead to a shift in soil microbial communities, the authors hypothesized that the combination effect of SOM and nitrogenous fertiliser will have a negative effect on bacterial and fungi communities.

Materials and Methods

The study was conducted in a long-term sugarcane trial (BT1) established on 25 October 1939 at Mount Edgecombe to investigate the effect of green cane harvesting and burning cane prior to harvest with and without fertiliser application on soil properties and crop yields (Mthimkhulu *et al.*, 2016). Details of this trial site and analyses of bacteria and fungi are described by Mthimkhulu (2017). The upper part is classified as a Mayo soil form (Cambisol) and the lower portion as a Bonheim (Nitisol). Treatments are: a) burned with tops removed (Bto); b) burned with tops scattered (Bt); and c) green harvested and mulched (M). Further treatments were no fertiliser (Fo) and the application of fertiliser (F). Soil samples were collected at 0-10 cm depth and used to measure a) double stranded deoxyribonucleic acid (dsDNA) using the PowerSoil®

isolation kit (Mo-Bio laboratories, Carlsbad, CA, USA), b) microbial community with quantitative polymerase chain reaction (*q*PCR) for bacteria and internal transcribed spacer (ITS) for fungi. The genetic richness was estimated for each taxa using number of fragments >0.5% of the total area and evenness by the Simpson-Yule index. All statistical analyses were performed with R software (version 2.12.0 R Development Core Team. 2008), while graphs were created using SigmaPlot 14.0 software.

Results and Discussion

The dsDNA (or total microbial abundance) in Fo treatments increased as follows: Bto (10.4 µg g^{-1}) < Bt (12.2 µg g^{-1}) < M (14.4 µg g^{-1}) (Figure 1a) suggesting that the organic matter from residue retention serves as the food source for microorganisms (Graham and Haynes, 2006). The absence of this trend in the fertilized plots suggests that the impact of crop residues on microbes was counteracted by fertilisation that potentially raised soil acidity leading to decreased soil microbial abundance (Jiang *et al*., 2014). The M treatment significantly (p<0.01) increased bacterial abundance in both F and Fo plots and showed no significant differences between fertilised and unfertilised treatments. Fungal abundance decreased significantly (p<0.05) at M than in Bto and Bt in both F and Fo plots though there were no clear differences found between fertiliser treatments (Figure 1c). In comparison to Bto, M generally decreased significantly in terms of fungal to bacterial ratio (Figure 1d). These findings could be associated with higher levels of food source and soil moisture, and the higher nitrogen content measured in M plots, previously reported by Mthimkhulu *et al*. (2016). According to Ramirez *et al*. (2012) the majority of bacteria have fast growth rates and rely on more labile carbon sources, making them likely to increase in abundance with nutrient additions. Fungi increase more slowly than bacteria and normally thrive with the addition of woody material low in nutrients. Their numbers, however, decline with the addition of fertiliser (Figure 2c).

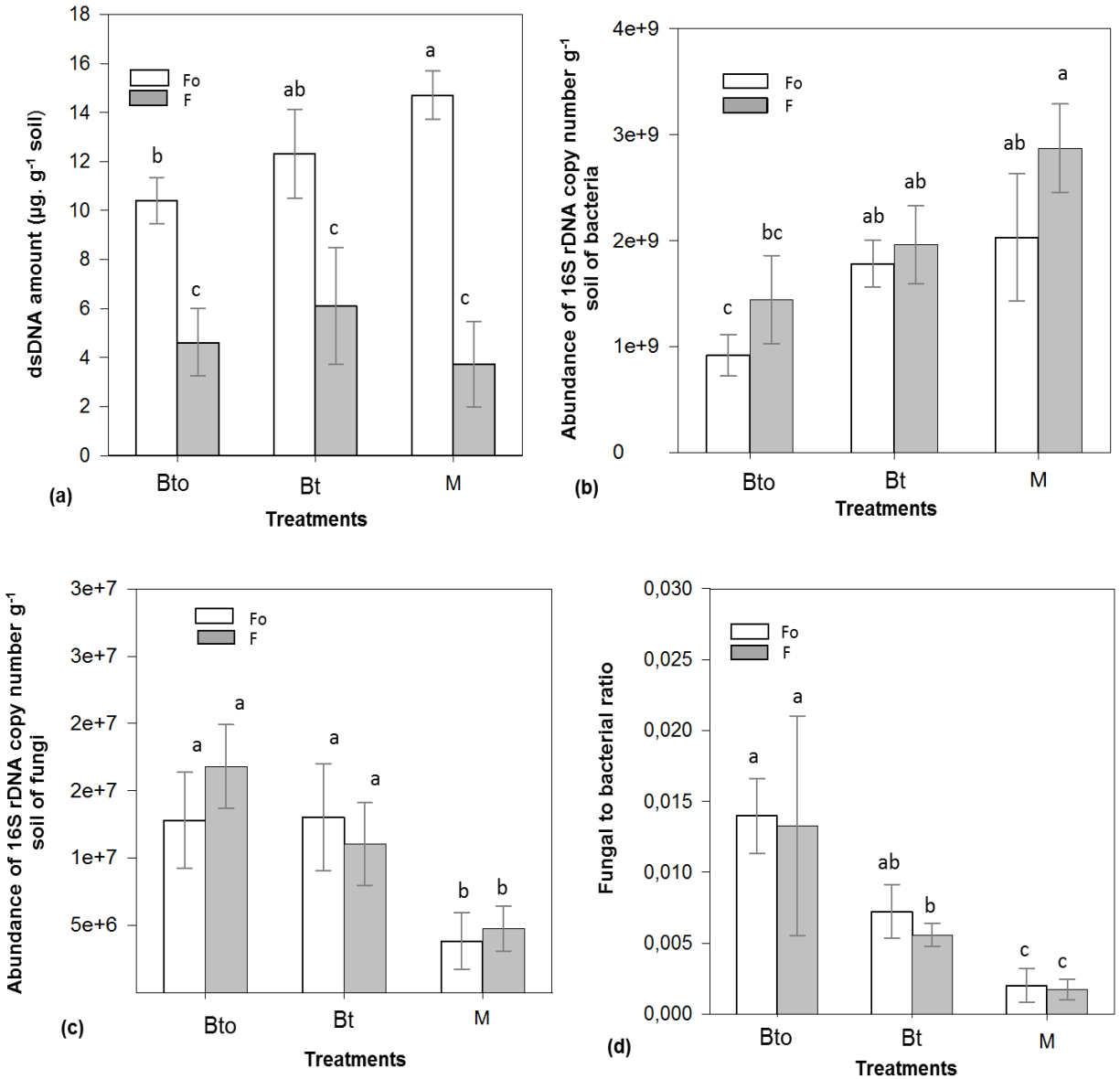

Figure 1. The mean (*n* = 4±standard error) of (a) dsDNA amount, and abundance of b) bacteria, c) fungi and d) fungal to bacterial ratio at 0-10 cm soil depth under different management treatments: Bto: burned with residues removed, Bt: burned with residues scattered and M: mulched in both Fo: not fertilised and F: fertilised treatments. Means associated with the same letter are not significantly different at *p*=0.05.

The M treatment increased bacterial and fungal richness in Fo and decreased them in F plots compared to the Bto treatment (Figure 2a and c). An overall significant ($p<0.05$) decrease in bacterial and fungal evenness with increasing in residue retention (Bt and M treatments) and fertiliser application was observed (Figure 2b and d). These results may suggest that the combinative effect of added residue and fertilisation may lead to less diverse but more specialised soil microbial community due to increased acidity (Tiquia *et al*., 2002). The negative relationship between bacterial richness and evenness measured in this study could indicate that, where there is a small number of bacterial species present, they accumulate in relatively similar amounts, while where there is a relatively large amount of bacteria, a small number of species dominate (Haynes and Graham, 2004).

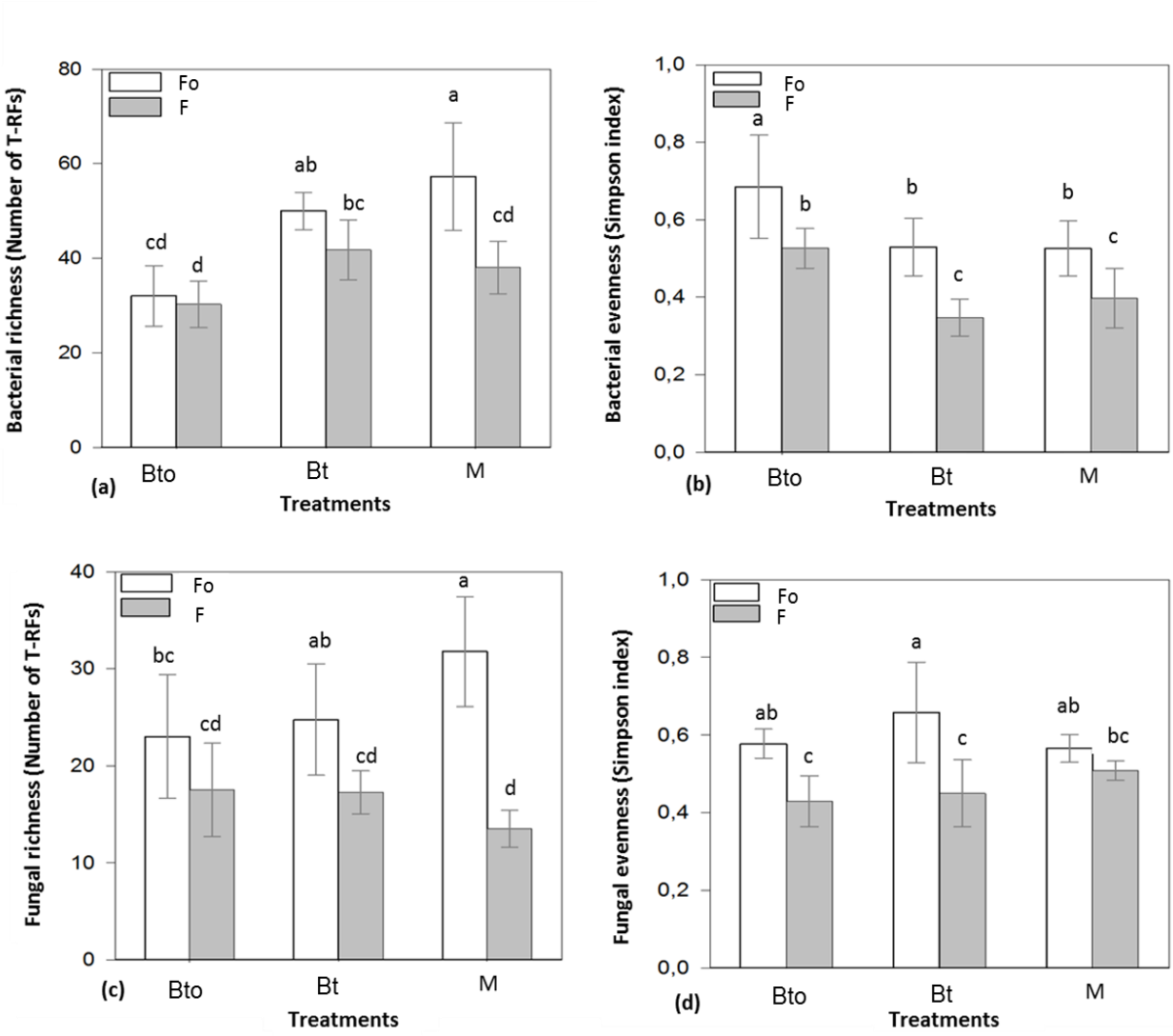

Figure 2. The mean (*n* = 4±standard error) of richness and evenness of bacteria and fungi at 0-10 cm soil depth under different management treatments: Bto: burned with residues removed, Bt: burned with residues scattered and M: mulched in both Fo: not fertilised and F: fertilised treatments. Means associated with the same letter are not significantly different at *p*=0.05.

Conclusions

The present study suggested that green cane harvesting generally improves the total abundance and community structure of microorganisms in comparison with burning prior to harvest in unfertilised plots. However, the positive effect of green cane harvesting was not found in fertilised treatments due to soil acidification. These results suggested that unbalanced fertiliser application may counteract the effect of green cane harvesting on soil microbiological properties where acidification of a clayey soil is not rigorously managed through regular soil analysis and application of liming materials.

REFERENCES

Graham MH and Haynes RJ (2005). Organic matter accumulation and fertilizer-induced acidification interact to affect soil microbial and enzyme activity on a long-term sugarcane management experiment. *Biol Fertil Soils* 41: 249-256.

Graham MH and Haynes RJ (2006). Organic matter and the size, activity and metabolic diversity of the soil microbial community in the row and inter-row of sugarcane under burning and trash retention. *Soil Biol Biochem* 38: 21-31.

Graham MH, Haynes RJ and Meyer JH (2002). Changes in soil chemistry and aggregate stability induced by fertilizer applications, burning and trash retention on a long-term sugarcane experiment in South Africa. *Eur J Soil Sci* 53: 589-598.

Haynes RJ and Graham MH (2004). Composition of the soil microbial community under sugarcane production as indicated by phospholipid fatty acid analysis. *Proc S Afr Sugar Technol Ass* 78: 331-342.

Jiang X, Cao L and Zhang R (2014). Effects of addition of nitrogen on soil fungal and bacterial biomass and carbon utilization efficiency in a city lawn soil. *Soil Res* 52: 97-105.

Mthimkhulu SS (2017). Long-term fertilizer and sugarcane residue management effects on structural stability of two soil types in South Africa. PhD thesis, University of KwaZulu-Natal, Pietermaritzburg campus.

Mthimkhulu S, Podwojewski P, Hughes J, Titshall L and Van Antwerpen R (2016). The effect of 72 years of sugarcane residues and fertilizer management on soil physico-chemical properties. *Agric Ecosyst Environ* 225: 54-61.

Rachid CTCC, Santos AL, Piccolo MC, Baliero FC, Coutinho HLC, Peixoto RS, Tiedje JM and Rosado AS (2013). Effect of sugarcane burning or green harvest methods on the Brazilian Cerrado soil bacterial community structure. *Pub Lib of Sci* 4: 1-8.

Ramirez K, Craine JM and Fierer N (2012). Consistent effects of nitrogen amendments on soil microbial communities and processes across biomes. *Global Change Biol* 18: 1918-1927.

Thompson GD (1966). The production of trash and its effects as a mulch on the soil and on sugarcane nutrition. *Proc S Afr Sugar Technol Ass* 40: 333-342.

Tiquia SM, Lioyd J, Herns DA, Hoitink HAJ and Michel FC (2002). Effects of mulching and fertilization on soil nutrients, microbial activity and rhizosphere bacterial community structure determined by analysis of TRFLPs of PCR amplified 16S rDNA genes. *Appl Soil Ecol* 21: 31-48.