# Microbial dynamics in hierarchical aggregates of tropical soil amended with bambara groundnut seed residue biochar

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## Introduction

• As a high-yield by-products (76 %) of bambara groundnut seed processing, the suitability of bambara seed residue (BSR) as a nutrient source for crop growth has been questioned due to suppressed microbial metabolism [1].

• We hypothesized that conversion of BSR to biochar would decrease the purported inhibitory properties and improve nutrient bioavailability in soil.

• Okebalama et al. [2] found an increasing availability of more nutrients (C, N, P, K and Mg) due to the addition of BSR biochar than BSR.

• By means of the hierarchical aggregate model, our understanding of the mechanisms of microbial responses to reapplied biochar can be improved.

• Aim: To investigate the effects of repeated application of BSR biochar and NPK fertilizer on soil respiration and microbial nutrient cycling in soil aggregates.

## Materials and methods

• Study location: Nsukka, Nigeria
Derived savannah zone
Humid tropical climate

Fig. 1: Map of Nigeria

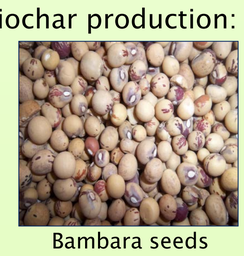
• Soil description: Sandy loam textured
Ultisol (USDA classification)

• Field experiment: 4x3 RCBD
Four years (2015 to 2018)
2015/2016: Bambara residue rates of 0, 10, 20 & 30 t ha$^{-1}$
2017/2018: Bambara biochar and NPK combination.


Fig. 2: Experimental field (224 m$^2$)

• 2018 treatment description:
control, 300kg ha$^{-1}$ $N_{20}P_{10}K_{10}$, 20t ha$^{-1}$ Biochar, and NPK+Biochar

• Biochar production: Pyrolysis in a metal barrel


Bambara seeds


Bambara residue


Bambara biochar

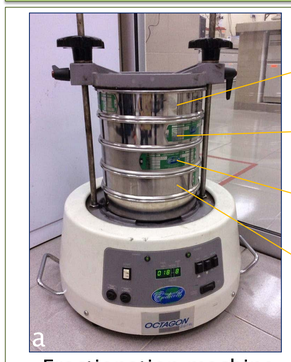
**Table 1: Soil and biochar chemical properties**

| Sample | pH KCl | Organic C % | Total N % | C/N | Avail. P mg kg$^{-1}$ | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | --------cmol$_c$ kg$^{-1}$--------- | | | |
| Soil (2015) | 4.0 | 1.26 | 0.07 | 18.00 | 10.26 | 0.04 | 0.05 | 3.00 | 0.40 |
| Soil (2017) | 4.4 | 0.97 | 0.11 | 8.82 | 13.99 | 0.01 | 0.07 | 0.12 | 0.06 |
| Biochar | 9.3 | 89.78 | 9.67 | 9.28 | 0.26 | 0.33 | 1.34 | 1.20 | 0.40 |

• Soil sampling: Undisturbed samples per plot
Post-harvest (cucumber fruit)

• Laboratory analysis:
Aggregate size separation (dry-sieving method)
Soil basal respiration (respirometer for 20 days incubation)
Microbial biomass C & N (fumigation extraction method)
Soil enzyme activities

• Data analysis: 4x4 factorial experiment in RCBD (4 treatments & 4 aggregates)



Fractionation machine

Large macroaggregates
Lma (4.75-2.00 mm)

Medium macroaggregates
Mma (1.00-2.00 mm)

Small macroaggregates
Sma (0.25-1.00 mm)

Microaggregates, silt and clay; Mia (< 0.25 mm)

Four aggregate fractions

Rewetted soil samples

Soil respiration set-up

Fumigation set-up

Soil enzyme determination

Fig. 3: Physical (a, b) and biochemical (c, d, e, f) laboratory determinations of amended soils

## Results

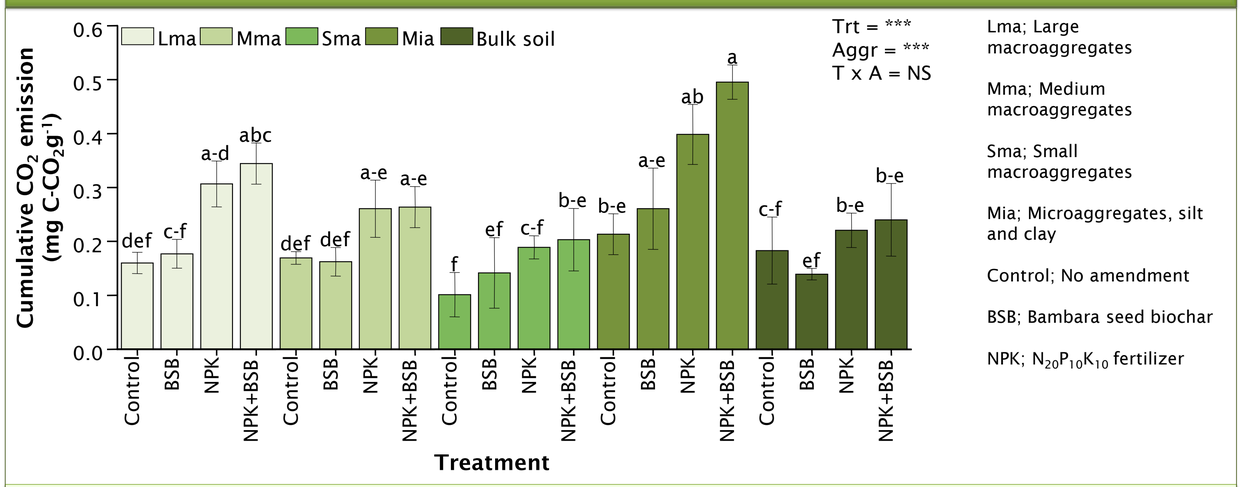


Fig. 4: Cumulative $CO_2$ emission in aggregates fractions after 20 days incubation of amended soils

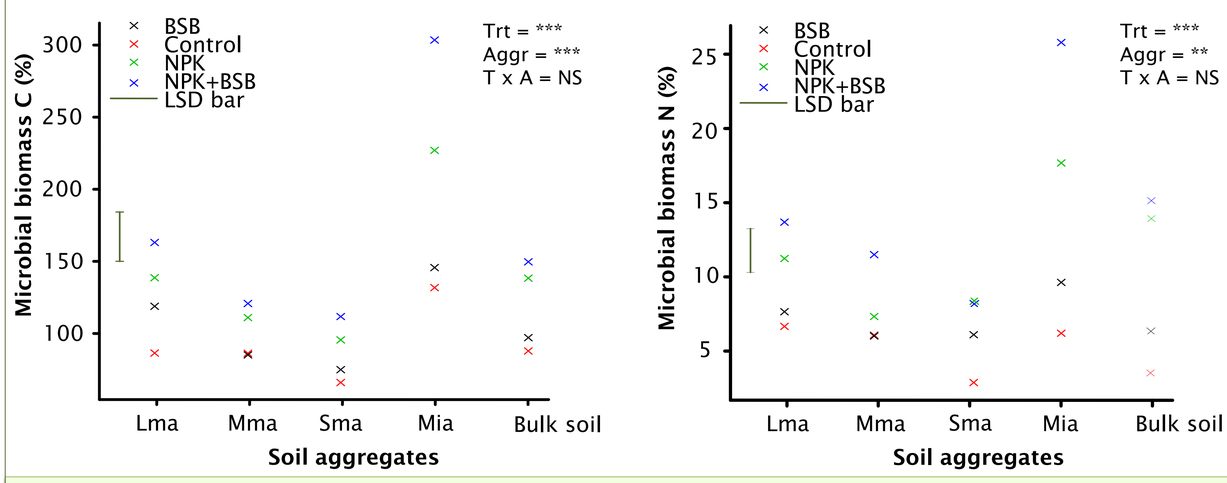


Fig. 5: Microbial biomass C in aggregates fractions after 20 days incubation of amended soils

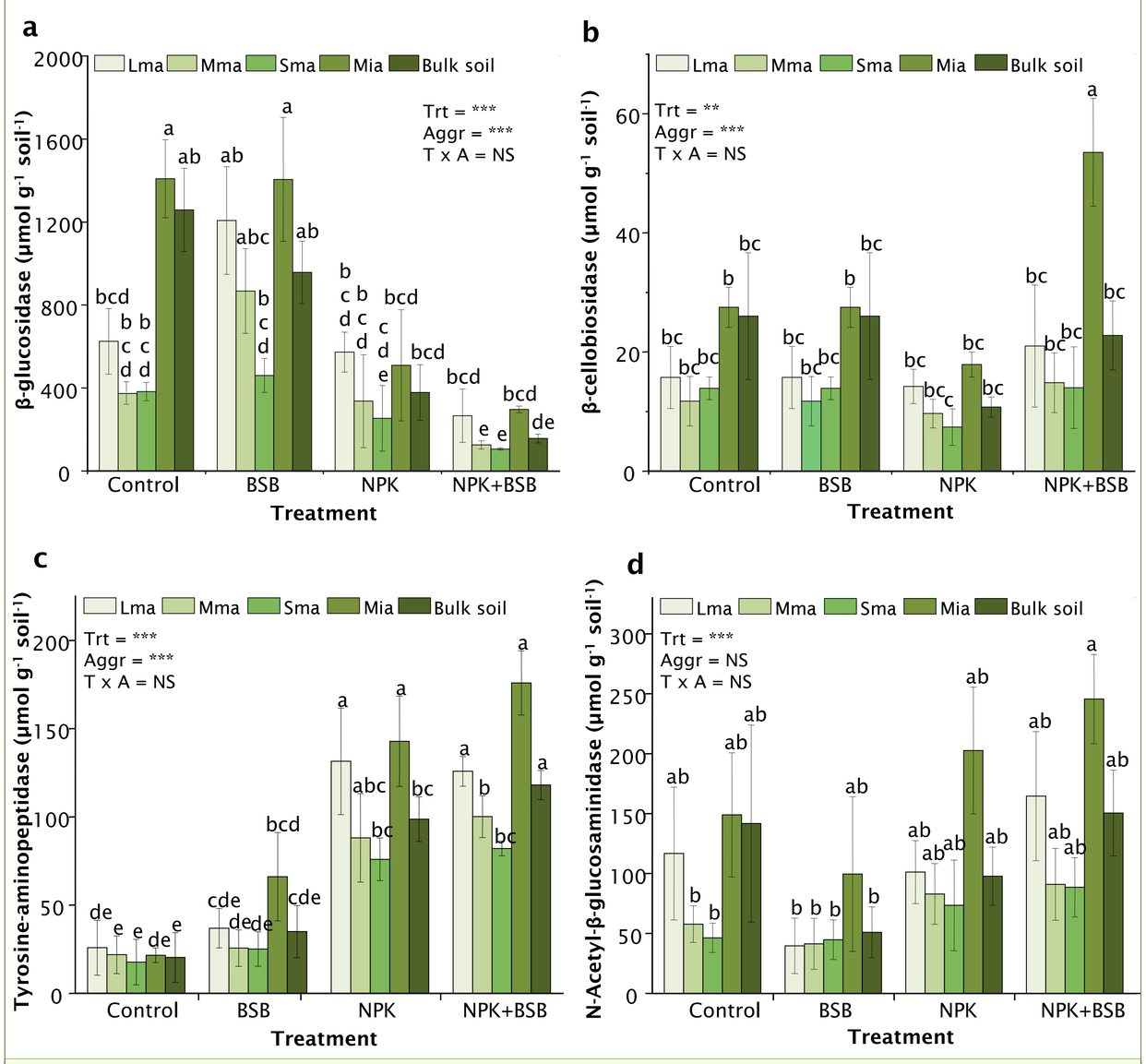


Fig. 6: Extracellular enzyme activity in amended soil aggregates fractions after 20 days incubation

## Conclusion

• The greater C mineralisation and C-cycle enzyme activities in < 0.25 mm than the macro-aggregates indicates longer turnover of the latter, contributing to SOM stabilization and soil nutrient retention.

• The substantial increase in microbial C and N with the NPK+BSB amendment demonstrates the importance of >1.00 mm macro-aggregates for more controlled, slower nutrient release and better nutrient retention of inorganic fertilizers.

• Therefore, regular applications of NPK+BSB are required to achieve long-term stabilization of SOM in macroaggregates and improvement of soil quality.

## References

[1] Okebalama, C.B. et al. (2020). *Biological Agriculture and Horticulture* 36(4): 249–266.

[2] Okebalama, C.B. et al. (2022) *Agro-Science* 21(2): 53-65.