The Effects of Organic and Inorganic Amendments on Soil Microbial Biomass Carbon Under Maize (*Zea mays*) Cultivation in Buea, Southwest Region of Cameroon

***Ekuri Brian Akom[1], Veronica Ebot Manga[1], Amahnui George Amenchui[1,2], Nkeng Joel Junior[4], Ntegang Venant Atem[3], Forbin Maxwell Aleanu[1]**

[1]Department of Environmental Science, Faculty of Science, University of Buea, P. O. Box 63, Buea, Cameroon.

[2]International Center for Tropical Agriculture (CIAT), Km 17 recta Cali-Palmira, Cali 763537, Colombia

[3]Department of Geology, Kangwon National University, Chuncheon 24341, Republic of Korea

[4]Pan African University Institute of Water and Energy Sciences Including Climate Change (PAUWES), Algeria

***Corresponding Author**

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ABSTRACT

The application of various fertilizers have been adopted by farmers all over the world to secure food supply that can cope with rapid population growth and urbanization, this has led to concerns on their effect on the natural environment. This study aimed to determine the effects of municipal solid waste compost (MSWC) and urea on soil microbial biomass carbon (MBC) under maize (zea mays) production over a four-month period (April-July 2022). The experiment was a Randomized Complete Block Design (RCBD) with three replicates, and three treatments; organic fertilizer (OF), no fertilizer (NF), synthetic fertilizer (SF) with an amendment rate of 100 kg per hectare. Soil samples were collected at a depth of 0-15cm. The effects of soil amendments on MBC were determined using the chloroform fumigation extraction method. ANOVA was used to determine the difference in MBC. Results showed that MBC varied significantly before and after amendments ($p<0.05$). All treatments show increased MBC after amendment. However, the largest relative increase occurred in OF plots, an indication that amendment stimulated microbial biomass where baseline MBC was low, showing a highest relative increase of 218.13% compared to 86.49% and 18.59% in NF and SF plots respectively. These findings underscore the potential of organic amendments to provide labile carbon and nutrients that stimulate microbial growth, promoting soil health and sustainability in agricultural practices. More research is needed to understand the dynamics of MBC at different depths with amendments and the effects of seasons on MBC in the volcanic soils of Buea.

Keywords: Microbial Biomass, Carbon, Fertilizer types, Agriculture

INTRODUCTION

World's population has increased dramatically in recent years and is projected to reach 9.8 billion by 2050 (United Nations, 2023), leading to concerns about global food security. In order to secure food supply that can cope with the rapid population growth and urbanization, the application of various fertilizers have been adopted by farmers all over the world. FAO cited in Motesharezadeh et al., 2017 reports that 33 to 66% of the increase in agricultural production over the past few decades was due to the application of chemical fertilizers. The global demand for fertilizer nutrients (N, P_2O_5, and K_2O) for 2015 was 184.02t and 201.66t in 2020. The demand for nitrogen fertilizer was estimated to increase from 110.03 to 118.76t from 2015 to 2020, with an annual growth rate of 1.5% (FAO, 2017). Fertilizers are known to have a devastating effect on the environment and soil ecosystem (Tilman et al., 2001). For instance, nitrogen (N) is an essential element for plant growth and development and is one of the most limiting elements in agriculture because it occurs in low levels in soils with low organic matter content (Bashir et al., 2013). However, excessive N additions can pollute ecosystems and alter both their ecological functioning and the living communities they support (Erisman et al., 2013).

SMB is the living component of soil organic matter other than fauna and plant roots in soil. It accounts for about 5% of organic matter in soil and contains all the mass of microorganisms such as bacteria, fungi, and protozoa (Jenkinson, 1981, Spohn et al., 2016). Soil microbial biomass reflect microbial size and soil fertility status and act as the living nutrient pool in soil (Nair, 2012). SMB is also considered an early indicator of soil health of agroecosystems (Sparling, 1997). The amount of microbial biomass Carbon is an indication of the ability of the soil to sequester Carbon - a greenhouse gas. The determination of microbial biomass could serve as an indicator of early changes in soil C stability following land use change, given that MB responds quickly to slight changes in soil environment (Brookes, 2001).

According to the Food and Agricultural Organisation Statistics FAOSTAT (2010), maize is produced on about 100 million hectares in developing countries, with estimated 70 % of the total maize production in the developing world coming from low and middle-income countries like Cameroon. Thus, the most important cereal that is cultivated in most parts of sub-Saharan Africa. In Buea sub-division, maize is the most consumed and produced crop, the crop provides a continuous and secured food supply in terms of good yields and is a source of income for farmers. Even more, maize provides a better option during periods of frequent food insecurity which usually arises due to climate-related problems (Sounders et al., 2017).

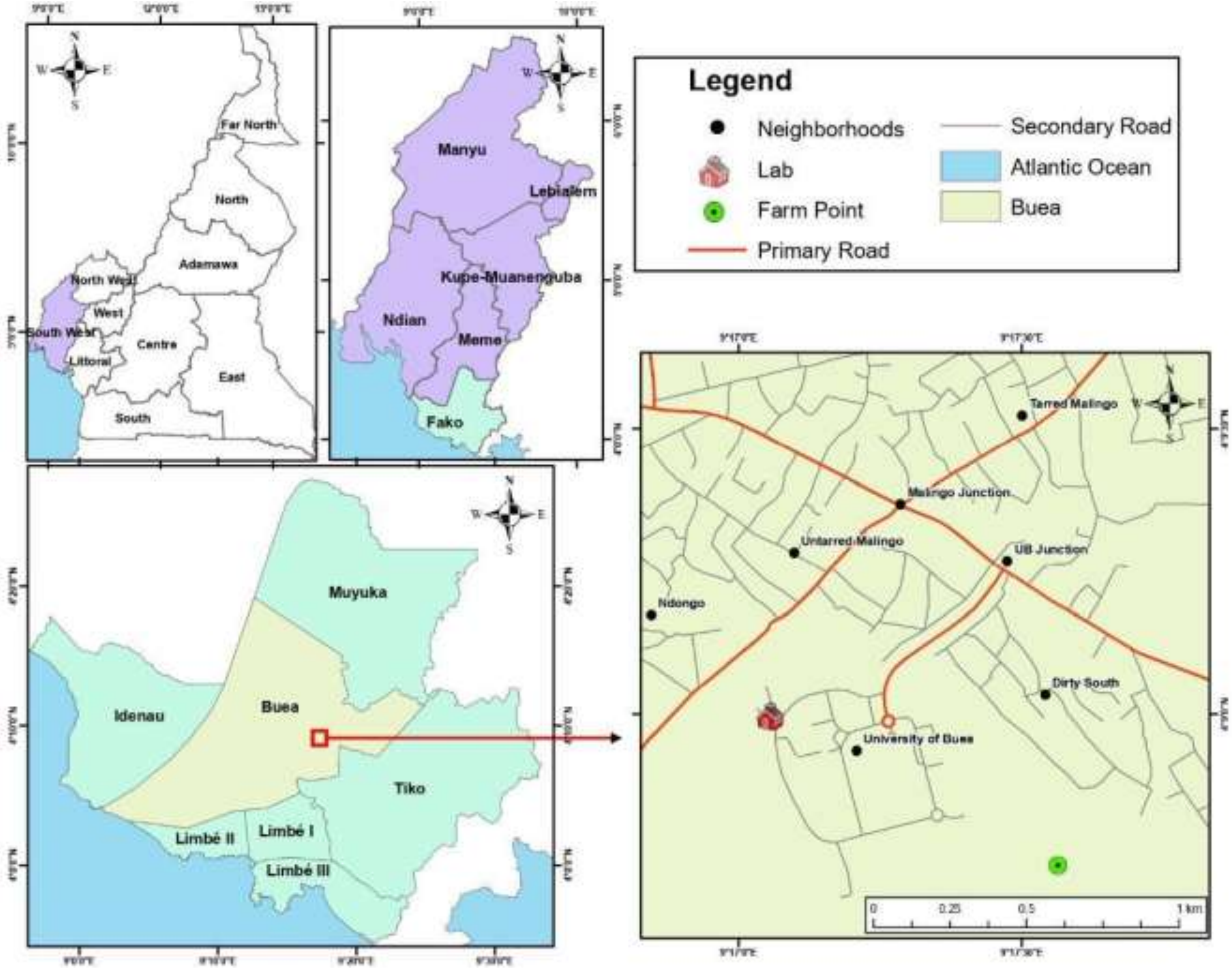
Agriculture in the tropics is rain fed and or is largely determined by climate, therefore more studies are necessary in finding ways to promote soil C sequestration and soil fertility in croplands. Integrated soil fertility management (ISFM) presents an opportunity to simultaneously address food security issues and climate change in Africa. ISFM is a set of agronomic practices adapted to local conditions to maximize nutrient use efficiency and sustainability (Ngosong et al., 2015). Research shows that the use of mineral fertilizers is constantly growing and there is increasing concern regarding the negative environmental effects of chemical fertilizers on the soil ecosystem. It is for this reason that this study was conducted to observe the behavior of microbial biomass carbon with MSWC and Urea in Buea, Cameroon on the premise that both soil amendments have a significant effect on microbial biomass carbon. An experiment was conducted in University Buea during the major growing season of 2022.

METHODOLOGY

Description of the Study Areas

Buea subdivision is located on the eastern slope of Mount Cameroon between latitude 3º57 ' to 4º27'N and longitude 8º58' to 9º25'E. The University of Buea where the experiment was conducted is located between latitudes 4º3’N and 4º12’N and longitude 9º12’E and 9º20’E (Ngosong et al., 2019). Buea falls under the equatorial climate, the Cameroon type or montane climate sub type. The climate of the Mount Cameroon region is characterised by its seasonal nature. The seasons are very well defined with two major seasons; a rainy season, which runs from Mid-March to Mid-October, and a dry season from Mid-October to Mid-March. March is the warmest month of the year, temperature in March averages 19.7°C. In July, the average temperature is 17.3°C and is the lowest average temperature of the whole year (Ajonina et al., 2021). The average temperatures vary during the year by 2.4°C. Mean annual rainfall ranges between 3000 – 5000 mm and a mean annual temperature of 20 -28°C (Ako, 2011). Buea has a mountainous terrain with thick evergreen forest vegetation and transitional changes along an altitudinal gradient. The soil type is basically volcanic (Cable and Cheek, 1998). There are two growing seasons for agricultural practices in Buea; the major growing season from March to July and the minor growing season from September to November. Figure 1 shows the map of the study area.

Figure 1: Map of the study area



Experimental Design and Treatment

A field experiment was conducted at the University of Buea during the major growing season of 2022 from May to July. This research employed the randomized complete block design (RCBD) with three treatments replicated three times. The main plots were separated by a 5M buffer. The experiment made use of compost and urea as soil amendments. The conventional system received inputs of a synthetic fertilizer (urea), while the organic system was amended with compost, no amendment was applied to the control plots. No pesticide or fungicide was applied in any of the systems. The soil was analyzed for physicochemical properties prior to treatment to establish baseline conditions.

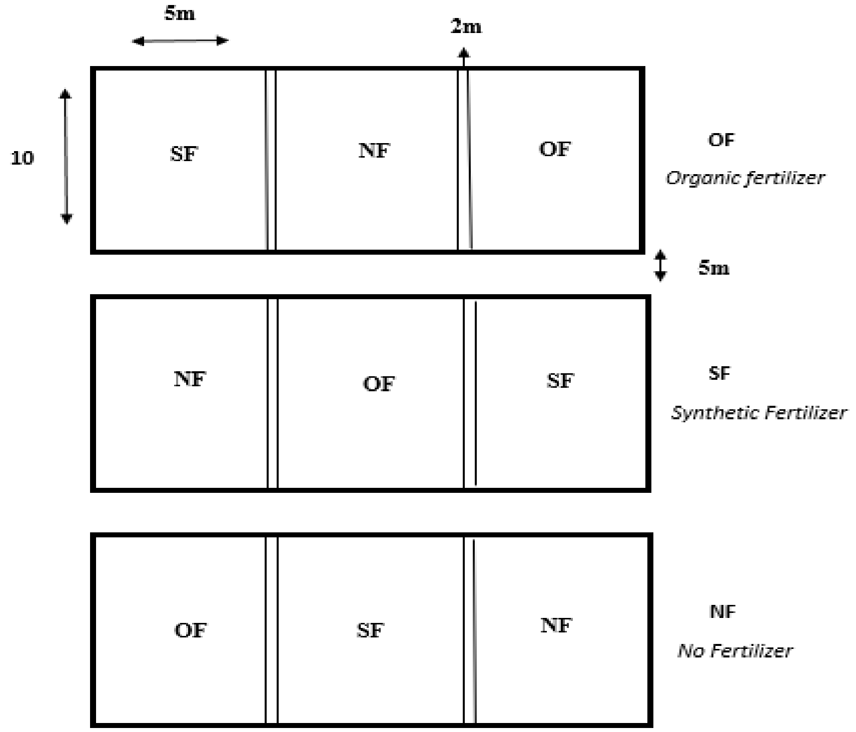
As shown in figure 2, the treatments were;

OF= organic fertilizer/MSWC (100kg/ha)

SF= synthetic fertilizer/Urea (100kg/ha)

NF= not fertilized/control (no amendment)

Figure 2: Randomized Complete Block Experimental Design



Plot preparation

The vegetation on the land was cleared manually with a cutlass and rake. The field was then lined, pegged, demarcated, and labelled into plots. A measuring tape was used to split the study site into 9 sub-plots of 50 m^2 each (10 m x 5 m). The spacing between columns and rows was 2m and 5m respectively. Maize was planted at a spacing of 80 cm by 40 cm.

Farm Management Practices

Amendment application

Soil amendments were applied by side placement 4 weeks after planting (WAP) a nitrogen fertilizer application rate of 100 kg ha-1 was adopted based on recommendations of Ngosong et al., (2019) on best N application rate in volcanic soils, both fertilizers were applied on the same day. Based on the N content (11%) of the compost samples analyzed, compost was applied at the rate of 4.550 kg per plot of 50 m^2 to provide 100 kg/ha equivalence application of N as recommended by Ngosong et al. (2019). For Urea, with a known concentration of N (46%), we applied it at the rate of 1.1 kg per plot to provide the equivalence of 100 kg/ha.

Planting and thinning

The cultivar of the test crop was the hybrid maize cultivar CMS 8704. Planting was done two weeks after the land was prepared, four maize seeds were sown per hill and were later thinned to two and three per hill, three weeks after germination.

Weeding

Removal of unwanted grass was done with the aid of a cutlass and hoe once a month in order to reduce competition of weeds with the maize plants.

Sample Collection and Analyses

A total of 18 soil samples were taken throughout the experiment, that is 9 samples before and 9 samples after soil amendment, collected twice at four- and eight-weeks interval and at a depth of 0 -15 cm with the aid of a soil auger. The sampling was done on the 5th of May and 5th of July. On the field, soil samples for microbial biomass analysis were stored in Zip lock bags and put in an ice cooler throughout the data collection period and stored in a refrigerator immediately after the data collection exercise.

Initial Sampling

Samples were taken at random from each plot. The five auger soil samples were then bulked as representative samples for each plot. As shown in table 1, the samples were analyzed for physicochemical properties such as soil texture, pH, electrical conductivity, soil organic carbon, organic matter, total nitrogen, and cation exchange capacity after air-drying. Municipal Solid Waste Compost was also analyzed for NPK characteristics (Table 2).

Table 1: Soil Physico-chemical properties of Plots

Soil properties	**OF**	**NF**	**SF**
Clay	29.25	22.33	31.58
Silt	22.44	29.25	31.5
Sand	48.31	48.42	36.92
pH-water	5.77	5.77	5.7
pH-KCl	4.7	4.70	4.7
Δ Ph	-1.07	-1.07	-1
OC (%)	2.29	2.29	2.51
OM (%)	3.94	3.95	4.31
Nitrogen tot. (%)	0.21	0.24	0.21
C/N	10.91	9.54	11.95
CEC pH7	12.33	12.33	12.5

Table 2 Results of NPK Content of Soil and MSWC

Sample	**N**	**P**	**K**
Soil sample	0.95	4.10	4.50
Compost	11	0.24	1.54

Measurement of microbial biomass

Soil samples were taken from the base of each plant at a depth of 0–15 cm. The samples were put in Ziplock bags, stored in an ice cooler on the field and taken rapidly to the biogas lab, university of Buea where the samples were stored in a refrigerator before being transported to the University of Dschang for microbial analysis. The representative samples (9) were subjected to microbial analyses in the fresh state after sieving through a 4-mm mesh at the University of Dschang, faculty of agriculture.

Microbial biomass carbon were determined by the chloroform-fumigation extraction method (Vance et al., 1987). Ten grams of field moist soil sample was passed through a 4mm mesh. Sample was then put in a crucible and placed in a desiccator. A shallow dish containing 30 ml of alcohol –free chloroform was placed by it. A crucible containing a control sample (10 g) was placed in a separate desiccator without chloroform. The desiccators were covered and allowed to stand at room temperature for 5 days (Anderson and Ingram, 1993). Fifty milliliters of 0.5 MK_2SO_4 solution was added to the soil samples to extract microbial carbon from the lysed microorganisms immediately after fumigation. Kjeldahl's method was used to determine the total nitrogen from the extract. The amount of microbial carbon in the extract was determined using the colorimetric method. An aliquot (5 ml) of the extract was pipetted into a 250 ml Erlenmeyer flask. Five milliliters of 1.0 N (0.1667 M) potassium dichromate and 10 ml concentrated sulphuric acid were added. Ten milliliters of distilled water was added after the resulting solution was allowed to cool for 30 minutes. A standard series was developed alongside with carbon concentrations ranging from 0, 2.5, 5.0, 7.5, 10.0 mg/ml C. These concentrations were obtained when volumes of 0, 5, 10, 15 and 20 ml of a 50 mg/ml C stock were pipetted into labelled 100 ml volumetric flasks and made up to the mark with distilled water. The absorbance of the standard and sample solutions were read on a spectronic 21D spectrophotometer at a wavelength of 600 nm. By plotting absorbance values of the standard solutions against their resultant concentrations, a standard curve was obtained. The standard curve aided in the determination of the concentration of the extracted carbon of the samples. For biomass C calculations, k -factors of 0.35 and 0.45 were used, respectively. The following equations according to Sparling et al., (1990) were used to estimate the microbial C from the extracted C

Microbial C (mg) = Ec/k

Where,

Ec = the extracted carbon produced following fumigation

k = the fraction of the killed biomass extracted as carbon under standardized conditions.

Statistical analysis

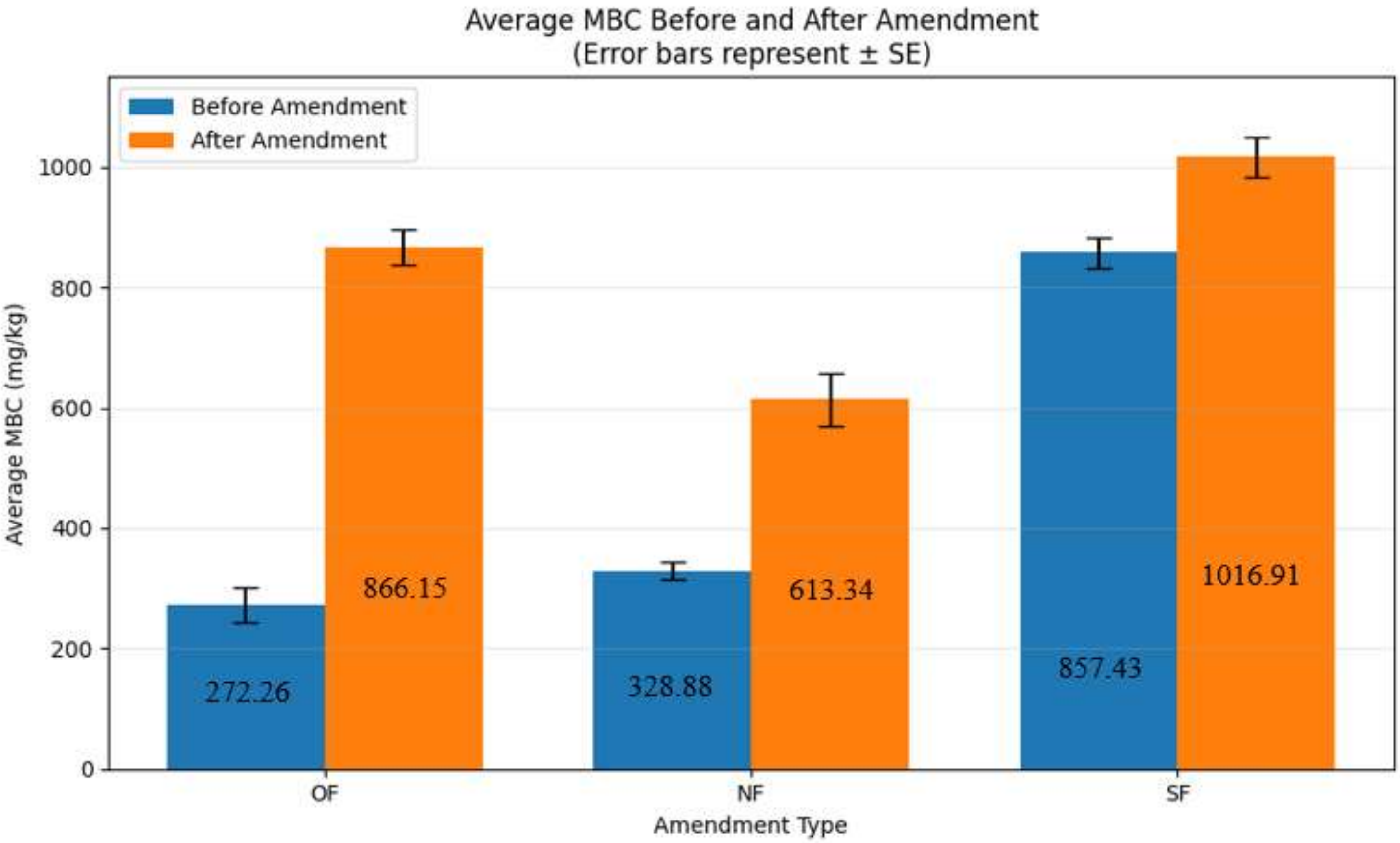
Results of microbial biomass carbon obtained from the laboratory were subjected to one way ANOVA with Microsoft Excel 2019 to test if there is significant difference in microbial biomass carbon with respect to soil amendments. Separation of means was done using the least significant difference (LSD) method at P = 0.05, and percentage differences were calculated to get the percentage increase or decrease in MB with amendments

RESULTS

Effect of Organic and Inorganic Amendments on Soil Microbial Biomass Carbon

Figure 3 shows sampling results for soil microbial biomass carbon before and after amendments. Soil microbial biomass carbon varied across the different plots. The highest average MBC occurred in SF plot (857.43 mg/kg) was observed, while the lowest average MBC (272.26 mg/kg) was observed in plot OF. The maximum MBC (897.11 mg/kg) occurred in a plot amended with urea (SF), whereas the minimum (211.89 mg/kg) occurred in a plot amended with compost (OF plot). The results of the analysis of variance (ANOVA) indicated a statistically significant difference in MBC among the different plots (P-value $< \alpha = 0.05$).

Figure 3: Results for microbial biomass carbon before and after amendment



Results for MBC eight weeks after the application of amendments indicate a general buildup of MBC in all plots. The highest average MBC (1016.91 mg/kg) was observed in the SF plots. The OF plots recorded 866.15 mg/kg, whereas the lowest occurred in the NF plots (613.34 mg/kg). Additionally, the maximum MBC (1074.89 mg/kg) occurred in a plot amended with urea (SF), and the minimum (543.35 mg/kg) occurred in a control plot (NF). The ANOVA results showed a significant difference in MBC among the plots after the application of the soil amendments (P-value< α 0.05).

DISCUSSION

Effect of soil amendments on microbial biomass carbon

There was a significant variation in microbial MBC before and after the application of soil amendments. All fertilizer types showed increases in mean MBC after amendment: from 272.26 to 866.15 mg/kg in the OF plots, from 328.87 to 613.34 mg/kg in the NF plots, and from 857.43 to 1016.91 mg/kg in the SF plots. Based on the percentage change in MBC, there was more than a doubling in the OF plots, with an increase of 218.13%. The NF plots recorded an 86.49% increase, whereas the SF plots showed an 18.59% increase from the initial value. Although the OF and NF plots had low baseline MBC compared with the SF plots, the highest relative increases occurred where the baseline values were lowest. This result is consistent with the findings of Garcia-Gil et al. (2000a). They reported that MSWC addition increased microbial biomass C by 10% and 46%, respectively, at application rates of 20 and 80 tons per ha-1 as compared to the control (no amendment).

The increase in MBC in OF plots signifies the availability of labile carbon and nutrients from organic amendment that stimulate microbial growth. The increase in NF plots suggests the positive effects of environmental conditions which have a fundamental role to play in the buildup of SMB. While the high baseline in SF plots occurred from previous enrichment in the 2020-2021 growing season.

The general buildup in MBC could be as a result of the tillage practice in operation, given that soils under zero tillage systems are known to harbor high MBC. Wright et al., (2015) noted that soil MBC was highest under no-tillage than any other tillage type observed at 2.5 - 20 cm in their study conducted in Nigeria. Also, tillage practices that are less disruptive to soil can increase the microbial biomass by increasing labile carbon in soil. These management practices also protect soil aggregates and do not break fungal networks, which are an important habitat for the microbial biomass in soil.

In addition, the moderate levels of SOC recorded in all plots also explains the general buildup in MBC given that SOC plays a significant role in reducing atmospheric CO_2 and serves as a source of food for microbes, enhancing soil quality, sustaining and improving food production. Moreover, the warm and wet/humid climatic conditions of the study area in the month of July could also be another reason for the increase in MBC. These conditions accelerate litter decomposition as microbial activities and decomposition peak, thereby increasing the immobilization of nutrients by the microbes. Furthermore, the high relative humidity during the wet period of July accelerates the growth of fungi, which further increases microbial biomass carbon. Lastly, the increase in MBC could also be attributed to the stable C/N ratio. The ratio favors the decomposition of organic materials which can supply sufficient nutrients for microbes.

The findings of this study are contrary to the findings of Agyenim & Ayisi (2015), who found that soil amendments did not affect MBC in arid soils of Ghana. Similarly, there was a significant variation in MBN between the different treatments before and after the application of soil amendments (P=0.00) in their study.

CONCLUSION

This study shows the positive impact of municipal solid waste compost on soil microbial biomass carbon, and its viability as a sustainable alternative to synthetic fertilizers. Further research into the effect of urea and compost on MBC at different depths and the long-term effects of compost applications on microbial dynamics is recommended to better inform agricultural practices.

It is recommended that farmers in Buea and Cameroon should consider using compost to enhance the buildup of microbial biomass carbon in the soil. In addition, farmers are encouraged to use both organic and inorganic amendments at the same time, a possible combination of chemical and organic fertilization is known to be a good way to not only improve soil health and fertility, but also for enhancing crop yield and ensure food security, particularly for soils with low N, P and organic carbon content. Additionally, farmers are advised to create a farm management plan to occasionally test the soil in order to plan effective and sustainable soil management operations. This will enable farmers to be aware of the right amendments to use at a given time.

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