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Responses of soil microbial biomass carbon to tillage and fertilizer types in maize cultivation in Buea, Cameroon

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Although soil microbial biomass (MBC) comprises less than 5% of soil organic matter, it responds rapidly to changes in soil management practices and, therefore, is generally used as an early indicators of changes in soil carbon. The objective of this study was to evaluate the effects of tillage practices (conventional tillage and no-tillage) and fertilizer types (synthetic, organic, and no fertilizer) on soil MBC. The field experiment, located in Buea, was arranged in a split-plot design with three replications and had tillage systems as main plots and fertilizer types as sub-plots. Soil samples were collected at 0–15 cm depth at an interval of 4 (early season), 8 (mid-season) and 12 (late season) weeks during the 2020 and 2021 minor and major growing seasons respectively, for the determination of soil MBC by the chloroform fumigation and extraction method. The findings of the study showed that the main effect of tillage practice and fertilizer types was nonsignificant ($p>0.05$) in the 2020 and 2021 study season throughout the sampling period. Plots under zero tillage with control experiments (No.Till:CON) recorded the highest soil MBC in the 2020 season (201 mg/kg) while in the 2021 season, plots under zero tillage with organic fertilization (No.Till:ORG) recorded the highest (400.4 mg/kg) soil MBC. Soil MBC was higher in the 2021 season than in the 2020 season. These findings suggest that the use of compost in combination with either conventional tillage or no-tillage in farms in the study area could potentially enhance soil MBC.

Key words: Tillage, fertilizer type, microbial biomass carbon, carbon sequestration.

INTRODUCTION

Soil organic carbon (SOC) in the top 100-cm soil layer holds about two times as much carbon (C) than is in the atmospheric pool, making the soil the largest C pool in the terrestrial biosphere (Chen et al., 2015). According to

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Jagadamma and Lal (2018), the C sink capacity of the earth's soil is about 1 Pg C year^{-1}. This means that relatively small change in SOC can have a significant impact on atmospheric CO_2 level (Lal et al., 2007). Currently, there is a strong interest in sequestrating C in soils to help decrease atmospheric CO_2 level (Liang et al., 2021). Agroecosystems, which represent large portions of terrestrial ecosystems, if well managed, can provide an opportunity to increase soil C pools and reduce atmospheric CO_2. In agroecosystems, enhanced C sequestration in agricultural soils does not only have the potential to help reduce atmospheric CO_2 concentrations (Sperow et al., 2003), but also promotes the productivity and sustainability of agricultural systems since increased soil C sequestration in agricultural soils improves soil quality, increases soil productivity, and reduces risk of soil erosion and sedimentation (Lal et al., 2007). In Africa, crop productivity is most affected by the adverse impacts of climate change. Therefore, more studies are needed that address how to promote enhanced C sequestration in cropland ecosystems.

Although soil microbial biomass comprises less than 5% of organic matter, it responds rapidly to changes in soil management and can be used as early indicators of changes in soil C and C sequestration (Kallenbach and Grandy, 2011). In agroecosystems, soil management practices such as tillage systems and fertilizer types affect soil microbial biomass. Tillage operations, which are the ploughing of the soil to prepare it for sowing, can decrease soil microbial activity and organic matter (Mohammadi et al., 2012). Continuous use of conventional tillage (CT) system influences the physical and chemical properties of soils which in turn directly affect the biological activities of the soil (Lupwayi et al., 2012). Tillage mechanically disturbs soil aggregates; increases soil aeration, and accelerate soil organic matter decomposition by soil micro-organisms. On the other hand, minimum and no-tillage can improve soil physical properties as macro-pore structure, aggregate stability, nutrients availability, and enhance the diversity and activity of microbial populations. In a four-year study conducted by Lupwayi et al. (2012) in Saskatchewan, Canada, authors noted that zero tillage increased soil microbial biomass (MBC) by 30 to 102% and tended to increase bacterial functional diversity under corn cultivation. Similarly, Wright et al. (2015) also noted that soil MBC and were often highest under zero tillage and minimum tillage in surface soils in tropical soils under corn. According, Wright et al. (2015), conventional tillage recorded the lowest soil MBC during the period of the study.

The application of fertilizer to provide nutrients for crops can influence soil chemical properties, and microbial biomass and activity. For example, the application of organic fertilizer enhances soil microbial activity, through improving activity of soil enzymes and increasing soil microbial biomass (Nair and Ngouajio, 2012). Chu et al. (2007) in a study conducted to investigate soil MBC response to fertilization application types noted that organic fertilization had a significantly greater impact on the soil MBC and the activity of soil microbes compared with mineral fertilizers. In a recent study conducted in the Liaoning Province of China, Luo et al. (2015) shared similar results as their findings revealed that long-term organic fertilization greatly increased soil MBC, while synthetic fertilization reduced soil MBC. The authors concluded that organic fertilizer had a significantly greater impact on soil MBC under corn cultivation. Aside of its carbon sequestration benefits in the soil, soil microbial biomass (SMB) is an immediate sink of N, P and S (Dick, 1992); and it is an agent of nutrient transformation and pesticide degradation. Soil microbial biomass is, therefore, a fundamental component of nutrient cycling in agroecosystems.

Despite the multiple benefits of sequestering C in agricultural soils, the impacts of key soil management practices such as tillage and fertilization types on SMB is still under reported in many agro-ecological areas across Africa. Also, in most parts of Africa including Cameroon, farmers apply both inorganic and organic fertilizers without taking into consideration their effects on SMB. This, sometimes, leads to poor planning and management of soil amendments, which in turn results in the reduction of farm productivity since SMB plays an important role in soil organic matter decomposition and nutrient cycling (Logah et al., 2010). One of the biggest challenges of agriculture in many parts of Africa is to find best soil management practices that guarantees food production and environmental sustainability, while minimizing the vulnerability of the farming system to the impacts of climate change (Jouzi et al., 2019). Therefore, localized studies on the role of soil management practices on SMB, which can be used as an indicator of C sequestration and nutrient cycling in agroecosystems, are more than needed. There is need to document the impacts of soil management practices on microbial biomass carbon in Buea, Cameroon. This study was designed to bridge this knowledge gap. We hypothesized that tillage and fertilizer types have a significant effect on microbial biomass carbon. To test this hypothesis, we investigated the response of soil microbial biomass carbon (MBC) to tillage regime (till vs no-till) and soil amendment types (that is, synthetic fertilizer, organic fertilizer, and unfertilized control) under maize cultivation in the 2020 and 2021 growing seasons in the Buea Municipality, Southwest Region of Cameroon.

MATERIALS AND METHODS

Description of study area

The field experiment was conducted at the research farm of the Department of Environmental Science, University of Buea. The University of Buea is located between latitudes 4º3'N and 4°12'N and longitude 9°12'E and 9°20'E (Ngosong et al., 2019). Buea, which is the capital of the southwest region of Cameroon, lies along the eastern slopes of Mount Cameroon, bounded to the north by a

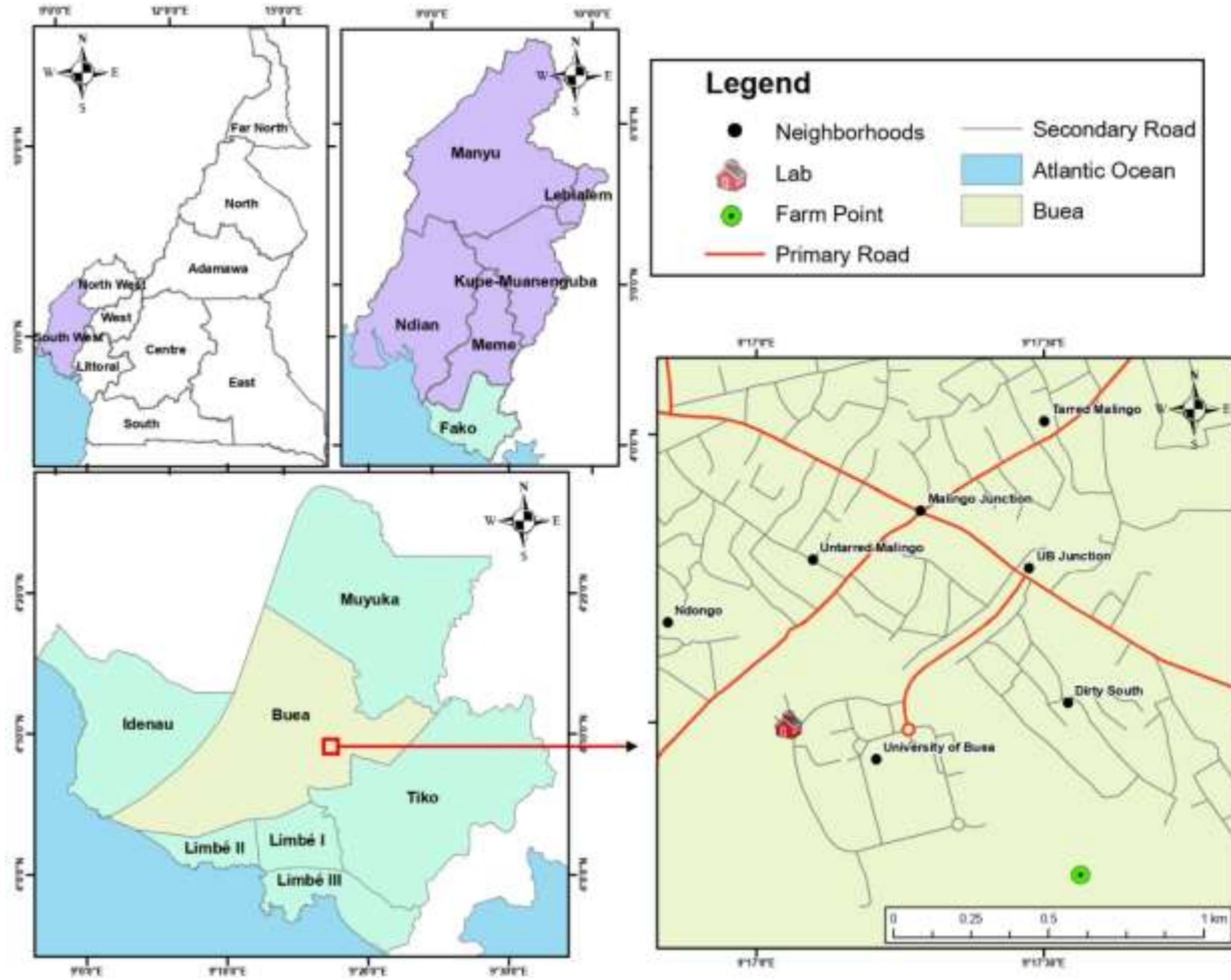

Figure 1. Map of the study area.
Source: Authors

tropical forest on the slope of mount Cameroon (4,100 m a.s.l.). The mountain range extends to the beautiful sandy beaches of the Atlantic Ocean. The town also shares boundaries with other major towns like the city of Limbe to the south-west, Tiko municipality to the southeast, Muyuka municipality to the east, and Idenau district to the west (Figure 1).

Buea has an equatorial climate with two major seasons; a rainy season, which runs from March to October; and a dry season, from November to February. Temperature ranges between 20 ^{o}C to 28 ^{o}C, while annual rainfall ranges between 3000 mm and 5000 mm. The equatorial climate of the city makes it possible to have two maize growing seasons in Buea; the major growing season from March to July and the minor growing season from September to November (Ako, 2011).

The soils of this region are developed from the weathering of a basaltic parent rock. These soils have been intensely weathered in some areas to produce well drained to clayey reddish brown and yellowish soils, which are over 10 m thick. Yet in other areas, the soils are well drained, relatively young black soils developed from protracted weathering of basaltic rock and pahoehoe lava flows (Ako, 2011). Buea soils are very rich in nutrients and support the cultivation of various crops such as maize, tomatoes, cabbage, okra, pepper, corn, cocoyam, yams, cassava, plantains, beans, vegetables and even some cash crops such as palm trees, cocoa, and bananas (Ngosong et al., 2019).

Experimental design and treatments

The field experiment was conducted during the 2020 minor growing season (Late September to Late December 2020) and 2021 major growing seasons (Late March to early July 2021). The field experiment was a split-plot design with three replications (Figure 2). The main plot factors were tillage practices (that is, conventional tillage and no-till) and the sub-plots were fertilizer types (that is, organic, inorganic, and no amendment used as control). Within each replicate, a 2-m buffer was kept between the main plots and the sub-plots and a 5-m buffer to separate the blocks or repetitions.

The tilling systems evaluated was no till and conventional till. Two fertilizer types (composted municipal solid waste and Urea) and a control (no amendment) were adopted. A nitrogen fertilizer application rate of 100 kg/ha was adopted based on the recommendations of Ngosong et al. (2019) on best N application rate in volcanic soils along the slopes of Mount Cameroon. Prior to applying the compost, samples were taken for analysis for the determination of N, P and K concentration in the compost manure.

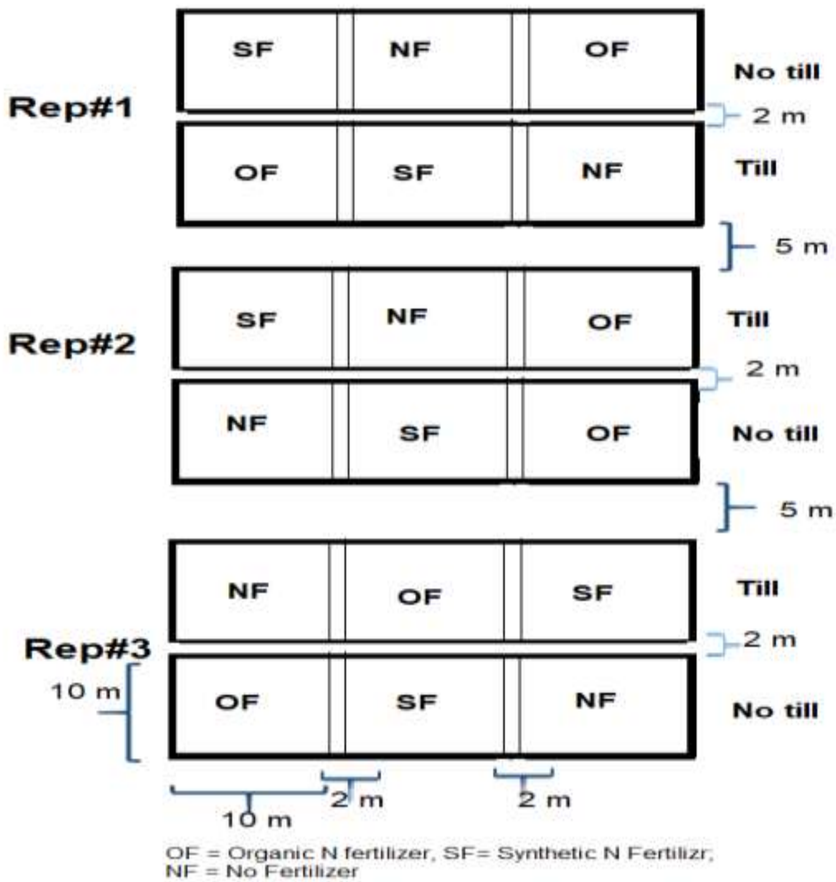

Figure 2. Experimental layout in a split plot design.
Source: Authors

Based on the N content (11%) of the compost samples analyzed, we applied compost at the rate 2.275 kg per plot of 25 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 0.55 kg per plot to provide the equivalence of 100 kg/ha. Both fertilizers were applied on the same day, one month after planting in both seasons.

The cultivar of the test crop was hybrid maize CMS 8704 cultivar obtained from the Regional Delegation of Agriculture in the Southwest Region of Cameroon. A seeding rate of 45.55 kg/ha was adopted. Based on this seeding rate, 114 g of maize seeds were planted within each sub plot of 25 m^2. Each maize stand had three seeds and a spacing distance of 80 cm was allowed between each maize stand and the next as recommended by FAO. Each sub plot had 36 maize stands in total. In situations where the maize did not germinate well within one week, seeds were replanted. On farm activities such as weeding was applied for all the plots throughout the growing season according.

Plot preparation

The study site was cleared on 2nd September 2020 for planting in the 2020 minor growing season and on 10th March 2021 in the 2021 major growing season. After clearing the field, all plant residues were removed from the plots the same way it is practiced by small holder farmers in the study area. A measuring tape was used to split the study site into 18 sub-plots of 25 m^2 (5 m x 5 m), each. A sawn timber of 1.5 m was used to demarcate the plot boundaries within the study site. Properly labelled plywood measuring 10 cm by 15 cm was placed at the center of the sub-plots to show the locations of the main plots and sub-plots. Conventional tillage was applied on the tilled plots using a hoe during all study seasons.

Initial soil sampling and analysis

Initial soil samples were randomly collected for the study on 14th of September 2020 to determine the physico-chemical parameters of the soil of the study site. A soil auger was used to collect 36 core samples at a depth of 0-15 cm from the study plot. Samples were air dried at the Department of Environmental Science Laboratory for 14 days, after which they were bulked to form one composite sample for analysis for soil physico-chemical parameters, such as soil texture, bulk density, pH, electrical conductivity, soil Organic C, total nitrogen, calcium, magnesium, potassium, sodium, available phosphorus and cation exchange capacity. Soil sample analysis was conducted at the Laboratory of Faculty of Agriculture, University of Dschang in Cameroon.

Measurement of soil Microbial C

Ten plants were selected at random from the middle rows of each plot. Soil samples were taken from the base of each plant at a depth of 0–15 cm (McClaran et al., 2008) using a hand auger. The

10 auger soil samples were then composited together (bulked) to form a representative sample for each plot in both growing seasons. Three samplings were made during each season at intervals of 4, 8 and 12 weeks during each growing season. Soil samples were kept in an ice cooler to halt any microbial activity and transported from the field to the Laboratory prior to analysis. The analysis of the soil MBC was determined at the laboratory of Faculty of Agriculture at the University of Dschang.

Soil MBC in the samples was determined using the chloroform fumigation and extraction method (FE) as described by Ladd and Amato (1989). Following this method, ten grams of field moist soil sample, after passing through a 4-mm mesh, were 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 (Ladd and Amato, 1989).

Immediately after fumigation, 50 ml of 0.5 MK_2SO_4 solutions was added to the soil samples to extract MBC from the lysed microorganisms. The amount of MBC in the extract was determined using the colorimetric method. An aliquot (5 mL) of the extract was pipetted into a 250-mL Erlenmeyer flask. To this, 5ml of 1.0 N (0.1667 M) potassium dichromate and 10 mL of concentrated sulphuric acid was added. The resulting solution was allowed to cool for 30 min after which 10 mL of distilled water was added. A standard series was developed concurrently with C concentrations ranging from 0, 2.5, 5.0, 7.5, 10.0-mg C mL^{-1} C. These concentrations were obtained when volumes of 0, 5, 10, 15 and 20 ml of a 50 mg C mL^{-1} stock was pipetted into labelled 100-mL volumetric flasks and made up to the mark with distilled water. The absorbance of the standard and sample solutions was read on a Spectronic 21D spectrophotometer at a wavelength of 600 nm.

A standard curve was obtained by plotting absorbance values of the standard solutions against their corresponding concentrations. Extracted C concentration of the samples was determined from the standard curve. For biomass C calculations, k -factors of 0.35 (Sparling et al., 1990) was used. The following equations (Sparling and West, 1988) were used to estimate the microbial C from the extracted C (Equation 1).

$$\text{Microbial C (mg)} = Ec/k \quad (1)$$

Where Ec = the extracted carbon produced following fumigation; k = the fraction of the killed biomass extracted as carbon or nitrogen under standardized conditions.

Statistical data analysis

After obtaining the data of soil MBC for all plots, R package Agricola was used to analyze the data for differences in treatments. The UNIVARIATE procedure was used to test the data and residuals for the assumption of normality to carry out a descriptive statistic and to draw graphs illustrating the effects of tillage, treatment and sampling period on soil MBC. An ANOVA test on R studio was conducted to test the effects of tillage and treatment on soil MBC. Soil MBC data was analyzed as a randomized complete block design (RCBD) using two-way ANOVA. Separation of means was done using the Tukey-Kramer adjustment least significant difference (LSD) method at alpha level of significance of 0.05 (Logah et al., 2010).

RESULTS

Physico-Chemical properties of the study site and compost analysis

The results of the physico-chemical properties of the study site and nutrient content of the compost are shown in Tables 1 and 2, respectively.

Impacts of tillage and fertilizer types on soil Microbial Biomass Carbon (MBC)

In the early growing season of 2020, tilled plots under control experiment (Till:CON) recorded the highest soil MBC (200.5 mg/kg), while the lowest (116.1 mg/kg) was recorded in not tilled plots under organic fertilization (No.Till:ORG).

In mid-growing season, the highest soil MBC (257.6 mg/kg) was recorded in plots under zero tillage with control experiment (No.Till:CON) and the lowest (182.mg/kg) was recorded in tilled plots under organic fertilization (Till:ORG).

During the late season sampling, the highest (261.6 mg/kg) soil MBC was recorded in No.Till:ORG, while the least (161.9 mg/kg) was recorded in plots under zero tillage with synthetic fertilization (No.Till:SYN). Overall seasonal analysis in the 2020 study season showed that No.Till.CON and No.Till:ORG recorded the highest MBC (201mg/kg and 200mg/kg respectively) while Till:ORG recorded the lowest (168 mg/kg) (Figure 3). Detailed data are in Appendix 1.

Results of this study also reveal that tillage and fertilizer types had no significant effect ($P>0.05$) effects on soil MBC in the early, mid and late season sampling in 2020 (Table 3). The means of soil MBC were statistically the same in both tillage and fertilizer application systems in these sampling periods (Figure 3). The overall growing season results for the three-sampling period showed that tillage and fertilizer types had no significant effect ($P>0.05$) on soil MBC. The interaction level means were also the same in both tillage practices and fertilizer application types (Figure 3).

During the 2021 study seasons, early season samples showed that, Till:ORG recorded the highest soil MBC (357.2 mg/kg) while the lowest (221.6 mg/kg) was generated in Till:CON. In the mid growing season, the highest soil MBC (385.5 mg/kg) was recorded in No.Till:ORG and the lowest (245.8 mg/kg) was recorded in Till:SYN. During the late season sampling, the highest (486.6 mg/kg) soil MBC was recorded in No.Till:ORG while the least (199.5 mg/kg) was recorded in Till:SYN. The overall seasonal results showed that the highest mean soil MBC occurred in No.Till.ORG (400.4 mg/kg), while the least occurred in Till.SYN (230.3 mg/kg) (Figure 4). Detailed results are shown in Appendix 2.

In the 2021 study season, the findings of this study revealed that tillage and fertilizer types had no significant effect ($P>0.05$) on soil MBC in the early, mid and late season sampling (Table 4). The means of soil MBC during the first sampling period were statistically the same in different tillage and fertilizer application systems (Figure 4). However, the means of soil MBC during the mid and late sampling period were statistically different in

Table 1: Physicochemical properties of the soil from the study site

Parameter	Unit of Measurement	Value
Sand	%	18
Silt	%	33
Clay	%	49
Electrical conductivity	ms/cm	0.04
Bulk density	g/cm^3	1.15
pH-H_2O (1:2.5)		5.8
pH-KCl (1:2.5)		4.7
Soil organic carbon	(%)	3
Total nitrogen	(%)	0.10
C/N		30
Calcium	(cmol/kg)	4.88
Magnesium	(cmol/kg)	3.44
Potassium	(cmol/kg)	4.50
Sodium	(cmol/kg)	0.01
Cation exchange capacity	(cmol/kg)	8.48
Available phosphorus	(mg/kg)	4.10

Source: Authors

Table 2. Results of NPK content of compost.

Parameter	% Content
Total Nitrogen	11
Total Phosphorus	0.24
Total Potassium	1.54

Source: Authors

plots under different tillage practices and fertilizer application systems as revealed by the LSD test. Overall growing season results for the three-sampling period showed that tillage and fertilizer types had no significant effect (P>0.05) on soil MBC (Table 4). However, the means of soil MBC in the different tillage practices and fertilizer types were not the same (Figure 3).

Findings of this study also revealed that there was a significant difference (p<0.05) in soil MBC in the first and second growing seasons of the study. Here, we noted that values of soil MBC were higher in the second growing season compared the first growing season.

DISCUSSION

Although there was no significant effects of tillage practice and fertilizer application types on soil MBC in both seasons, the study noted that No.Till:ORG recorded in the highest mean soil MBC in the first and second study season. Zero tillage leads to accumulation of higher concentration of organic C and microbial biomass C (Yeboah et al., 2016; Wright et al., 2015). The application of organic fertilizer in these plots under zero tillage also helped in the addition of C-rich organic compounds to the microbial communities (Knapp et al., 2010; Luo et al., 2014). Thus, this could be the reason for increased soil MBC in No.Till: ORG in this study. In a similar study in Iran conducted by Mohammadi et al. (2012), the authors also reported that the addition of organic manure increased soil MBC relative to synthetic fertilizer in plots under zero tillage. Especially in tropical climates, soil MBC is highest in the top 0–2.5 or 0–5 cm depths of undisturbed soil (Rai et al., 2018); therefore, limiting tillage can be a means to increase soil MBC in cropland ecosystems. Also, with the increasing cost of imported synthetic fertilization especially for small scale farmers in the tropics, using compost recycled from organic waste can reduce farmers cost in agriculture as well increase soil MBC in their farms, which helps in the long run sustainability of the farming systems. However, other trade-offs associated to the use of organic fertilizers (such as bulk and slow rate of reaction compared to synthetic fertilizers) needs to also be considered. These trade-offs can limit the application of organic fertilizer, especially in situations where farmer have long distance farms.

The authors also noted that soil MBC was significantly different (P<0.05) in the 2020 and 2021 study seasons. The means of soil MBC were higher in the 2021 study

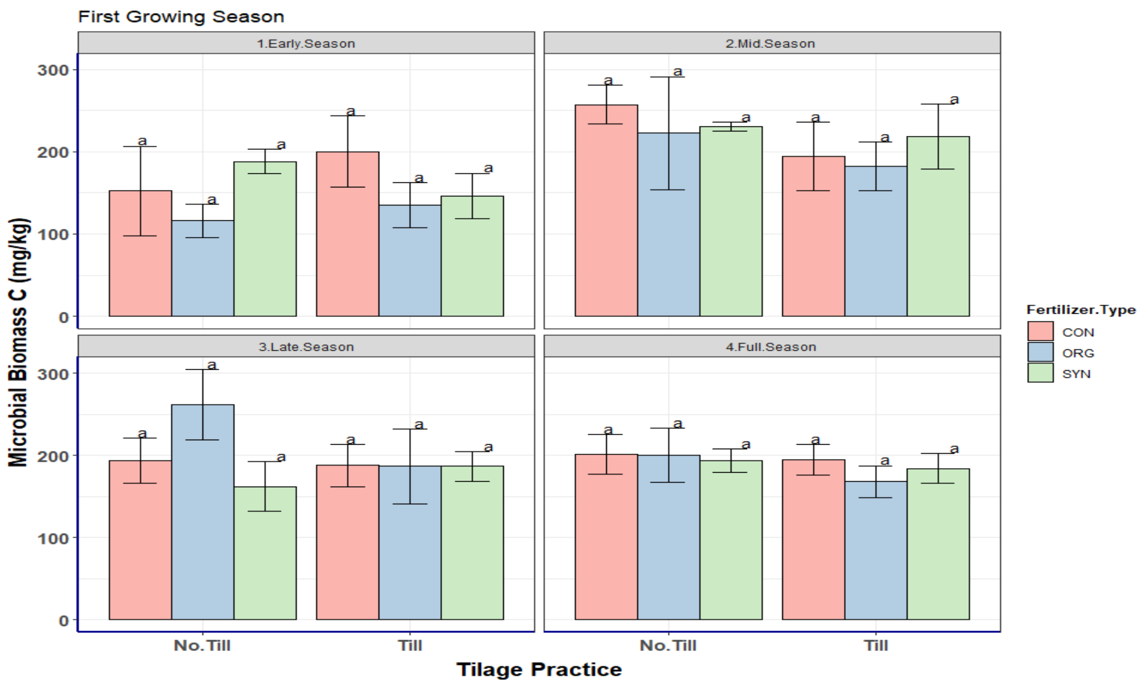

Figure 3. Mean Soil MBC in plots under different tillage and fertilizer types across sampling date in the first growing Season.
CON = Control, SYN=Synthetic Fertilizer, ORG=Organic Fertilizer, No Till=No Tillage Applied, Till: Conventional Tillage Applied.
Source: Authors

Table 3. ANOVA results on the effects of tillage and fertilizer type on soil MBC in the 2020 study season.

Variable	Df	Sum sq	Mean sq	F value	Pr(>F)
Early season					
Fertilizer type	2	8793	4396.6	1.2571	0.3194
Tillage practice	1	316	315.8	0.0903	0.7689
Fertilizer type: Tillage practice	2	6384	3192.1	0.9127	0.4276
Residuals	12	41968	3497.3		
Mid-season					
Fertilizer type	2	2097	1048.6	0.2214	0.8046
Tillage practice	1	6625	6624.8	1.3985	0.2599
Fertilizer type: Tillage practice	2	2004	1001.8	0.2115	0.8123
Residuals	12	56844	4737		
Late season					
Fertilizer type	2	2097	1048.6	0.2214	0.8046
Tillage practice	1	6625	6624.8	1.3985	0.2599
Fertilizer type: Tillage practice	2	2004	1001.8	0.2115	0.8123
Residuals	12	56844	4737		
Full season					
Fertilizer type	2	1724	861.9	0.1978	0.8212
Tillage practice	1	3551	3551.2	0.8148	0.3712
Fertilizer type: Tillage practice	2	1723	861.7	0.1977	0.8213
Residuals	48	209197	4358.3		

Source: Authors

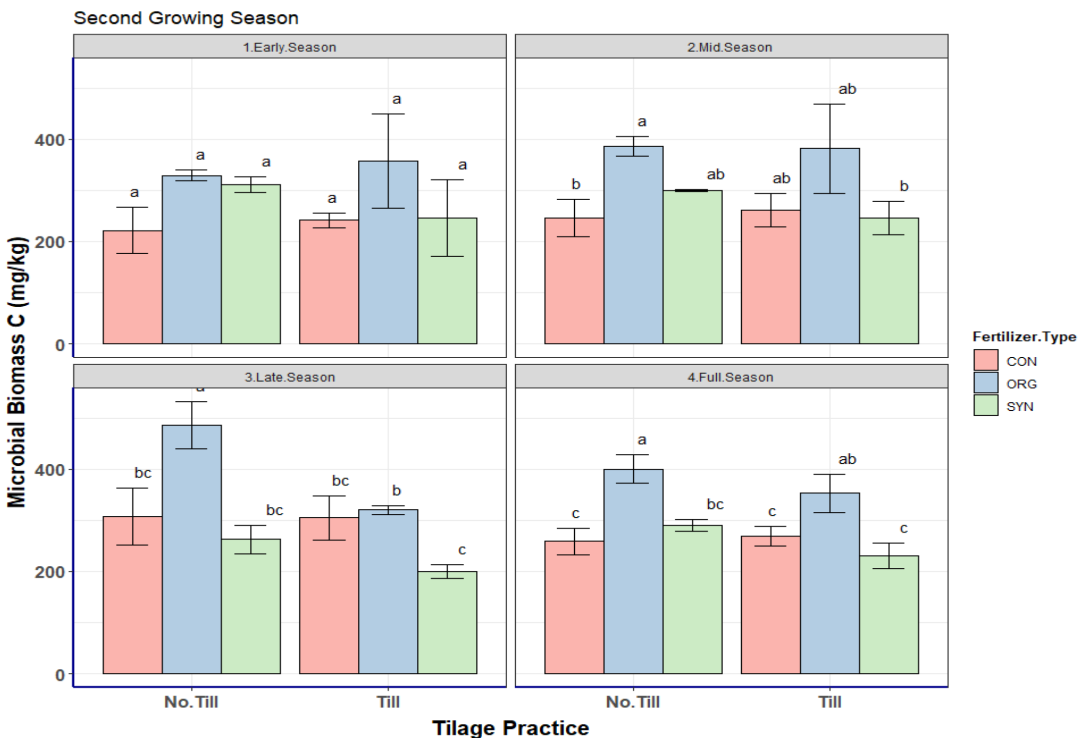

Figure 4. Mean Soil MBC in plots under different tillage and fertilizer types across sampling dates in the second growing Season.
Source: Authors

Table 4. ANOVA results on the effects of tillage and fertilizer type on soil MBC in the 2021 study seasons.

Variable	Df	Sum sq	Mean Sq	F value	Pr(>F)	
Early season						
Fertilizer type	2	37835	18917.3	2.2758	0.1452	
Tillage practice	1	156	155.6	0.0187	0.8934	
Fertilizer type :Tillage practice	2	7996	3997.8	0.4809	0.6296	
Residuals	12	99750	8312.5			
Mid-season						
Fertilizer type	2	59001	29500.4	5.0501	0.02563	*
Tillage practice	1	902	901.9	0.1544	0.70127	
Fertilizer type :Tillage practice	2	3679	1839.3	0.3149	0.73574	
Residuals	12	70099	5841.5			
Late season						
Fertilizer type	2	89420	44710	11.079	0.00188	**
Tillage practice	1	27085	27085	6.7112	0.02363	*
Fertilizer type : Tillage practice	2	20569	10284	2.5483	0.11957	
Residuals	12	48429	4036			
Full season						
Fertilizer type	2	157334	78667	13.097	2.89E-05	***
Tillage practice	1	14294	14294	2.3798	0.1295	
Fertilizer type: Tillage practice	2	12880	6440	1.0721	0.3503	
Residuals	48	288312	6007			

Source: Authors

season compared to the 2020 season. These differences may have occurred due to the differences in environmental conditions of rainfall, soil moisture and soil temperature across the two seasons. During the 2020 season, soil samples for this analysis were collected between late September and late December, a period characterized by a lower rainfall and higher atmospheric and soil temperatures. In the 2021 study season on the other hand, samples were collected between late March and early July, which corresponded to a typical rainy season period. Besides tillage practices and fertilizer application types, temperature and moisture predominantly determine the amount of microbial biomass in a soil (Wardle and Parkinson, 1990).

According to Kopittke et al. (2017), microbial biomass increases with increasing mean annual precipitation; however, it decreases with mean annual temperature increase above 20°C in a semi-arid subtropical environment. Furthermore, seasonal fluctuations in soil microbial biomass occur due to changes in the number of substrates, temperature, and moisture. For example, Lynch and Panting (1982) found that the amount of microbial biomass reached a maximum around the time of maximum root biomass and thereafter declined.

Conclusion

This study has effectively documented main effects of tillage practices and fertilizer types on soil MBC under maize cultivation. The results show that the main effect of tillage practice and fertilizer types was insignificant ($p>0.05$) in the 2020 and 2021 study season. However, the mean values of soil MBC in different tillage and fertilizer application types were statistically the same in the 2020 season; while in the 2021 study season, the means were statistically different.

No.Till:CON and No.Till:ORG recorded the highest soil MBC in the 2020 season (201 and 200 mg/kg respectively) while in the 2021 season, No.Till:ORG recorded the highest (400.4 mg/kg) soil MBC. Soil MBC was higher in the 2021 season than in the 2020 season. Based on these findings, we recommend the use of minimum tillage and organic fertilizer application in farms around the study area to guarantee the maximum benefits of carbon sequestration like improved soil quality, increased soil productivity and reduced risk of soil erosion and sedimentation in farmlands around the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix 1. Data summary (Mean, std, min, max) of soil MBC for the 2020 growing season.

Sampling period	Fertilizer type	Tillage practice	Mean (mg/kg)	Sd (mg/kg)	Min (mg/kg)	Max (mg/kg)
Early season	CON	Till	*200.5*	74.4	120.3	267.3
Early season	SYN	No till	188.4	25.4	162.7	213.5
Early season	CON	No till	152.3	95.0	49.5	236.9
Early season	SYN	Till	146.2	48.0	115.7	201.5
Early season	ORG	Till	135.1	47.5	80.5	166.1
Early season	ORG	No till	*116.1*	34.9	94.1	156.3
Mid-season	CON	No till	*257.6*	40.7	210.6	281.3
Mid-season	SYN	No till	230.3	9.5	223.0	241.1
Mid-season	ORG	No ill	222.6	119.4	104.5	343.3
Mid-season	SYN	Till	218.7	68.2	148.7	284.9
Mid-season	CON	Till	194.5	71.4	136.0	274.1
Mid-season	ORG	Till	*182.3*	51.6	150.1	241.8
Late season	ORG	No till	*261.6*	74.7	203.4	345.8
Late season	CON	No till	193.2	47.2	141.8	234.5
Late season	CON	Till	187.8	44.4	147.8	235.6
Late season	ORG	Till	186.6	78.5	133.1	276.7
Late season	SYN	Till	186.3	30.7	157.6	218.7
Late season	SYN	No till	*161.9*	52.3	129.8	222.2
Full season	CON	No till	*201.0*	73.1	49.5	281.3
Full season	ORG	No till	*200.1*	97.6	94.1	345.8
Full season	CON	Till	194.3	56.4	120.3	274.1
Full season	SYN	No till	193.5	42.0	129.8	241.1
Full season	SYN	Till	183.8	54.5	115.7	284.9
Full season	ORG	Till	*168.0*	58.2	80.5	276.7

CON = Control, SYN=Synthetic Fertilizer, ORG=Organic Fertilizer, No Till=No Tillage Applied, Till: Conventional Tillage Applied.

Appendix 2. Data summary (Mean, std, min, max) of soil MBC for the 2021 growing season.

Sampling period	Fertilizer type	Tillage practice	Mean (mg/kg)	Sd (mg/kg)	Min (mg/kg)	Max (mg/kg)
Early season	ORG	Till	*357.2*	158.8	215.7	529.0
Early season	ORG	No till	329.3	19.5	312.1	350.5
Early season	SYN	No till	310.7	25.8	282.5	333.0
Early season	SYN	Till	245.4	129.8	101.9	354.4
Early season	CON	Till	241.3	25.0	215.0	264.8
Early season	CON	No till	*221.6*	78.3	167.0	311.4
Mid-season	ORG	No till	*385.5*	33.0	355.0	420.4
Mid-season	ORG	Till	381.1	152.8	252.3	550.0
Mid-season	SYN	No till	298.9	3.3	296.0	302.4
Mid-season	CON	Till	261.0	57.6	212.7	324.8
Mid-season	CON	No till	246.1	62.8	200.1	317.6
Mid-season	SYN	Till	*245.8*	57.8	205.5	312.0
Late season	ORG	No till	*486.6*	79.5	398.1	552.1
Late season	ORG	Till	319.9	14.2	304.9	333.1
Late season	CON	No till	307.8	96.4	224.1	413.2
Late season	CON	Till	304.7	74.7	220.4	362.6
Late season	SYN	No till	262.5	48.2	218.4	313.9
Late season	SYN	Till	*199.5*	22.4	174.2	216.6
Full season	ORG	No till	*400.4*	81.9	312.1	552.1
Full season	ORG	Till	352.7	113.6	215.7	550.0
Full season	SYN	No till	290.7	35.0	218.4	333.0
Full season	CON	Till	269.0	56.3	212.7	362.6
Full season	CON	No till	258.5	79.5	167.0	413.2
Full season	SYN	Till	*230.3*	75.5	101.9	354.4