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REVIEW ARTICLE

EFFECT OF INORGANIC FERTILIZERS ON SOIL FERTILITY AND MICROBIAL BIOMASS IN THE RHIZOSPHERE OF SOYBEAN

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ABSTRACT

Soil microbial biomass is an important source of nutrients for crops. However, the response of microbial biomass- C (MBC) and -N (MBN) to various inorganic fertilizers in legume cultivation is lacking. A two-year impact of inorganic fertilizers [urea, single superphosphate (SSP), $N_{15}P_{15}K_{15}$] addition on soil fertility and microbial biomass was determined in the rhizosphere of soybean (*Glycine max*) grown in an Ultisol. Treatments were laid out in randomized complete block design in triplicates. Rhizosphere soils from soybean plants was collected at 30, 60, and 90 days after sowing (DAS). Results showed that the soil had a sandy loam texture, moderately acid (pH 5.2), low in organic matter, total nitrogen, exchangeable bases and CEC, but moderate in available phosphorus. In both cropping years, the retention of these soil chemical parameters was significantly ($p < 0.05$) increased, apart from/expect total N in the second cropping year. Furthermore, there was improvement in soil MBC at 30, 60 and 90 DAS in both cropping years and an improvement in MBN at 60 and 90 DAS in the first year and at 90 DAS in the second year due to fertilizer treatment. This positive effect was highest with $N_{15}P_{15}K_{15}$ compared to the individual addition of SSP and Urea. Study result showed that the contribution of rhizo-C to microbial biomass depends on the fertilizer-induced changes on soil pH, organic matter and NPK nutrients reserves in the study soil. These results will benefit farmers in the study area and similar study soils in selecting inorganic fertilizers to maintain soil biochemical fertility.

KEYWORDS

Urea, Single Super Phosphate, NPK fertilizer, soil rhizosphere, soil chemical properties

1. INTRODUCTION

The soil is one of the most active sites of biological activities in nature. Biochemical reactions involved in organic matter breakdown, weathering of rocks and in the nutrition of cultivated and uncultivated plants are carried out by a vast population of microorganisms. Soil microorganisms play an essential role in the cycling of virtually all the major plant nutrients, mostly in natural and agricultural ecosystems with low inputs (Smith and Paul, 1990). Bacteria, fungi, and archaea, protists, meso and macro-fauna (microarthropods, macroarthropods, enchytraeids) constitute the total living biomass in soil (Beare, 1997).

Microbial biomass is the part of organic matter in soil that constitutes living microorganisms smaller than 10 µm. Soil microbial biomass as a major source of plant nutrients is very much associated with the organic matter content of soils and the level of soil microbial biomass is a significant factor in determining soil health (Pankhurst et al., 1995). A close relationship has also been reported between soil fertility and microbial biomass (Brookes, 1995; Insam et al., 1991). Microbial biomass is commonly used as an early indicator of changes in soil chemical and physical properties resulting from soil management and environmental stresses in agricultural ecosystems (Jordan et al., 1995). A group researcher revealed that microbial biomass is a labile source of C, N, P and S nutrients (Dalal et al., 1991). Soil microbial biomass C constitutes only 1 – 3 % of total soil C while biomass N up to 5 % of total soil N (Jenkinson and Ladd, 1981). The ratio of microbial biomass C to microbial biomass N is frequently used to describe the structure and the state of the microbial community. Accordingly, a high microbial biomass C to N ratio indicates that the microbial biomass contains a higher percentage of fungi, whereas a low value suggests dominance of bacteria in the microbial population (Campbell et al., 1991).

In a soil-plant system, the rhizosphere represents the soil's energy powerhouse and, therefore, any alteration in fertility management (balanced or unbalanced fertilization) often exerts serious impacts on agricultural productivity, ecosystem sustainability and nutrient dynamics between the soil-plant interface (Mandal et al., 2007). Microbial communities are essential for the functioning, both in terms of direct interaction with plants and in terms of nutrient and organic matter cycling. Therefore, the nutrient availability and productivity of agroecosystems depend mainly on the size and activity of the microbial biomass (Friedel et al., 1996).

Soybean (*Glycine max*) is one of the most important food crops of the world. It is an annual crop that is virtually easy to grow and produces more protein and oil per unit of land than almost any other crop (Martin, 1988). It is a versatile food crop that can be used in different forms due to its capability of supplying most nutrients. It can be a substitute for meat and sometimes milk and is able to reduce protein malnutrition. Additionally, soybeans are a source of high-quality animal feed. In modern times, the production of soybeans has been done with improved cultural practices such as the use of organic and inorganic fertilizers to maximize crop yield (Yamika and Ikawati, 2012; Verde et al., 2013; Wijanarko et al., 2016). Studies have shown that nutrient additions can considerably improve the population, composition, and functions of soil microorganisms (Mandal et al., 2007; Hopkins et al., 2008; Geisseler and Scow, 2014). Since microbes

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respond differently to different nutrient elements in the soil, the application of single or compound mineral fertilizers is assumed to produce responses that can improve the nutrient balance of soils, and consequently result in an increase in crop yield (Li et al., 2019; Cai et al., 2020). Application of inorganic fertilizer is known to improve soil nutrients and productivity. Therefore, this study aimed to evaluate the effect of various inorganic fertilizers on soil nutrient retention and microbial biomass in the rhizosphere of soybean.

2. Materials And Methods

2.1 Study location

The study was carried out in the University of Nigeria (UNN) Teaching and Research Farm at Nsukka in Enugu State in south-eastern Nigeria. The UNN Teaching and Research farm behind the Meteorological Station, which is located on latitude 6º 52 'N and longitude 7º 24'E in the derived savannah agroecological zone of Enugu State, South-Eastern Nigeria. This area has an elevation of 477 meters above mean sea level. The location is characterized by two seasons, namely; rainy and dry seasons. The rainy season lasts from April to October with a short break in the month of August (August Break). Average annual rainfall is about 1550 mm and more than 85% of this rain falls within the rainy season. March which is the warmest month of the year has an average temperature of 27ºC while August which is the coldest month has an average temperature of 27ºC (Phil-Eze, 2012). The average relative humility rarely falls below 60% (Asadu, 2002). The soils of the area have high percentage of sand and granular structure at the top and the topsoil is characterized by rapid to very rapid permeability (Obi and Asiebgu, 1980). The soil is an Ultisol, which belongs to Nkpologu series (Nwadialo, 1989).

2.2 Treatment Description

The details of the treatments along with their representational symbols are as listed below:

T_1 : Control

T_2 : 30 kg ha^{-1} of urea, which contains 45 % N

T_3 : 60 kg ha^{-1} of single super phosphate (SSP), which contains 18 % P

T_4 : 200 kg $ha^{-1}$of NPK 15:15:15

The above four (4) treatments were laid out in a randomized complete block design with 3 replications. Accordingly, the treatments were assigned to 12 plots measuring 2 m x 1 m and spaced 1 m and 1.5 m between plots and between replicate blocks, respectively. Each plot contains eight rows of four stands each (two plants per stand), resulting in 64 plant stands per plot. The fertilizers were applied to the experimental plots in ring form at two weeks after sowing (immediately after the first weeding), at different rates.

2.3 Soil data collection

Composite soil samples were taken from a depth of 0 - 20 cm from the experimental site prior to land preparation. The samples were taken randomly across the field using an auger. The samples were then air-dried under laboratory conditions, thoroughly mixed and passed through a 2 mm mesh sieve and packaged for laboratory analyses. After soybean harvest, three auger soil samples were taken and then composited for each plot. The composite samples were analyzed to assess changes in soil fertility status due to the effect of the application of inorganic fertilizer application.

Sampling of rhizosphere soils from soybean stand was carried out within a period of 90 days. Samples were collected at 30-day intervals (30, 60 and 90 days after sowing) by uprooting four border plants from each plot and keeping the soil around the root system intact for analysis. After removing the bits of plant roots and other debris from the intact root system of the uprooted plants, the soil particles that adhered strongly to the roots were analyzed immediately without drying them, following the method as described (Basul et al., 2010).

2.4 Laboratory analysis

Auger- soils samples were sieved to pass through 2mm mesh for laboratory analysis. The samples were analyzed for soil pH, total nitrogen (Kjeldahl digestion method), and organic carbon (dichromate oxidation). Exchangeable base cations were determined in 1M NH_4OAC; pH 7.0, available phosphorus by Bray-1 method and particle size analysis was determined by the hydrometer method. The physical and chemical properties of the soils at the study areas are presented in Table 2. Soil MBC and MBN were determined using the chloroform-fumigation extraction method as described (Anderson and Ingram, 1993).

2.5 Statistical Analysis

The data obtained from the different parameters were analyzed using analysis of variance (ANOVA). The Duncan Multiple Range Test was used to separate the significant means at 5% probability level using SPSS software. Correlation between microbial biomass and soil chemical properties were carried out to determine their relationship.

3. Results And Discussion

3.1 Pre-crop soil physical and chemical properties of the study soils

Soil physical and chemical properties of the soil were determined prior to the commencement of the field work to assess the soil nutrient status. Results of the characterization of the soils at the experimental site are shown in Table 1.

3.1.1 Soil physical characterization

Particle size distribution of the pre-cropped soil showed a high percentage of sand with 756 g kg^{-1} and low content of silt (124 g kg^{-1}) and clay (120 g kg^{-1}). The textural class of the soil was sandy loam. Such soils may lack the capacity to adsorb and retain basic plant nutrients and may be susceptible to erosion menace (Abua and Edet, 2007). The soil bulk density was 1.43 g/cm^3, which is within the 1.2 to 1.8 g/cm^3 range for sand and sandy loam dominated soils (Brady and Weil, 2002). Such values are likely to support aeration and water movement for optimum crop growth (Esu, 2010).

3.1.2 Soil chemical characterization

The pH (distilled water) of the study soils was 5.2, indicating a strongly acid status. This condition is typical for the soils of the tropical southeastern region that are highly weathered and leached of basic cations from the soil solum (Obi, 1999). This may be due to high rainfall associated with the tropical environment, in addition to the predominance of low activity clays and the porous nature of the soil (Obi, 1991). Acid condition can induce phosphate fixation and reduce the ability of micro-organisms to fix atmospheric nitrogen (Ande et al., 2010).

Soil organic matter was 2.82 %, indicating a moderately low concentration (Adaikwu and Ali, 2013). Low SOM may be associated to rapid mineralization against humification or high temperatures that favour mineralization (Haynes, 2005; Ibia, 2001). The low total N content (0.22 %) may be linked to the SOM content, which could most likely cause stunted growth of soybean crop. The low N levels can also cause the plant's older leaves to appear light green or pearly yellow from the tip down (Ibrahim and Raji, 2022; Hosier and Bradley, 1999). This may affect the plant growth and development, resulting in low yield. The available phosphorus content of the soil was 12.90 mg kg^{-1}. This value falls within the moderate level of the fertility rating required for productive soils (Adaikwu and Ali, 2013).

The exchangeable calcium content of the soil was 0.93 cmol kg^{-1}, which was within the low range according to (Adaikwu and Ali, 2013). Strongly acid soils are calcium deficient and are not good enough for most crops (NPFS, 2009). Exchangeable magnesium and potassium content was 0.60 cmol kg^{-1} and 0.11 cmol kg^{-1}, respectively, and were classified as low (Adaikwu and Ali, 2013). These low values may be due to the low exchange capacity due to poor content of colloidal particles in the soil. The low value of exchangeable potassium was consistent with the values reported (Olowolafe, 2002). Exchangeable Na content was 0.12 cmol kg^{-1} and was classified as low (Adaikwu and Ali, 2013). In general, these low concentrations of exchangeable bases may be due to the high sand content in the soil, which predisposes to excessive leaching due to high rainfall in the study area. As such, the low CEC of 4.85 cmol kg^{-1} indicates low nutrient reserves, which is probably due to factors such as high rainfall, dominance low activity and low clay content and low soil organic matter content (Agbede, 2009; Donahue et al., 1983).

Table 1: Pre-crop physiochemical properties of the study soil	
Soil properties	**Values**
Clay (g kg^{-1})	120
Silt (g kg^{-1})	124
Sand (g kg^{-1})	756
Textural class	Sandy loam
Bulk density (mg m^{-3})	1.43
Hydraulic conductivity (cm hr^{-1})	16.3
pH (H_2O)	5.20
Organic matter (%)	2.82
Total N (%)	0.12
Available P (mg kg^{-1})	12.90
Ca^{2+} ($cmol_c$ kg^{-1})	0.93
Mg^{2+} ($cmol_c$ kg^{-1})	0.60
K^+ ($cmol_c$ kg^{-1})	0.11
Na^+ ($cmol_c$ kg^{-1})	0.12
CEC ($cmol_c$ kg^{-1})	4.85

CEC = Cation exchange capacity

3.2 Post-harvest chemical properties of the study soils

The results of the soil chemical properties after soybean harvest showed that the soil pH in the first cropping year ranged from 5.31 to 5.49, indicating a strongly acid status and a pH range of 5.62 - 6.06, indicating moderately acid status in the second cropping year (Table 2). The acidity levels could be attributed to high rainfall and removal of basic cation during the process of eluviation. Similar soil acidity level was earlier reported (Obi, 1991). Nevertheless, a slight increase in soil pH was observed in the second cropping year. This increase can be attributed to the significant improvement in the exchangeable bases of the treated plots. The SOM content and CEC were highest in T_4 followed by T_3 and T_2, with the lowest values obtained from T_1 (Table 2), for both first and second cropping years.

The highest SOM in T_4 may be attributed to higher carbon content in T_4. SOM content is known to contribute significantly to CEC of tropical soils (Asadu and Akamigbo, 1990; Asadu, et al., 1997). There was a significant difference ($p < 0.05$) in CEC values amongst treatment plots in both cropping years. The application of T_4 resulted in the highest CEC values of 20.82 and 20.85 $cmol_c$ kg^{-1} in the first and second cropping years, respectively, while T_1 produced the lowest values of 19.36 and 19.08 $cmol_c$ kg^{-1}, respectively. The increase CEC content with T_4 could be attributed to high availability of OM which provide more nutrients (NPK) compared to the other single fertilizer treatments (T_2 and T_3). The CEC values obtained in the soil in all the plots at the end of the cropping seasons were high and generally above the initial (pre-planting) concentration of 4.83 cmol kg^{-1}. These values are regarded as suitable for crop production if other factors are favourable (FAO, 2004).

The soil total N content in all the plots was within the same range (0.25 - 0.28 %) for both cropping years. The total N content of the study area was moderate, both before and after the experiment (FAO, 2004). The moderate level of total N observed after harvesting (plant uptake) could be attributed to the ability of the crop to fix atmospheric nitrogen to the soil (Ciampitti et al., 2021; Singh et al., 2012). The soil available P was moderate to high and ranged from 19.95 to 46.69 mg kg^{-1} in the first cropping year with the highest values in T_3 followed by T_4 and T_2 (Table 2), while the lowest value of available P was obtained in T_1. In the second cropping year, the available P content was high and ranged from 36.80 to 56.95 mg kg^{-1} with the highest values in T_3 followed by T_4 and T_2, while the lowest value of available P was obtained in T_1. The highest available P content in T_3 may be attributed to the application of SSP to the plots. Generally, the values of available P content obtained after harvest in both cropping years were above the initial status (12.90 mg kg^{-1}) of the soil. Phosphorus is less likely to leach vertically into the ground water but more likely to move from the plot by means of runoff (Elliot et al., 2009; Prasad and Chakraborty, 2019).

The exchangeable bases (Ca, Mg, K and Na) ranged from 0.41 to 0.67 cmol kg^{-1} for Ca; 0.57 to 0.65 cmol kg^{-1} for Mg; 0.11 to 0.15 cmol kg^{-1} for K and 0.07 to 0.12 cmol kg^{-1} for Na. The exchangeable bases were generally very low (FAO, 2004) in all the plots for both cropping years. These low values of exchangeable bases can be attributed to the high sand content in the soil which makes the soil susceptible to excess leaching of the cations down the profile, due to high rain fall in the study area (Igwe and Udegbunam, 2008).

3.3 Effect of treatments on soil microbial biomass C and N

The effect of inorganic fertilizers on MBC in the rhizosphere of soybean showed significant differences ($p < 0.05$) in MBC values amongst treatment plots in both cropping years (Table 3). In general, the soil MBC in the fertilized soil was significantly higher compared to the control. During the first cropping year, MCB content at 30 DAS was higher in T_3 (452.33 μg C g^{-1} soil) and T_4 (459.00 μg C g^{-1} soil) soils than in T_2 soil. At 60 and 90 DAS, the application of T_4 resulted in the highest MBC values of 324.67 and 286.00 μg C g^{-1} soil, respectively, while T_1 produced the lowest values of 267.67, 192.00 and 106.33 μg C g^{-1} soil, respectively.

Table 2: Effect of inorganic fertilizers on some chemical properties of the experimental soil after planting

Treatment	pH H_2O	OM %	TN %	Av. P mg kg^{-1}	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC
					………………………… $cmol_c$ kg^{-1} …………………………				
First cropping year									
T1	5.31c	1.97c	0.25b	19.95d	0.41d	0.57c	0.11c	0.11b	19.36c
T2	5.45b	2.76b	0.28a	34.58c	0.47 b	0.64a	0.14a	0.12a	19.59b
T3	5.45b	3.90a	0.25b	46.69a	0.51a	0.62ab	0.13b	0.07c	20.80a
T4	5.49a	3.94a	0.28a	41.09b	0.43c	0.61b	0.12b	0.10b	20.82a
Second cropping year									
T1	5.62c	1.57d	0.26a	36.80d	0.42c	0.62b	0.13b	0.11a	19.08d
T2	5.92b	1.73c	0.27a	46.59c	0.67a	0.65a	0.14ab	0.11a	19.23c
T3	6.06a	3.26b	0.28a	56.96a	0.47b	0.63ab	0.14ab	0.07b	20.55b
T4	6.02a	3.38a	0.28a	55.26b	0.47b	0.64a	0.15a	0.08b	20.85a

OM = organic matter; TN = total nitrogen; Av. P = available phosphorus; CEC = cation exchange capacity; T1, T2, T3, and T4 = control, 30 kg ha^{-1} of urea; 60 kg ha^{-1} of single super phosphate; 200 kg $ha^{-1}$of NPK 15:15:15; means with the same letter(s) in the columns are not significantly different (Duncan's Multiple Range Test, ($p \leq 0.05$).

Table 3: Effect of inorganic fertilizers on microbial biomass carbon

Treatments	First cropping year				Second cropping year		
	30 DAS	60 DAS	90 DAS		30 DAS	60 DAS	90 DAS
	……… µg C g-1 soil ………				……… µg C g-1 soil ………		
T1	267.67c	192.00c	106.33c		239.67c	157.33c	112.33d
T2	445.67b	311.00b	198.00b		448.00b	296.00b	187.00c
T3	452.33ab	315.67b	193.33b		454.33b	305.67a	243.00b
T4	459.00a	324.67a	286.00a		472.00a	307.67a	261.67a

DAS = days after sowing; T1, T2, T3, and T4 = control, 30 kg ha^{-1} of urea; 60 kg ha^{-1} of single super phosphate; 200 kg $ha^{-1}$of NPK 15:15:15; means with the same letter(s) in the columns are not significantly different (Duncan's Multiple Range Test, ($p \leq 0.05$).

The increased MBC content with T_4 could be due to the high input of organic matter and changes in the chemical properties of the soil resulting from the provision of more nutrients (NPK) compared to the other single fertilizer treatments (T_2 and T_3). Fertilization as a strategy to improve soil nutrients also provides nutrients for bacterial growth and metabolism (Lian et al., 2022). A group researcher found that the abundance of bacterial or fungal species was sensitive to fertilization due to changes in soil chemical properties caused by chemical fertilization (Dincă et al., 2022).

In the second cropping year, at 30, 60 and 90 DAS, the application of T_4 also resulted in the highest MBC values of 472.00, 307.67 and 261.67 µg C g^{-1} soil, respectively, while T_1 produced the lowest MBC values of 239.67, 157.33 and 112.33 µg C g^{-1} soil, respectively. However, the increase in MCB with T_3 was higher than with T_2 at 60 and 90 DAS, indicating that P was more beneficial for MBC compared to N fertilizer. A group researcher found a significant increase in microbial biomass with P rather than N addition and concluded that microbial growth may be limited by P in tropical soil (Liu et al., 2015). The higher MBC with T_3 is mainly attributed to the relatively slow release and cycling of P, which alleviates microbial P limitation, the P-induced reduced soil acidity and the increased contribution of rhizo-C, as well as the increased SOM which was about twice as high as with T_2. In both cropping years, there was a decreasing trend in MBC and MBN with increasing number of DAS (Liu et al., 2008). This decline may be due to rhizo-C metabolism, and nutrient losses via plant uptake, volatilization and possibly through leaching and erosion which are prevalent in the study location.

The effect of inorganic fertilizers on MBN showed no significant ($p > 0.05$) difference in MBN among the treatments at 30 DAS in the first and second cropping year, and at 60 DAS in the latter year (Table 4). At 60 and 90 DAS however, the addition of T_4 in the first cropping year, resulted in the highest MBN of 26.80 and 20.93 µg C g^{-1} soil, respectively, while the lowest values of 20.07 and 10.27 µg C g^{-1} soil, respectively, were observed in T_1 soil. In the second cropping year, MBN was highest with $T_4 > T_3 > T_2 > T_1$ at 90 DAS. A group researchers reported a negative effect on MBC and MBN contents with addition of inorganic N fertilizer (Černý et al., 2008). The lack of a clear effect of fertilization on soil MBN, as mentioned above, is unlikely due to the low N and moderately P status of the soil. Fertilizer N and NPK inputs were expected to reduce N constraint and increase soil MBN. The observed lag effect of N input may be due to the fact that C limitation occurred after inorganic fertilization in the first 30 DAS (in the first cropping season) and up to 60 DAS (in the second cropping season). However, litter-falls increased, alleviating C limitation for soil microorganisms after these DAS, suggesting that the growth of soil microorganisms may be limited by NPK as the application of T_4 resulted in optimal MBN. At 90 DAS, the different response of soil MBN to inorganic fertilizer inputs in both cropping years may be related to the differences in soil reaction and nutrient status caused by the different element composition of the fertilizer inputs. Our results showed that the soil MBN response to inorganic fertilization was driven on the changes in soil pH, organic matter, total N, available P, Ca, Mg, K nutrients.

Table 4: Effect of inorganic fertilizers on microbial biomass nitrogen

Treatments	First cropping year				Second cropping year		
	30 DAS	60 DAS	90 DAS		30 DAS	60 DAS	90 DAS
	……… µg C g-1 soil ………				……… µg C g-1 soil ………		
T1	24.03a	20.07c	10.27c		22.27a	15.63a	10.53d
T2	30.43a	25.43ab	19.83b		33.57a	18.70a	16.33c
T3	45.00a	20.67bc	19.43b		41.97a	22.43a	17.70b
T4	45.83a	26.80a	20.93a		44.83a	20.87a	19.20a

DAS = days after sowing; T1, T2, T3, and T4 = control, 30 kg ha^{-1} of urea; 60 kg ha^{-1} of single super phosphate; 200 kg $ha^{-1}$of NPK 15:15:15; means with the same letter(s) in the columns are not significantly different (Duncan's Multiple Range Test, ($p \leq 0.05$).

3.4 Correlation coefficient (*r*) between microbial biomass and soil chemical properties in the first and second cropping years

A significant correlation existed between microbial biomass and some chemical properties (Table 5). The MBC had a significant positive correlation with pH ($r = 0.92$*), SOM ($r = 0.83$*), TN ($r = 0.68$*), available P ($r = 0.73$*), Mg^{2+} ($r = 0.61$*) and CEC ($r = 0.75$*) while the MBN was positively associated with pH ($r = 0.94$*), SOM ($r = 0.74$*), available P ($r = 0.84$*), Mg^{2+} ($r = 0.90$*) and K^+ ($r = 0.80$*). These parameters (pH, SOM, TN, available P, Mg^{2+}, K^+ and CEC) were the drivers for the increased activity of rhizo-microbial growth and metabolism in the first cropping year. In the second cropping year, the MBC and MBN were significantly correlated with all the chemical parameters except Ca^{2+} and Mg^{2+} (Table 5). This lack of correlation with Ca^{2+} and Mg^{2+} and the negative significant correlation between Na^+ and MBC ($r = -0.85$*) or MBN ($r = -0.73$*) could be related to their deficiency status. Our study result shows that the contribution of rhizo-C to microbial biomass in a biennial soybean cultivation depends on the fertilizer-induced changes in soil pH, organic matter, and N, P and K nutrients reserves.

Table 5: Correlation coefficient (r) between microbial biomass and soil chemical properties in the first cropping year

Dependent variables	pH	SOM	TN	Av. P	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC
	First cropping year								
MBC	0.916*	0.828*	0.680*	0.735*	-0.243	0.607*	0.350	-0.093	0.751*
MBN	0.939*	0.742*	0.538	0.841*	0.285	0.904*	0.800*	-0.127	0.574
	Second cropping year								
MBC	0.967*	0.904*	0.581*	0.998*	0.091	0.256	0.671*	-0.845*	0.887*
MBN	0.980*	0.792*	0.596*	0.965*	0.297	0.378	0.624*	-0.726*	0.771*

* = Correlation is significant at the 0.05 level, MBC = microbial biomass carbon; MBN = microbial biomass nitrogen; SOM = soil organic matter; TN = total nitrogen; Av. P = available phosphorus; CEC = cation exchange capacity.

Conclusion

The study showed that the study soil was sandy loam, acid, and poor in organic matter, total N and base cation concentrations. The application of urea, single super phosphate and NPK fertilizers improved the chemical fertility and microbial biomass of the soil. While this improvement was greater under SSP than urea fertilization, the application of NPK fertilizer which resulted in optimal soil fertility and biochemical responses, is the best option for promoting nutrient retention and cycling processes in soybean phase of a two-year cropping in an Ultisol. Thus, NPK availability was limiting factors for microbial growth. The correlation between microbial biomass and chemical properties showed that MBC and MBN were more closely related to pH, SOM, TN, available P, K and CEC. This indicates that treatments that increase microbial biomass will improve soil health and productivity. Our study reveals that pH, organic matter and N, P, K pools were the drivers for the increased activity of rhizo-microbial growth and metabolism in the study soil. These results will benefit farmers in the study area and similar study soils in selecting inorganic fertilizers for soybean production.

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