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Comparative Evaluation of Short Term Organic Carbon Sequestration under Different Nutrient Managements during Cropping Cycles on a Ferric Acrisol in Ghana

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Abstract. There is scanty information on the short term effect of soil management practices on soil carbon sequestration during cropping cycles in the tropics. This study is a short term experiment conducted in 2006 and 2007 to evaluate the extent to which nutrient management strategies could impact soil carbon sequestration during cropping seasons in the short term. The study was conducted on a Ferric Acrisol in the semi-deciduous forest zone of Ghana and was laid in a split plot, arranged in a randomized complete block design with three replications. Management strategies such as poultry manure - PM (4 t/ha), chemical fertilizer (CF) - NPK 15-15-15 (90-60-60 kg/ha), complementary application of poultry manure and chemical fertilizer – PM + CF (45-30-30 kg/ha NPK + 2 /ha poultry manure) and a control (no amendment) were evaluated under selected cropping systems such as continuous maize (CM), maize/soybean (M/S) intercropping and maize cowpea (M/C) rotation. Soil samples were taken from treated plots at a depth of 0 – 15 cm and analyzed for soil organic carbon.

Results indicated a significant ($P < 0.05$) build up of soil organic carbon under PM + CF and CM system from 2006-major season to 2007 –major season. The PM + CF recorded soil organic carbon (SOC) values of 1.18 – 1.31% from 2006 -major to 2007- major season which indicated that 0.13 % carbon was sequestered within the short period. Continuous maize cropping system recorded an increase in SOC from 1.19 % in 2006 – major season to 1.31 % in 2007- major season. Crop residues under PM + CF and PM managements sequestered the highest carbon values of 49.05 and 49.11% respectively. The implication is that crops under PM + CF and PM amendments can serve as good carbon sinks to reduce global warming and at the same time produce higher soil organic carbon which can enhance high soil productivity especially on low nutrient status soils.

Keywords: carbon sequestration, nutrient managements, cropping systems

1. Introduction

There is a growing concern that increasing levels of carbon dioxide in the atmosphere will change the climate, making the Earth warmer and increasing the frequency of extreme weather events [2]. Over the past 150 years, the amount of carbon in the atmosphere has increased by 30% [3]. One of the proposed methods to reduce atmospheric carbon dioxide is to increase the global storage of carbon in soils which can eventually result to simultaneous enhancement in agricultural production [3].

Organic matter in soils acts as a large carbon sink and plays an important role in the CO_2 balance [10].

However, there is little information on how different nutrient management strategies could influence soil carbon sequestration in the short term during cropping cycles. Earlier studies considered soil carbon sequestration in the long term and mostly in temperate climates. This study was specifically conducted in a

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tropical climate to evaluate soil carbon sequestration under different nutrient management strategies. In an era when global warming is increasingly becoming an environmental threat to human existence, there is a need for studies of this nature which can provide information on the best soil amendments and cropping systems which will enhance soil carbon sequestration in the short term with increased crop yield/productivity. An understanding of the dynamics of carbon (C) stock in soils, as impacted by management strategies, is necessary to identify the pathways of C sequestration in soils and for maintaining soil organic C (SOC) at a level critical for up keeping soil health and also for restraining global warming [7].

2. Materials and Methods

2.1 Description of the study site

The study was conducted at the Central Agricultural Station, Kwadaso, Kumasi, Ghana in three consecutive cropping seasons (i.e. 2006 – major, 2006 – minor and 2007 – major seasons). The area is located in the semi – deciduous forest zone of Ghana [11] and lies between latitudes 06^0.39' and 06^0.43' North and longitudes 01^0.39'and 01^0.42' West of the Greenwich meridian.

2.1. Climate and soil

The area is characterized by a bimodal rainfall distribution with an annual precipitation of about 1500 mm while monthly temperatures range from 24 – 28 ^{0}C. The study was undertaken on Asuansi soil series classified by [1] as Ferric Acrisol, according to [4] and Typic Haplustult according to [12].

Initial soil analysis of the site in 2006 showed a pH of 6.7 in 1:2.5 suspension of soil and water. Soil texture (sandy loam) was determined by the hydrometer method. Initial soil organic carbon determined by the modified Walkley and Black procedure as described by [8] was low (1.08 %). Other soil chemical properties of the site were total N, 0.07 %, available P, 45.13 mg/kg soil and exchangeable K, 0.38 cmol/kg soil. Generally, the nutrient status of the soil was poor.

2.2. Field experiment

2.2.1. Crop establishment and treatments

The field experiment was a split plot arranged in a randomized complete block design (RCBD) with three replications. The main plot factor was cropping system and consisted of continuous maize (CM), maize/soybean (M/S) intercropping and maize/cowpea (M/C) rotation. The sub-plot factor was nutrient management strategy. Three different nutrient management strategies and a control (no amendment) were considered. Poultry manure – PM (4 t/ha), chemical fertilizer – NPK 15 – 15- 15 (60 – 60 – 60 kg/ha) and poultry + chemical fertilizer (2 t/ha PM + 30 – 30– 30 kg/ha NPK) were applied by side placement two weeks after planting (WAP). At five WAP, plots amended with poultry manure + chemical fertilizer (PM + CF), and chemical fertilizer (CF) were 'top dressed' with nitrogen at the rate 15 kg/ha and 30 kg/ha, respectively. The cultivars of the test crops were maize (Dorke SR), cowpea (Soronko) and soybean (Ahoto). The total land area measured 42.5 m x 14.0 m (595.0 m^2).

2.3. Soil sampling

Soil samples were taken at the depth of 0 – 15 cm during each season prior to crop harvest.

2.4. Laboratory analysis

Soil organic carbon was determined by the modified Walkley and Black procedure as described by [8].

2.5. Data analysis

The collected data was subjected to analysis of variance (ANOVA) using the GenStat statistical package [6]. Separation of means was done using the least significant difference (LSD) method at $P = 0.05$. Carbon sequestrations was calculated from the equation

% C sequestrated = $SOC_{2007} - SOC_{2006}$

where SOC_{2007} and SOC_{2006} indicate the soil organic carbon stocks in 2007 – major and 2006-major seasons, respectively.

3. Results

Table 1 shows soil organic carbon under the different nutrient managements and cropping systems. The control recorded no statistical differences over the period of study. PM and CF plots recorded increases in soil carbon storage from 2006-major to 2007-major but the differences were not significant ($P > 0.05$). However, plots under complementary management of poultry manure and chemical fertilizer (PM + CF) recorded significant increases in soil carbon sequestered over time (Table 1). Carbon sequestered under the PM + CF management between 2006-major to 2007-major season was 0.13 % (Table 2) which differed significantly ($P < 0.05$) from all other amended plots. Carbon sequestered under cropping systems (Table 2) was not significant even though CM cropping system recorded significantly higher values in 2007-major season (Table 1).

Maize residues from PM and PM + CF plots sequestered higher ($P < 0.05$) carbon than residues under CF management and the CTRL (Table 3). The carbon sequestered in maize residues ranged from 48.23 % under CTRL plots to 49.11 % on PM managed plots.

Table 1: Soil organic carbon variation under treatments over cropping seasons

Season of cropping	Nutrient mgt.				Cropping system		
	CTRL	PM	PM + CF	CF	CM	M/S	M/C
2006-major	1.10	1.16	1.18	1.07	1.19	1.02	1.10
2006-minor	1.07	1.17	1.16	1.11	1.26	1.06	1.07
2007-major	1.17	1.27	1.31	1.15	1.31	1.14	1.22
LSD (0.05)	NS	NS	0.12	NS	0.11	NS	NS

CTRL: Control, PM: Poultry manure, PM + CF: Poultry manure + chemical fertilizer, CF: chemical fertilizer, CM: Continuous maize, M/S: Maize / soybean, M/C: Maize / cowpea; Mgt: Management, NS: not significant at $P < 0.05$.

Table 2: % C sequestered under treatments from 2006 - major to 2007- major seasons

Treatments	% C sequestered
Nutrient mgt	
CTRL	0.07
PM	0.11
PM + CF	0.13
CF	0.08
LSD	0.01
Cropping system	
CM	0.12
M/S	0.12
M/C	0.12
LSD	NS

CTRL: Control, PM: Poultry manure, PM + CF: Poultry manure + chemical fertilizer, CF: chemical fertilizer, CM: Continuous maize, M/S: Maize / soybean, M/C: Maize / cowpea;
NS: not significant at $P < 0.05$.

Table 3: Organic C sequestered in maize residues under nutrient management systems after harvest

Management system	% Org. C
CTRL	48.23
PM	49.11
PM + CF	49.05
CF	48.56
LSD (0.05)	0.03

Values are the means of three replications; CTRL: Control, PM: Poultry manure, PM + CF: Poultry manure + chemical fertilizer, CF: Chemical fertilizer, Org: organic, NS: Not significant at $P < 0.05$.

4. Discussion

Seasonal variation of SOC in this study indicated no appreciable increase in plots under the nutrient management strategies except in PM + CF plots which recorded significantly higher value in 2007-major season over value observed in 2006 –major season. This suggests that soils which are often characterized by low SOC could be improved to some extent in the short term by complementary application of chemical fertilizer and poultry manure. The higher values of C sequestered in maize residues on plots under PM and PM + CF managements than on CF and CTRL plots (Table 3) signify that the former nutrient management systems are effective and could provide sinks to store carbon in the soil in the short term.

Plots under CM cultivation recorded significantly higher value of SOC ($P < 0.05$) in 2007-major season than in the previous seasons of 2006 (Table 1). This was because CM cropping is a crop intensification system. [9] indicated that cropping intensification increased crop residue production and organic carbon storage in the soil. This further explain why results in Table 1 indicated significant increase in SOC in CM plots over cropping seasons whereas M/S and M/C plots recorded no significant increase. Conservation tillage and residue management can provide a constant buildup of soil organic carbon and together constitute an agronomic practice that does not only produce a crop but also reduces greenhouse gas emissions by preventing carbon from transforming into carbon dioxide through decomposition [5].

5. Conclusion

The study has indicated that complementary application of poultry manure and chemical fertilizer during cropping cycles could be an effective nutrient management strategy which can contribute to increased carbon sequestration in the soil and in crop residues even in the short term especially on low nutrient status soils. Cropping systems involving continuous maize cultivation under effective nutrient management could produce appreciably higher soil organic carbon value than intercropping system in the short term.

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