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Organic amendments: Effect on carbon mineralization and crop productivity in acidic soil

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ABSTRACT

Addition of organic amendment with inorganic fertilizers is a suitable strategy to achieve sustainable agricultural production. But this practice is associated with increased carbon mineralization leading to release of carbon dioxide, a potential greenhouse gas for global warming. In this perspective, the present experiment was conducted in acidic sandy loam soils of north-east India to characterize the carbon mineralization, soil enzyme activities and okra (*Abelmoschus esculentus* L.) productivity under three (farmyard manure, vermicompost and biochar) commonly used organic amendments when added with inorganic fertilizers. Eight treatments were laid in a randomized block design with three replications. Vermicompost application increased the activities of soil enzymes with greater availability of soil nitrogen, phosphorous and potassium while biochar (hardwood) addition decreased the enzyme activities. Addition of biochar recorded the lowest rate of carbon mineralization (9%), the highest half -life of carbon (64%), higher soil organic carbon (12%) and stable organic carbon fractions (F3 fraction-12% and F4 fraction- 9%) with the highest okra yield compared to vermicompost and farmyard manure. Plant morphological attributes (plant height, leaf number, leaf area and photosynthesis of okra) were significantly enhanced due to addition of organics especially vermicompost and biochar with inorganic fertilizers. The addition of biochar recorded lower benefit cost ratio (3.5 and 3.8) but its application with inorganic fertilizers recorded the highest agronomic efficiency signifying potentiality to uphold efficient nitrogen use and environmental sustainability. Thus, addition of biochar in acidic soil would be a sustainable option to reduce carbon mineralization and uphold crop productivity.

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1. Introduction

Long term use of inorganic fertilizer in conventional agricultural system has led to soil acidification, nutrient imbalance, loss of organic matter leading to disturbances in the chemical and biological balance (Bobul'ská et al., 2015) and reduced cation exchange capacity of soil that enhances salt accumulation (Matocha et al., 2016). Therefore, application of organic amendments under this situation is an environment friendly approach and has been well documented by many researchers (Okur et al., 2016; Sarma et al., 2016). Also the application of organics have positive role in efficient crop growth and yield enhancement. Akande et al. (2010) reported that the application of 2.5 t of organic based fertilizers along with 60 kg N increases okra growth and yield compared to only inorganic applied plots. Application of vermicompost and farmyard manure (FYM) also improves the fruit quality of okra (Attarde et al., 2012).

The added organic amendments influence the soil organic matter (SOM) dynamics through the process of microbial mineralization and immobilization. However, the rate of C-mineralization releasing soil nutrients and CO_2 is governed by the C:N ratio of applied organic amendments and N mineralization (Mohanty et al., 2013). The added N and organic amendments also exert a positive effect on soil microbial structure and enzyme activities along with C-mineralization (Song et al., 2014). Hence, the judicious fertilization strategy through conjoint application of organic amendments and inorganic fertilizer (especially N) is essential for improving nutrient dynamics and maintaining soil organic carbon (SOC) pool in agricultural soil. Fresh organic amendments (e.g. crop residue and FYM) and composted amendments (compost and

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vermicompost) are more prone to decomposition compared to condensed organic materials due to their less humified nature and thereby release more CO_2 to the atmosphere. Thus in recent times, biochar, a pyrolysis product is gaining importance due to its high recalcitrant carbon and its role in increasing water holding capacity, soil pH and cation exchange capacity (Lehmann et al., 2011) and is also reported to provide refugia for mycorrhizae and microbial population which in turn influence binding and bioavailability of the nutritive cations and anions (Maroušek et al., 2017). Growing crops also create an environment conducive for microbial growth by supplying fresh organic materials in the form of sloughed off roots, root exudates and metabolic by products. These added labile plant residues, which act as C or N sources for microorganisms accelerate the enzyme activities and C-mineralization (Song et al., 2014). Furthermore, the C-mineralization rate is strongly affected by the *in-situ* soil environment, climatic parameters and the type of crop grown (Nayak et al., 2012; Mohanty et al., 2013). Therefore, predicting C-mineralization of the applied organic amendments for each crop and soil type can help not only to estimate the nutrient status essential for crop growth but also to forecast the emission of CO_2 into the atmosphere.

Based on these perspectives, the present study was conducted to assess the responses of added organics (FYM, vermicompost and biochar) and inorganic fertilizers on C-mineralization and growth of okra (*Abelmoschus esculentus* L.), an ideal popular vegetable crop of tropics and subtropics. The main objective of this study was to assess the C-mineralization pattern of commonly used organics in acidic sandy loam soils of north-east India. Investigating plant performances and changes in soil chemical and biological properties in the field under the same treatments is another objective of this study. We hypothesized that the responses of C-mineralization kinetics and crop growth to the applied organic amendments will vary from each other. The outcome of the study will aid to screen out the organic amendment that will sustainably maintain SOC pool and crop productivity.

2. Materials and methods

2.1. Experimental site

The experiment was conducted in the experimental field of Tezpur University (latitude 26°14′N and longitude 94°50′ E), Assam, India located on the north bank plain zone of the Brahmaputra basin during the months from April to August, 2015 (Year 1) and 2016 (Year 2). Air temperature during the experimental period ranged between 20 and 36 °C with mean rainfall of 1851 mm. Derived from alluvium of the river Brahmaputra, the soil of the experimental site is a typical inceptisol with sandy loam texture (typic endoaquepts: pH-5.69, soil organic carbon- 12.8 g kg^{-1}; available N, P, K- 275.97, 36 and 279.59 kg ha^{-1} respectively; bulk density- 1.1 Mg m^{-3}; water holding capacity- 44.4%; sand- 71.68%; silt- 15.32% and clay- 13%).

2.2. Experimental design and layout

Okra (*Abelmoschus esculentus* L. cv. OH-397) was grown under irrigated condition in a randomized block design with eight fertilizer treatments replicated thrice. Organic amendments (FYM, vermicompost and biochar) and inorganic fertilizers (N, P and K) were used for the treatments. Based on the package of practices recommended by the Assam Agricultural University, India on fertilizer application in okra, the dose of organic amendments were fixed at 5 t ha^{-1} and N:P:K at the rate of 50:50:50 kg ha^{-1} (recommended doses). The treatment combinations were: Unfertilized control (T_1); N:P:K at the rate 50:50:50 kg ha^{-1} (T_2); 5 t ha^{-1} FYM (T_3); 5 t ha^{-1} vermicompost (T_4); 5 t ha^{-1} biochar (T_5); 50% N+ 100% PK + 5 t ha^{-1} FYM (T_6); 50% N+ 100% PK + 5 t ha^{-1} vermicompost (T_7) and 50% N+ 100% PK + 5 t ha^{-1} biochar (T_8).

Other management practices, such as weeding, irrigation, plant protection measures were uniformly maintained over the experimental period. The experimental area was previously covered with wheat cultivation and after harvest of wheat, the field was ploughed (3 times) and leveled properly for preparation of the seed bed. Full dose of N, P and K were applied as basal (1 day before sowing) while organic fertilizers were added 10 days before sowing. Twenty four pre-soaked (for 24 h) seeds were sown (5–6 cm deep) per plot (of size 2 m × 2 m) maintaining a buffer zone of (1 m) and spacing 45 × 30 cm (row to row and plant to plant) and covered with soil. Depending on the dry spells (after 3–4 rainless days), irrigation was applied.

Cow dung mixed with straw (3:1 with a moisture content of about 85% and 12% respectively) was used as FYM for the experiment. Vermicompost was prepared from crop residue (rice straw) and garden waste (leaf litter and vegetable peels) using *Eisenia fetida* and was ready after 65 days. Biochar was prepared from locally available hardwood obtained from different plant species (mixed wood) by pyrolysis in a muffle furnace (450° C for 4 h) and ground before application in the field. While the sources of N, P and K were urea, single super phosphate and muriate of potash respectively. Before application, organic amendments were sieved with 2 mm sieve and dried samples were analyzed for basic physicochemical properties which are presented in Table 1.

The physical (bulk density, water holding capacity) and chemical (pH, total P, available P and K) properties of the organic amendments were analyzed following Tripathi (2009). Total N and organic C were determined in CHN analyzer (Series 2 CHN S/O Analyzer 2400, Perkin Elmer, USA). Wet digestion in di-acid mixture (9:4 HNO_3:$HClO_4$) followed by quantification in inductively coupled plasma-optical emission spectroscopy (ICP-OES, Optima 2100 DV, Perkin Elmer, USA) was done to estimate the nutrient content in the organic amendments (K, Ca, Mg, Fe and Zn).

2.3. Plant data collection

At six weeks after seed sowing (at the time of first plucking) data on plant morpho-physiological parameters were taken from 5 plants per replications. Plant height, number of nodes and leaf number were measured in the field manually to assess plant growth. Leaf area was recorded by using a laser leaf area meter (model CI-203, USA). Plant photosynthesis rate was measured under ambient environmental condition using an infrared gas analyzer (LI-6400 portable photosynthesis system, LI-COR, USA) in the fourth fully expanded young leaves from top of the okra plant between 10 a.m. and 12 noon. Destructive sampling method was followed to quantify the shoot (stem, leaves and fruit) and root biomass. The plant was separated into shoot (stem, leaves and fruit) and roots. Dry weights were recorded after being oven dried at 80 °C till constant weights were obtained.

Fruits (3–4 days old) were harvested manually for 12 times from 41 (6 week) to 90 days after sowing (DAS) (13 weeks) at 4 days interval. The number, size and weight of the fruits were recorded. Yield was computed on fresh weight basis and cumulative yield was calculated by adding all the harvests for each treatment.

2.4. Agronomic performance and economic evaluation of the fertilizers

To assess the agronomic performance of different treatments, the agronomic efficiency was calculated by the formula given by Guarda et al. (2004). Agronomic efficiency is the economic

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