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Integrated nutrient management in wheat grown in a northeast India soil: Impacts on soil organic carbon fractions in relation to grain yield

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ABSTRACT

The effect of integrated nutrient management practices on soil organic carbon (SOC) fractions, soil carbon (C) storage and grain productivity was investigated in winter wheat *(Triticum aestivum)* for two consecutive seasons (2013–2015). Fertility treatments were NPK as recommended inorganic fertilizer, NPK + cowdung, NPK + whole parts of the green manure plant *Sesbenia aculeata*, NPK + compost of *Azolla caroliniana* and NPK + rice husk dust. Application of NPK through inorganic fertilizer and in combination with organic amendments increased SOC and its active (microbial biomass C and dissolved organic C) and passive carbon fractions (humic and fulvic C, recalcitrant C). Application of organics with inorganic fertilizers resulted in greater soil C accumulation over inorganic fertilizer alone. Greater proportion (46%) of oxidizable organic C in the less labile fraction (F3) and recalcitrant fraction (F4) were found in the soil due to NPK + *Azolla* compost application. Higher concentration of microbial biomass C (MBC) was recorded at NPK + cowdung and NPK + *Sesbenia aculeata*. The trends in dissolved organic C (DOC) are similar to trends with the soil labile C pool (F1 and F2). Principal component analysis (PCA) demonstrated a close association among the recalcitrant C fraction, humic and fulvic C and the degree of humification of SOC. These fractions were apparently transformed more slowly in the soil and persisted for longer when *Azolla* compost was added. *Azolla* compost application with inorganic fertilizer (NPK) may therefore be a good strategy for reducing carbon dioxide (CO_2) in the atmosphere through increased flag leaf photosynthesis and by formation of stable humified substances in the soil without compromising the grain productivity. The amendments significantly increased the photosynthetic rate of wheat in reproductive growth stage. Grain yield was increased 27% due to NPK + *Azolla* compost application compared to control (NPK). The inorganic and organic amendments tested in this study enhanced soil C storage and plant C fixation in a continuous winter-wheat cropping system in India.

1. Introduction

Quantification of changes in soil organic carbon (SOC) and SOC fractions under the influence of fertilization practices is needed for improvement of soil carbon (C) sequestration and soil quality (Tian et al., 2015). Photosynthetic carbon dioxide (CO_2) fixation is the ultimate source of organic C and thus is essential for crop production and C sequestration (Cai et al., 2014). Sequestration of C within the soil provides a sink for atmospheric CO_2, with 0.4–0.8 Gt C currently sequestered globally (Lal, 2004). Plant derived C is the primary source of organic C driving the C cycle in terrestrial ecosystems (Ge et al., 2012). The use of farmyard manure and green manures along with returning crop residues to the soil is generally beneficial for crop production (Singh et al., 2007). Changes in the SOC fractions like labile C, water soluble C, and microbial biomass C (MBC) can be promptly influenced by changes in C inputs (Bolinder et al., 1999). Labile C is the fraction of total C that declines and is restored relatively quickly and therefore more immediately sensitive to changes in farmer soil management practices (Tirol-Padre and Ladha, 2004; Benbi et al., 2012a). Soil dissolved organic carbon (DOC) and MBC have been identified as important fractions in active labile C pool (Lutzow et al., 2007). Soil organic matter (SOM) and labile fractions have been used as sensitive indicators of changes in soil quality (Bayer et al., 2002; Haynes, 2005). Non-humic substances are labile compounds with relatively rapid turnover in soil, since they are readily utilized as substrates by soil microorganisms (Schmidt et al., 2011). Humic substances are more

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stable organic matter compounds, which make up a significant portion of the total SOC (Lal, 1994; Milori et al., 2002). Humic substances can improve soil buffering capacity, increase moisture retention, and may supply plants with available micronutrients. Moreover, these compounds may also bind certain metals, alleviating both heavy metal toxicity and metal deficiency in soils, but resulting in copper or manganese deficiency if the amount of humic substances in soil are too great (McCarthy, 2001). Changes in field management practices can alter the chemical properties of soil humic substances (Moraes et al., 2011). High levels of SOC are often related to greater crop productivity (Yang et al., 2012). Short-term changes in SOC are difficult to measure against the large background of relatively stable organic C in soil (Haynes, 2005). Numerous studies have examined the long-term effects of residue management and fertilization on SOC and labile organic C fractions (Yang et al., 2012; Nayak et al., 2012). Little attention has been paid to the short-term effects of organic amendments on the distribution of SOC and labile organic C fractions.

Soils under a rice-wheat cropping system held a greater proportion of organic C in recalcitrant fractions (Benbi et al., 2015) and the researchers suggested that this could be beneficial for sustainability of organic C in soils under agricultural management. Judicious soil nutrient management can enhance photosynthesis, leading to biomass production and SOC content (Kuzyakov and Gavrichkova, 2010). Wheat is a major cereal crop widely cultivated after rice in northeastern part of India. Intensive cultivation typically results in soil C depletion and reduced productivity. However, the addition of organic amendments is a management technique which may increase SOC content and improve soil quality (Ghosh et al., 2012). Addition of organic amendments may be very useful in tropical regions such as northeast India, where inorganic fertilizer costs are high but organic materials not harvested are plentiful. The organic materials, with the exception of cowdung are produced in natural systems, can be produced in idle between crop fallow periods, or produced as byproducts in the rice mills and are readily available to farmers. Therefore, utilization of these materials in wheat production along with sufficient inorganic fertilizers might contribute to higher grain productivity, and increase SOC.

This study was conducted to evaluate the effects of organic and inorganic amendments on soil C dynamics including changes in the different C fractions. We also assessed the impacts of treatments on leaf photosynthetic rate and biomass partitioning of wheat plants related to grain productivity.

2. Materials and methods

2.1. Study area

A field experiment was conducted through two consecutive winter-wheat growing seasons (November–April) of 2013–2014 and 2014–2015 at the experimental farm of Tezpur University (26° 41′ N, 92° 50′ E and 48 m above mean sea level), Assam, a northeastern province of India. The site is located in the North Bank Plain Agro-climatic Zone of Assam (Fig. 1). The range of maximum and minimum air temperatures during the experimental period ranged between 17.4–36.0 °C and 8.8 and 22.8 °C during 2013–2014 and 20.5–34.9 °C and 9.8–22.0 °C during 2014–2015 respectively. The total rainfall recorded were 16.51 mm (2013–2014) and 76.45 mm (2014–2015). The soil is characterized as sandy loam in texture (55.75% sand, 15.9% silt, 28.35% clay) with a soil pH of 5.5 (1:5 w/v in H_2O). It has a bulk density of 1.05 Mg m^{-3} and concentrations of organic C, available nitrogen, available phosphorus and available potassium of 10.4 g kg^{-1}, 135.33 kg ha^{-1}, 30.15 kg ha^{-1} and 220.02 kg ha^{-1} respectively. The climate of this zone is subtropical monsoon with warm and humid climate during summer months.

2.2. Seed rate, spacing and fertilizer application

The experiments were conducted in a randomised block design (RBD) with 5 treatments, in fixed plots for two consecutive years. Each treatment was replicated 4 times in 4 m × 4 m plots. The treatments consisted of a control (NPK, T1) with a recommended rate of inorganic fertilizer (N:P:K = 80:34:42 kg ha^{-1}) application; NPK + cowdung (CD) (CD at 5 t ha^{-1}, T2), NPK + green manure (GM)

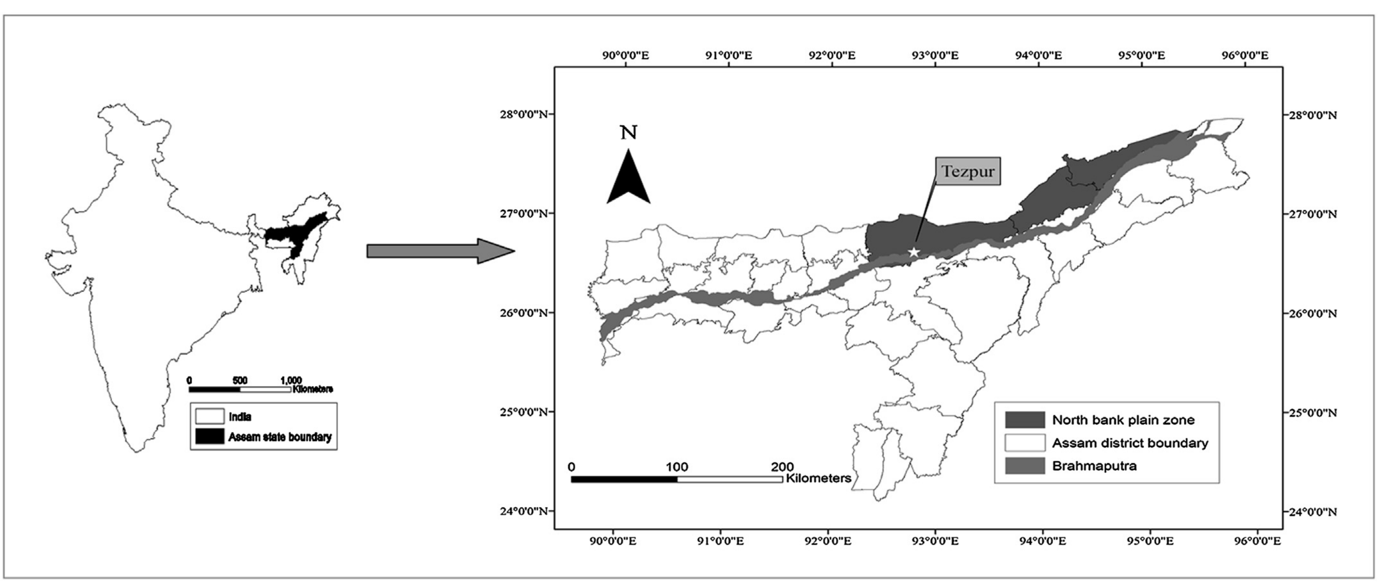

Fig. 1. Map showing the experimental site.