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Research paper

Low carbon resource conservation techniques for energy savings, carbon gain and lowering GHGs emission in lowland transplanted rice

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A R T I C L E I N F O

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A B S T R A C T

Six resource conservation techniques (RCTs) including control were imposed in field during 2013, 2014 on lowland rice (dry season) – rice (wet season) system to assess their impacts on rice production, energy savings, carbon storage, soil carbon fractions, functional microbial diversities and greenhouse gases (methane and nitrous oxide) emission. The resource conservation techniques broadly included i) residue incorporation, ii) in-situ green manuring, iii) zero tillage, iv) mechanical transplanting and v) mechanical transplanting with real time nitrogen management. The control refers to conventional practices (manual transplanting, weeding and harvesting). The energy savings was found highest under zero tillage technique which was 14.4, 17.9% and 13.3, 16.4% higher than conventional practices in dry and wet cropping seasons in 2013 and 2014, respectively. However, in 2013, energy output-input ratio was found maximum under mechanical transplanting with real time nitrogen management (7.64) in dry seasons and under residue incorporation technique (10.78) in wet season. But, in the year 2014 the energy ratio was found maximum 7.62 (dry season) and 10.0 (wet season) under in-situ green manuring. Soil organic carbon (SOC) stock change was significantly higher under zero tillage transplanted rice by 5.3, 6.8% and 8.3, 9.7% as compared to control in the dry and wet seasons of 2013 and 2014, respectively. Methane (CH_4) emission was significantly less in zero tillage than control (11.7%). However, nitrous oxide (N_2O) emission was significantly low (18.3%) in real time nitrogen management technique as compared to other treatments. In general, soil labile carbon fractions and enzymatic activities were significantly higher under RCTs over control, signified improvement of soil quality. Resource conservation technique having zero tillage and real time nitrogen management in transplanted rice could offer a low carbon technology in long run in one hand as these minimize greenhouse gases (GHGs) emission and increase soil carbon stock and also sustain yield in tropical lowland rice.

1. Introduction

Soils act both as source (by releasing CO_2, CH_4 to the atmosphere during soil respiration and anaerobic decomposition) and sink for GHGs and soil organic carbon (SOC) (Rudrappa et al., 2006; Kundu et al., 2007; Bhattacharyya et al., 2012a, 2014). It is an important component of global carbon (C) cycle and has the double potential to accumulate C than atmosphere (Davidson and Verchot, 2000; Lal, 2004). Climate change feedback and crop productivity in agricultural soils also significantly depends on soil organic C dynamics and C storage (Li et al., 2007). Therefore, a concern of GHGs-C emission and fear about global warming has led to an increased attention on soil C storage (Banger et al., 2009). Soil C storage is a function of climate, soil type (Miller et al., 2004; Chabbi and Rumpel, 2009), cropping systems (Jagadamma and Lal, 2010), management practices including tillage (Ogle et al., 2005) and fertilizer application (Bhattacharyya et al., 2007). Specifically, the net C emissions in the form of CO_2 or CH_4 from the paddy soil are governed by several factors viz. crop biomass, air transport mechanisms, growing condition, type of cultivars, soil types, fertilizer practices, amendments use, cultural practices and water management (Brodt et al., 2014; Palm et al., 2014).

Resource conservation techniques provide an opportunity to handle agricultural complexity in small scale farming in tropics (Hobbs, 2007). Literally it helps to manage the problems of soil degradation, depletion of organic matter and nutrient content of soil and to address the burgeoning problem of labour scarcity in agriculture (Giller et al., 2009). Faster decomposition of soil organic matter (SOM) leads to loss of SOC from soil. RCTs could regulate the rapid decomposition process in soil and tends to increase SOC storage (Das et al., 2013). These include minimum or zero tillage, residue management, green manuring, farm

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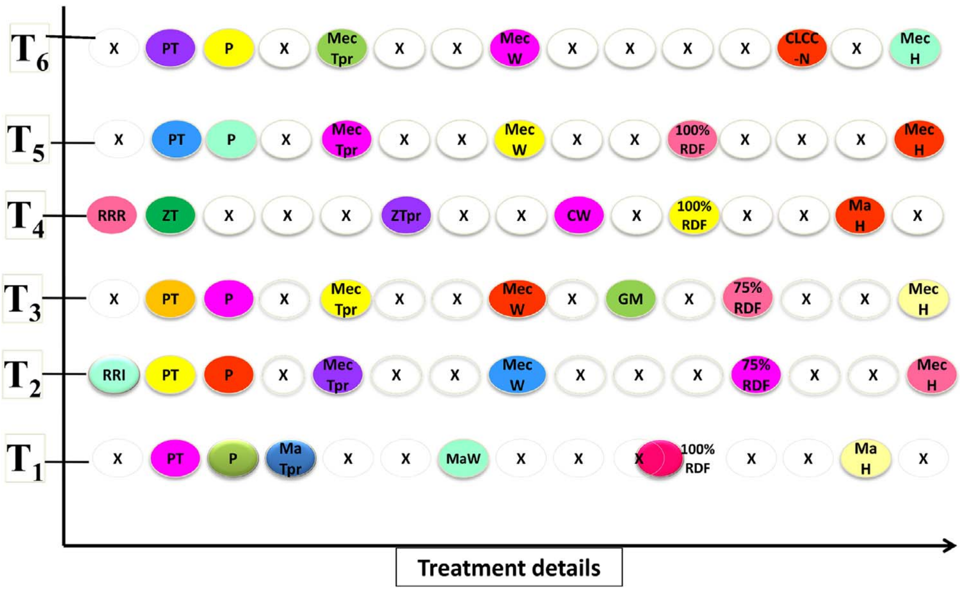

Fig. 1. Schematic representation of treatment details of the study.

mechanization and crop diversification. In zero tillage seeds are sown into soil without tillage in presence of previous crop residue. It is having higher ability to store C in soil, enhancing water infiltration, reducing water/nitrate runoff and stabilizing aggregates (Suddick et al., 2010). Further, it reduces emission of CO_2 by regulating microbial decomposition of SOM which otherwise stimulated by soil tillage. Above all, now a day, in large-scale agricultural production systems zero tillage could be used efficiently due to evaluation of second generation farm machineries which could effectively used in light textured soil (CIMMYT, 2010). Real sense zero-tillage (ZT) practice was born out of a necessity to combat with soil degradation and has been widely adopted by farmers of different scale (Bolliger et al., 2006). The ZT along with residue retention and crop rotation are the pillars of conservation agriculture and is now actively promoted by environment and extension activists, supported by major international initiatives (Haque et al., 2016).

Mitigation of atmospheric GHGs (CO_2, CH_4 and N_2O) which contributes significantly to global warming creating a major challenge in present day agriculture (Lal, 2004). Judicious land-use and appropriate RCTs can mitigate the GHGs emission and thereby the process of climate changes (Wright and Hons, 2004). Soil organic carbon (SOC) pool is the largest terrestrial C pools and its management and enhancement is an important step towards mitigation (Lal, 2004). Therefore, influences of RCTs on SOC pools and its dynamics need to be assessed in tropical rice-paddy and more so in heavy textured soil (Zhang et al., 2007; , 2012a; , 2013).

Enhancement in productivity of agriculture in last five decades have primarily been linked to energy-intensive systems for growing crops such as rice and wheat in tropics. A high input conventional tillage and intensive weed management systems consist of primary and secondary tillage implements. Further, transplanted paddy cultivation demands huge amount of energy in terms of labour for land preparation, puddling and transplanting (Hobbs et al., 2007). Transplanted rice paddy requires 4000–5000 l of water per kg of rice production. Moreover, considerable amount of energy is needed for application of water and at the same time it also caused significant CH_4 emission (Bhatt and Kukal, 2017). On the advancement of second generation farm implements and worldwide concern about energy savings and GHGs emissions issues, RCTs like, zero tillage, residue retention, use of small farm machineries, green manuring, real time N management through leaf colour chart (LCC) provide a platform to address these issues. Among these techniques, zero-till transplanting without puddling opens a new opportunity for energy and C saving. In view of these facts a comparative study of five RCTs including zero tillage transplanting in lowland tropical rice was conducted for two years, in order to quantify the yield change, energy savings, GHGs emissions and C storage related to SOC pools and enzymatic activities in soils.

2. Materials and methods

2.1. Site characters

The experiment was conducted at the research plots of National Rice Research Institute, Cuttack, (20° 44′ N, 85° 94′ E; 24 m above mean see level) in tropical India. The site is characterized by monsoon climate with an average annual rain fall of 1500 mm. Soil texture was sandy clay loam (Aeric Endoaquept) with, bulk density of 1.41 Mg m^{-3}. Electrical conductivity (EC) was 0.49 dS m^{-1} and pH (using 1:2.5, soil: water suspension) was in the range of 6.6 to 6.8. Organic C, total N, available P, and available K content were 6.7 g Kg^{-1}, 0.72 g Kg^{-1}, 11 mg kg^{-1} and 244 mg kg^{-1}, respectively.

2.2. Treatment details and crop management

The study was conducted in both dry and wet seasons during 2013–2014 with the rice cultivar *Naveen* (dry season) and *Pooja* (wet season). Five resource conservation techniques along with conventional package of practice as control were tested with 3 replications. The detail agricultural operations followed in each technique have been described in Fig. 1. Broadly the treatments included, T1: conventional practice as control (power tiller driven puddling + manual transplanting + manual weeding + manual harvesting); T2: power tiller driven puddling + incorporation of paddy straw (5 t ha^{-1}) + 75% N + mechanical transplanting (to reduce the labour (manual) energy and seed during transplanting) + mechanical weeding (cono weeder) + mechanical harvesting (reaper); T3: power tiller driven puddling + in-situ green manuring (incorporation at the time of puddling) + mechanical transplanting + 75% N + mechanical weeding and harvesting; T4: Zero tilled manual transplanting + 100% RDF + chemical weeding (Bispyribac sodium) + manual harvesting. T5: power tiller driven puddling + mechanical transplanting + 100% RDF + mechanical weeding and harvesting and T6: power tiller driven puddling + mechanical transplanting + real time N-management + mechanical weeding and harvesting. Twenty one to twenty five days old seedlings of rice were transplanted at a spacing of 20 cm × 15 cm with one to two seedlings per hill. Chemical fertilizers were applied as