EUROPEAN JOURNAL OF SOIL BIOLOGY 44 (2008) 334–340

available at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/ejsobi

Original article

Evaluation of soil quality parameters in a tropical paddy soil amended with rice residues and tree litters

B.K. Rajashekhara Rao*, R. Siddaramappa

Department of Soil Science and Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore 560 065, Karnataka, India

ARTICLE INFO

Article history:
Received 26 November 2007
Accepted 8 April 2008
Published online 7 May 2008

Keywords:
Biochemical properties
Carbon sources
Enzyme activity
Humic acids
Humification
Humic substances
Microbial biomass
Rice crop
Soil quality
Tree leaf litters

ABSTRACT

Laboratory and greenhouse experiments were conducted to study the effects of applications of rice residue and *Pongamia pinnata* and *Azadirachta indica* leaf litters on biochemical properties (extraction yield of humus, composition of humus, microbial biomass carbon, activities of urease and acid phosphatase) of a lowland rice soil under flooded conditions. Bulk soil sample collected from the Mandya paddy fields was used for the green house trials and the laboratory incubation studies. The organic materials were added at three rates – zero, 25.0 g carbon kg^{-1} (2.5% C) and 50.0 g carbon kg^{-1} dry soil (5.0% C). Results showed that tree leaf litter and rice residue at 5.0% C rate decreased instantaneous decay constant (k), there by retarded the rate of C mineralization. Carbon contents of HA increased with the rate of C added. Study of delta–log K values and C contents of humic acids revealed that greatest molecular weight of HA was in the pongamia litter treatment, followed by neem litter and rice residue. Grain and straw yields of rice crop in the pot culture study were statistically correlated to the soil quality parameters. Neem and pongamia tree litter incorporation at 2.5% C could be considered for improving soil health and crop yields of rice under flooded conditions; however, application at higher rates significantly ($P \leq 0.05$) lowered total dry matter production in rice, despite favorable soil health parameters such as humic yields, microbial biomass – C content and acid phosphatase and urease activity. Among different soil health parameters, microbial quotient was found to be more sensitive indicator of decline in soil quality.

1. Introduction

Sustainable soil management emphasizes use of organic manures and crop residues for maximizing profitability and maintaining environmental quality. A better understanding of soil processes influenced in the soil environment as a consequence of organic matter addition is important for a judicious use of crop and organic residues. When fresh organic carbon (C) is added to soil, an array of complex biochemical and microbiological processes, leading to organic matter and nutrient transformations take place. For example, native humus and applied C influence soil nutrient availability and soil physical properties [5]. Soil humus is composed of different compartments, which differ from each other in biochemical

* *Corresponding author*. Global Theme Agro Ecosystems, The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India. Tel.: +91 94 4977 9336; fax: +91 040 3071 3074/3071 3075.
E-mail address: rsraobk@rediffmail.com (B.K. Rajashekhara Rao).
1164-5563/$ – see front matter
doi:10.1016/j.ejsobi.2008.04.002

composition, biological stability and carbon turnover rates. Soil humus undergoes quantitative and qualitative changes with time and this has implications for soil fertility. The humification process of freshly added C substrates is quite distinct under flooded soil conditions of rice crop (*Oryza sativa*), due to the fact that decomposition is slower than in aerated soils. Rice cultivation increases soil organic matter content and under intensified irrigated rice system phenolic compounds derived from humic acids [18,24]. Under well aerated soil conditions continuous cropping results in lower total and mineralizable organic C and phenols [24]. However, production of toxic, reduction products, accumulation of resistant materials coupled with the formation of poorly humified humic acids under rice growing lowlands are known to cause deleterious effect on crop yields [17,24]. Systematic characterization of humus of rice soils includes extractions of: the Mobile Humic Acid (MHA) pool, which represents relatively young, N-rich HA fraction and the calcium humate (CaHA) pool, which is much more humified and contains less N than MHA [16]. However, we noted that there is dearth of information available in the literature on the immediate process of humification in flooded rice soils, when a variety of residues with contrasting biochemical properties are incorporated [24].

Under upland systems organic C inputs improve soil quality and health. Microbial biomass, microbial quotient and soil enzyme activities are some of the parameters used to measure soil quality [6]. Microbial biomass provides an insight in to the composition and activity of microorganisms responsible for nutrient transformations in soils. Carbon inputs to soil generally enhance soil microbial biomass and enzyme activities [3]. Enzymes catalyze all biochemical reactions and are an integral part of nutrient cycling in soil. Urease activity is involved in urea N cycling, where as acid phosphomonoesterase activity is involved in the transformation of P in the soil. Enzymatic activities have not been investigated for using them as potential tools to reflect short term soil managements effects (C input) in relation to soil quality, especially in flooded soil environment.

Farmers in Southern Karnataka, India use the litters and tree loppings of neem tree (*Azadirachta indica* Adr. Juss.), pongamia tree (*Pongamia pinnata* [L] Pierre and Glabra) in rice culture for maintaining soil fertility. Rice residues are locally-available input in paddy fields, which has the potential to be used as a nutrient and C source. We chose C levels based on the hypotheses that in tropics and subtropics there is need to maintain soil organic carbon contents of 2.5–3.0% [9]. We hypothesize that under flooded conditions of paddy culture the C input dosages above such levels could have negative effects on some soil quality parameters and performance of rice crop. To test the hypothesis, we selected C rate of 5% C to compare tree litters of neem and pongamia with rice residues. This investigation was undertaken with the objectives to: (1) compare the ability of paddy straw and tree litters to influence humification process and associated soil quality attributes under the flooded rice situation; (2) focus on relationship existing between the biochemical properties of the carbon sources with the soil quality indices like microbial biomass, activities of the selected hydrolytic enzymes and humic properties; and (3) examine the response of rice crop to the measured soil quality parameters. Earlier work showed that incorporation of tree litters and rice residues could result in significant accumulation of toxic allelochemicals in soil and there by induce histological abnormalities in the roots of rice crop [21].

2. Materials and methods

2.1. Soils

Experiments were initiated at the Department of Soil Science and Agricultural Chemistry of the University of Agricultural Sciences, Bangalore, Karnataka, India (latitude 12°58′ N, longitude 77°35′ E, altitude 930 m MSL and normal annual rainfall of 869 mm). The bulk soil samples were collected from the Zonal Agricultural Research Station situated at Mandya, in the State of Karnataka having irrigated paddy fields under rice–rice double cropping system. Soil sample from the plough layer (0–15 cm soil depth) of the rice fields were collected from five locations and mixed. The soil sample was air dried, gently crushed, and sieved with a 2-mm mesh sieve. The sieved samples were used for incubation study and for analysis. The soil is Lithic Rhodustalfs with a cation exchange capacity of 11.70 C mol kg^{-1} dry soil, pH (H_20) 6.36, EC (1/5 soil: water) 0.07 dSm^{-1}, and organic carbon content of 4.20 g kg^{-1}.

2.2. Organic carbon sources

Paddy straw and tree leaf litters from *Azadirachta indica* and *Pongamia pinnata* were used as C sources. Green leaves from the neem [*Azadirachta indica* Adr. Juss.] and pongamia [*Pongamia pinnata* (L) Pierre and Glabra] trees were collected, at the fully mature stage, and air-dried to a constant weight. Later, the plant materials were chopped into small pieces of 1.5 cm and used for C enrichment of the soil. Total carbon content of the ground sub sample was estimated by the wet oxidation process with external heating [4]. Proximate composition relative to lignin, cellulose, hemi cellulose, labile fractions was also determined [23]. One gram of powdered sub sample of plant material was refluxed with acid detergent solution (20 g cetyl trimethyl ammonium bromide in 1 L of one normal sulfuric acid) to remove labile water soluble plant materials. The residue obtained was treated with 72% H_2SO_4 to oxidize cellulose and the loss in weight was gravimetrically determined. Material remained following oxidation by the 72% H_2SO_4 was attributed to lignin content. Polyphenols were extracted with absolute ethanol and estimated by Folin–Ciocalteau reagent method using catechol as a standard [23].

2.3. Experimental

2.3.1. Experiment I

Soil was mixed with different C sources at rates of zero (control), 25 g C kg^{-1} soil (2.5% C) and 50 g C kg^{-1} soil (5.0% C) of rice residue, neem litter or pongamia litters. The contents were transferred to 2000 ml polypropylene bottles with an inner diameter of 8 cm, and distilled water was added to maintain a flood water level of 5-cm above the soil layer. Each treatment was replicated three times ($n = 3$) and in total there were 126 bottles. Soil samples were drawn from the containers at 30, 60, 90 and 120 days after incubation to determine C remaining in the soil. Incubation study was carried out