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Effects of conventional tillage and no tillage permutations on extracellular soil enzyme activities and microbial biomass under rice cultivation

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ABSTRACT

Extracellular soil enzymes hold a cardinal position in nutrient dynamics by regulating bioavailability of elements, and hence are linked with soil health. The present study aimed to analyze the responses of extracellular enzymes involved in mineralization of carbon (β-D-glucosidase (BG), cellobiohydrolase (CBH), polyphenol oxidase (PPO)), nitrogen (urease (UR), glycine-amino peptidase (GAP)) and phosphorous (alkaline phosphatase (ALP)) under four permutations of conventional tillage and no tillage under rice–wheat system in eastern Indo-gangetic plains during rice cultivation period. The permutations were: tillage before sowing/transplantation of each crop (RCT–WCT), tillage before transplantation of rice and no tillage before sowing of wheat (RCT–WNT), tillage before sowing wheat and no tillage before sowing of rice (RNT–WCT) and no tillage before sowing of each crop (RNT–WNT). Microbial biomass carbon and nitrogen and activities of BG, CBH, ALP and UR increased with reduction in tillage frequency, becoming the highest under RNT–WNT and the lowest under RCT–WCT. Principal component analyses (PCA) condensed the variables in to two components, apparently described by soil temperature and moisture content under all the tillage permutations. Most of the enzymes and soil properties identified to be associated under PCA followed linear relationships. Under RCT–WCT, CBH, UR and ALP were related with BG. Different orders of residue incorporation and tillage under RCT–WNT, RNT–WCT and RNT–WNT masked these relations. Results indicated that reduction in tillage frequency made the soil healthier. Relationship of BG with other enzymes appeared as a probable indicator to reflect deviations from the conventional cultivation practice in the study region.

1. Introduction

Soil being an essential resource to biosphere and human beings, is also amongst the most complex and least understood systems. While its role in affecting crop productivity is widely studied, our understanding over biochemical controls on elemental dynamics in soil, still needs improvement. Plant growth depends positively on nutrients which are released during reactions catalyzed by enzymes secreted into the soil by microbes and plants (Kibblewhite et al., 2008; Karaca et al., 2011). Because microbial population interacts closely with the soil environment and extracellular enzyme activities (EEAs) play crucial role in transformations of carbon, nitrogen, phosphorous and sulphur at fundamental level of nutrient cycling, these parameters have been proposed as sensitive indicators for soil quality and health than physico-chemical properties (Dick, 1997; Sinsabaugh et al., 2008; Hartmann et al., 2009; Finkenbein et al., 2012). These indicators become even more significant for assessing the performance of different management practices in cultivated soils aiming to improve soil fertility.

Among different resource conserving practices, no tillage is becoming popular among farmers of India, particularly in those areas of Indo-Gangetic plains, which are facing deterioration in soil fertility due to extensive tillage operations (Ladha et al., 2003). Apart from low economic input, no tillage practice has added benefits of nutrient conservation and minimizing soil erosion (Lal, 2004). However, complete elimination of tillage under many cases is considered practically unfeasible due to increased compaction, reduced aeration and increased incidences of weed infestation (Pandey et al., 2012). Therefore, frequency and timing of tillage and

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no tillage practices are needed to be studied under diverse cropping systems. Rice–wheat system covers 13.5 million ha in south-east Asia, the largest part of which falls in India (Timsina and Connor, 2001). While agronomists are assessing economic turnouts under different permutations of tillage and no tillage, it is essential to understand the behavior of biochemical properties and their controls for strategic evaluation of soil quality.

Studies conducted under different climatic regimes have shown that these EEAs respond to even the slightest modifications in environmental conditions and management practices like organic and mineral fertilization (García-Ruiz et al., 2008), tillage operations (Alvear et al., 2005), and herbicides and pesticides applications (Seghers et al., 2003; Gianfreda and Rao, 2011). BG is found to be useful as a soil quality indicator for management effects, organic matter stabilization, and physicochemical changes (Bandick and Dick, 1999; Ndiaye et al., 2000). Class of enzymes called phosphatases are significantly correlated to phosphorous stress, and are also good indicators of soil fertility (Mudge et al., 2002). Enzymes involved in protein decomposition are known to control nitrogen mineralization, but their interaction with soil environment is still unclear. It is suggested that proteases including GAP might be playing crucial role in maintaining soil health (Das and Varma, 2011). UR on the other hand has received lot of attention because it hydrolyses urea, which is the most common nitrogen fertilizer applied in cultivated soils. UR activity responds to organic matter content, soil depth, fertilizer applications, heavy metals, and environmental factors such as temperature (Tabatabai, 1977; Yang et al., 2006).

With above considerations, the present study was undertaken in rice–wheat system subjected to different permutations of conventional tillage and no tillage to understand the changes in microbial biomass carbon and nitrogen and extracellular enzymes participating in carbon, nitrogen and phosphorous mineralization during rice cultivation period. The extracellular enzymes, β-glucosidase (BG), cellobiohydrolase (CBH), polyphenol oxidase (PPO), glycine aminopaptidase (GAP), urease (UR), and alkaline phosphatase (ALP), widely used in soil quality assessments were quantified, and their relationships were calculated for better understanding of soil biochemistry and identification of probable indicators to reflect changes in soil conditions under different tillage permutations.

2. Materials and methods

2.1. Experimental set up

Field experiment involving four permutations of conventional and no tillage practices in rice (cv PHB-71)–wheat (cv HD 2824) sequence was established in June 2003, at Agriculture farm of Banaras Hindu University, India. The site is located in the eastern Indo-Gangetic plains at 25.14°N, 82.03°E and 76.19 m above mean sea level. The experimental soil was inceptisol with sandy loam texture. Under conventional tillage, soil was ploughed up to 15 cm depth during land preparation for sowing of wheat or transplantation of rice. Under this practice, preceding crop was harvested manually, removing the above ground biomass. In case of no tillage, only ripened ears of the preceding crop was harvested while rest of the plant part (>20 cm) was left standing behind. Sowing of the next crop was done by placing seeds into the holes drilled between the standing stubbles. The four permutations of tillage practices were: (i) conventional tilling before transplantation/sowing of each crop (RCT–WCT), (ii) no tilling before sowing of rice and conventional tilling before sowing of wheat (RNT–WCT), (iii) conventional tilling before transplantation of rice and no tilling before sowing of wheat (RCT–WNT) and (iv) no tilling before sowing of each crop (RNT–WNT). The present study was conducted during rice cultivation period of 2010 (July–October 2010). Average soil properties at inception of the tillage experiment in 2003 and before the transplanting of rice in 2010 is presented in Table 1.

Under RNT–WCT and RNT–WNT, sowing of rice (*Oryza sativa* cultivar PHB-71) was done on the same date when seeds were soaked for nursery raising. Under RCT–WCT and RCT–WNT, 21 days old seedlings were transplanted on puddled bed. Urea was applied at a rate of 150 kg N ha^{-1} in three splits, half at the time of transplantation/sowing and the rest in two equal splits at critical tillerring and panical initiation stages. Phosphorous and potassium were applied each at the rate of 75 kg ha^{-1} as P_2O_5 and K_2O, respectively at the time of sowing/transplantation.

2.2. Soil sampling and analyses

Measurement of gravimetric water content (GWC), oxidoreduction potential (ORP), soil temperature (Ts) and EEAs was initiated on the day of transplantation and continued up to the harvesting. It was tried to maintain an interval of five days between two successive measurements. ORP was measured with the help of double junction ORP Tester 10 (Eutech Instruments, Mumbai, India). The electrode was inserted 15 cm deep into the soil and was left undisturbed for approximately five minutes till ORP value displayed on the instrument stopped became constant. The measurements were done at ten randomly selected sites per treatment. When soil was dry enough to prevent good contact between soil particles and electrode, as

Table 1
Soil properties at time of sowing/transplanting rice in 2003 and in 2010 (mean ± 1SE). Different letters in a row indicate that means of 2010 are different from each other in accordance with Duncan's test ($p < 0.5$).

	2003	2010			
	RCT–WCT	RCT–WCT	RNT–WCT	RCT–WNT	RNT–WNT
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Sand (%)	59.51	62.58	63.73	63.21	60.47
Silt (%)	14.19	13.64	13.76	11.12	17.23
Clay (%)	26.30	23.78	22.51	25.67	22.30
pH	7.20 ± 0.01	7.21 ± 0.01^{ns}	7.21 ± 0.07^{ns}	7.20 ± 0.10^{ns}	7.22 ± 0.04^{ns}
Dry bulk density ($g\,cm^{-3}$)	1.44 ± 0.01	1.47 ± 0.01^{c}	1.49 ± 0.01^{c}	1.53 ± 0.10^{b}	2.55 ± 0.01^{a}
Soil organic C ($mg\,g^{-1}$)	3.33 ± 0.02	3.32 ± 0.02^{c}	6.21 ± 0.02^{b}	7.82 ± 0.06^{b}	9.91 ± 0.09^{a}
Total N ($mg\,g^{-1}$)	0.32 ± 0.02	0.38 ± 0.03^{b}	0.62 ± 0.02^{a}	0.53 ± 0.04^{a}	0.58 ± 0.03^{a}
NO_3^--N ($mg\,g^{-1}$)	0.11 ± 0.01	0.14 ± 0.01^{c}	0.17 ± 0.01^{c}	0.16 ± 0.01^{c}	0.14 ± 0.01^{c}
NH_4^+-N($mg\,g^{-1}$)	0.19 ± 0.01	0.22 ± 0.01^{c}	0.38 ± 0.01^{c}	0.38 ± 0.01^{c}	0.40 ± 0.01^{c}
Total P ($\mu g\,g^{-1}$)	2.45 ± 0.05	2.44 ± 0.07^{d}	2.65 ± 0.06^{c}	2.71 ± 0.04^{b}	2.96 ± 0.03^{a}
Available P ($\mu g\,g^{-1}$)	1.23 ± .07	1.05 ± 0.04^{c}	1.43 ± 0.08^{b}	1.46 ± 0.06^{b}	1.87 ± 0.05^{a}

RCT–WCT, tillage before transplanting rice and sowing of wheat; RNT–WCT, no tillage before sowing of rice and tillage before sowing of wheat; RCT–WNT, tillage before transplanting rice but no tillage before sowing of wheat; RNT–WNT, no tillage before sowing of both rice and wheat.