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Review Article

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Soil Enzyme Activity as Affected by Tillage and Residue Management Practices under Diverse Cropping Systems

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A B S T R A C T

Soil enzyme plays a crucial role in nutrient transformation in soil hence referred as an important factor of crop productivity. This review aims to strengthen the state of knowledge of different soil enzymes responsible for transformation of carbon (β-glucosidase, xylanase and cellulase), nitrogen (urease and amidohydrolases), phosphorus (phosphatases and phytase) and organic matter decomposition in soil (dehydrogenase, fluorescein diacetate, phenol oxidase and peroxidase). This review further summarise the effect of tillage and residue management on soil enzyme activities from different literatures and also focuses on the potential use of soil enzymes as soil quality indicator under diverse management practices in various cropping systems. From this study it can be suggested that soil management practices clearly influences soil enzyme activity. All the studied enzymes increase with residue retention and reduction in tillage intensity as compared with intensive tillage practices. It was concluded that soil enzyme activity can potentially used to distinguish sustainable management practices from unsustainable one, hence could be useful to determine soil quality in diverse cropping systems under wide range of agro-climatic conditions.

Introduction

Soil management practices influences population of microorganisms and soil microbial processes through changes in the quantity and quality of plant residues in the soil profile (Kandeler *et al.,* 1999). Soil enzymes are indispensible for nutrient cycling in ecosystems and biotic and abiotic factors including quantity and quality of litter input, moisture and temperature are determining factor for their activity. The hydrolytic enzymes are involved in the dynamics of soil nutrient transformations and their activity in soil is considered to be a major contributor of overall soil microbial activity (Frankenberger and Dick, 1983) and soil quality (Visser and Parkinson, 1992). Modification of microbial dynamics on account of management practices may also be reflected in differences in enzyme activities in soils. Soil physical, chemical, biological and biochemical properties can be significantly altered by tillage and residue management practices, which in turn lead to alteration of the composition, distribution and activities of soil microbial community and enzymes (Dick, 1984; Magnan and Lynch, 1986). Accumulation of organic matter and nutrients at the surface soil layer under reduced tillage produces beneficial effects on soil physical, chemical and biological properties (Beare *et* *al.,* 1997). These improvements are generally associated with enhanced rhizosphere biological activities (Kladivko, 2001). No-tillage (NT) has been shown to increase microbial biomass (Helgason *et al.,* 2010), improve soil carbon (Lal *et al.,* 2003), increase mineralizable N (Spargo *et al.,* 2011), soil moisture (Ma *et al.,* 2008) and enzyme activities (Alvear *et al.,* 2005). Soil enzyme activities are accepted as early and more reliable bio indicators than soil physico-chemical properties under different tillage systems. Dick *et al.,* (1988) and Nannipieri (1994) recommend the measurement of enzymatic activity as both an early and sensitive indicator of management-induced changes in soil quality. This paper intend to summarise studies pertaining to different soil enzymes as affected by tillage and residue management practices and also depicts its potential to be used as sensitive indicator of soil quality in different cropping system in different agro-climatic conditions. This is an approach to seriously contemplating to realise the importance of this hitherto unexplored sector.

Dehydrogenase and fluorescein diacetate activity

Dehydrogenase activity (DHA) is reported to be a sensitive indicator of overall soil biological and microbial activity (Quilchano and Maranon, 2002) because it is associated with oxidation-reduction processes in living cell (Alef and Nanniperi, 1995). DHA represents the total range of oxidative activity of soil microflora and therefore acts as a good indicator of microbiological activity (Nannipieri *et al.,* 1990). DHA has been reported to be an efficient indicator of soil quality in rice–wheat–jute and other cropping systems (Chaudhury *et al.,* 2005). Fluorescein diacetate activity (FDA) is reported to be an indirect appraisal of metabolic activity of microbial population in soils. The FDA represents the hydrolytic activity of soil microorganisms and quantify overall microbial activity (Adam and Duncan, 2001; Dutta *et al.,* 2010). The hydrolysis of fluorescein diacetate has the latent ability to broadly depict soil enzyme activities (Schnurer and Rosswall, 1982) and accumulated biological effects since FDA is hydrolyzed by a number of diverse groups of enzymes such as protease, lipase and esterases (Rotman and Paperaster, 1966) which are associated with the microbial decomposition of organic matter in soil. Parihar *et al.,* (2016) carried out a long term field experiment comprising different tillage permutations (permanent raised bed, zero tillage and conventional tillage) and intensive maize-based cropping systems (Maize-wheat-Mungbean, Maize-Chickpea-*Sesbanea*, Maize-Musturd-Mungbean, Maize-Maize-*Sesbanea*). They observed that DHA and FDA were significantly higher under zero tillage and permanent bed than conventional tillage (CT). They further observed higher DHA and FDA under Maize-Chickpea-*Sesbanea* cropping system as compared with other systems. Majchrzak *et al.,* (2016) observed significant impact of tillage systems on DHA in a wheat crop. It showed significantly higher activity under NT at all the growth stages of wheat. Bhaduri *et al.,* (2017) observed that DHA after harvesting of wheat crop was 11% higher under previously non puddled soil as compared with puddled soil in a long term rice-wheat system in Indo-Gangatic plain in India. Kumawat *et al.,* (2017) reported significant increase of FDA in 0-5 cm soil layer in a maize-wheat system with 50% and 75% residue retention of each crop. Kumar *et al.,* (2017) reported significant increase of FDA under reduced tillage practices (30.8 μg ha^{-1}), followed by no tillage (27.9 μg ha^{-1}) as compared with conventional tillage practices (22.9 μg ha^{-1}) in 0-15 cm soil layer. Neogi *et al.,* (2014) reported 15.4% increase in FDA under minimum tillage as compared with conventional tillage in a rice-maize-cowpea cropping system.

Phosphatases and phytase activity

Acid and alkaline phosphatases are associated with release of inorganic phosphate from organic matter, and are known to perform important role in phosphorus cycle in soil ecosystems (Speir and Ross, 1975). These extracellular enzymes act as an important link between biologically unavailable and mineral phosphorus as they catalyze the hydrolysis of organic phosphate esters to orthophosphate. Alteration of soil environment by tillage, water logging, compaction and fertilization significantly affect phosphatase activity in soil. Acid and alkaline phosphatases have different substrate specificity and pH optimum (Balota *et al.,* 2003; Canarutto *et al.,* 1995). These enzymes originate either from plant roots (and associated mycorrhiza or other fungi) or from bacteria (Tarafder and Marschner, 1994). Alkaline phosphatases are mainly produced by bacteria, fungi and earthworm (Hebrien and Neal, 1990). These enzymes are frequently referred as ecto–enzymes i.e. enzymes acting outside but still linked to cells of their origin. Acosta-martinez *et al.,* (2003) observed significant increase in alkaline phosphatase activity under conservation tillage as compared with conventional tillage practices in semi-arid agricultural soil under cotton based cropping systems. Gajda *et al.,* (2013) reported 18-30% higher alkaline phosphatase activity in a wheat crop under reduced tillage (RT) as compared with conventionally tilled wheat. Singh and Ghosal (2013) concluded that application of FYM and wheat straw along with inorganic fertilizer significantly increased the activity of alkaline phosphatase in 0-10 cm soil layer as compared with the application of inorganic fertilizer alone in a double no-till rice-wheat system. Mathew *et al.,* (2012) reported that acid and alkaline phosphatase activity was higher under NT than CT soil at 0-5 cm soil depth in a long-term tillage experiment in continuous corn system in a silt loam soil.

Phytase (myo-inositol hexakisphosphate phosphohydrolases) catalyses the hydrolysis of inositol phosphates and are potentially important in the soil for their role in phosphorus mineralization due to conversion of organic-P from phytate to plant available form (Ariza *et al.,* 2013). The stability and activity of phytases in soil is affected by sorption on soil particle surfaces which may reduce the potential for interaction with substrates. However this may also provide long-term advantages for their persistence and function in soil (Nannipieri *et al.,* 1996). Yadav and Tarafdar (2004) observed that NT practices substantially increases phytase activity in soil. They concluded that roots of the weeds decomposed and contributed to increase in organic matter and microbial build up thereby increased phytase activity in soil.

Urease and amidohydrolases activity

Urease is a microbial enzyme, which hydrolyses the C-N peptide bonds of linear amides of urea and urea type N substrates, producing carbon dioxide and ammonia (Tabatabai, 1982). Urease is released from living and disintegrated microbial cells and acts as extracellular enzymes adsorbed on clay particles or encapsulated in humic complexes (Nannipieri *et al.,* 1994). Raiesi and Kabiri (2016) reported higher urease activity in a barley crop under reduced tillage practices comprising of chisel and disk plough as compared with CT practices comprising of rotary and mouldboard plough in a 6 year study in semi-arid calcareous soil in central Iran. Evazi *et al.,* (2003) reported that soil enzymatic activities (acid and alkaline phosphatases, alpha-glucosidase, arylsulfatase and urease) were higher in continuous corn under no tillage than conventionally tilled soil. Zhang *et al.,* (2016) observed that activity of the enzymes (urease and sucrase) increased with the amount of straw applied. Incorporation of maize straw was more effective to increase enzyme activities as compared with wheat straw incorporation because of narrow C: N ratio of maize straw than wheat straw which facilitates faster decomposition of maize straw.

Amidohydrolases are enzymes associated with the hydrolysis of organic N compounds in soils. These enzymes are extensively distributed in nature and have been found in plants, animals and microorganisms (Tabatabai, 1994). One of the most important enzyme belong to this group is L-asparaginase, which catalyzes hydrolysis of L-asparagine to L-aspartic acid and ammonia. Hamido and Kpomplekou (2009) observed that no tilled plot preceded by leguminous crimson clover (*Trifolium incarnatum* L.) exhibited higher activity of L-asparaginase enzymes as compared with the plots preceded by black oat (*Avena strigosa* L.) or mixture of crimson clover and black oat. Ekenler and Tabatabai (2004) investigated the dynamics of arylamidase, L-asparaginase, L-glutaminase, amidase, urease and L-aspartase activity under three different tillage systems (no till, ridge till and chisel plough). They observed higher activity of all the enzymes under no till systems.

β-Glucosidase, xylanase and cellulase activity

β-glucosidase catalyzes the hydrolysis of β-glucosides in soil (Hayano and Tubaki, 1985) and such hydrolysis is of fundamental importance for microorganisms to obtain energy from soil (Evazi and Zakaria, 1993). The enzyme β-glucosidase acts in the final stage of decomposition of cellulose by hydrolysing the cellubiose residue to simple sugars (Passos *et al.,* 2008), which are an important energy source for microbes (Waldrop *et al.,* 2000). β-glucosidase enzyme is sensitive to any change in the management practices in soil and directly related to the amount of organic matter and considered as a promising soil quality indicator for assessing the changes induced by tillage practices (Ekenler and Tabatabai, 2003). De la Horra *et al.,* (2003) observed that NT exhibited significantly higher activity of β-glucosidase enzyme at the surface (0-5 cm) soil layer as compared with CT. Roldan *et al.,* (2003) concluded that NT with moderate amount of crop residue (33%) and legume cover has significantly improved soil enzyme activities (DHA, urease, protease, β-glucosidase and acid phosphatase).

Xylanase (endo-1, 4-β-xylanase) enzymes are mainly responsible for decomposition of the polysaccharides of xylose. Xylanases are directly associated with decomposition of the hemicelluloses (Sinsabaugh *et al.,* 1994) into short chain glycosides (Wong *et al.,* 1988). Kandeler and Bohm (1996) observed higher xylanase activity at 0-10 cm soil layer under minimum tilled soil as compared with conventionally tilled soil in a fine sandy Haplic chernozem soil. Conversely, an opposite trend was observed at 20-30 cm soil layer; in this soil layer xylanase activity was significantly higher under conventional tillage as compared with minimum tilled soil.

Cellulases are a group of enzymes that catalyze the breakdown of cellulose, a polysaccharide formed of β-1, 4 linked glucose units. Hence, cellulases perform a crucial role at the initial phase of decomposition of organic matter in soil. Li *et al.,* (2016) investigated the effect of different combinations of mineral fertiliser and rice straw nitrogen on cellulase activity at different wheat growth stages. They observed that cellulase activity increases with application of rice straw as compared with application of mineral fertilizer and control (no fertilizer or straw). Cellulase activity was maximum under treatment with 30% rice straw N plus 70% fertilizer N. Bini *et al.*, (2014) reported that cellulase activity under no tillage was lower as compared with conventional tillage. In contrary with the above results, Meena *et al.,* (2008) reported that cellulase activity under conventional tillage system was 31.3-74.6% higher than ZT practices in lentil-finger millet cropping system in a sandy clay loam soil in Himalayan sub-temperate region. Deng and Tabatabai (1996) reported that cellulase activity was higher under no till/double mulch as compared with chisel and mouldboard plough without mulching. Balota *et al.*, (2003) recorded 68%, 90%, 219%, 46% and 61% increase of amylase, cellulase, arylsulfatase, acid phosphatase and alkaline phosphatase activity under NT as compared with CT in wheat based cropping systems in a subtropical ecosystem in Brazil.

Phenol oxidase and peroxidase activity

Phenol oxidase enzyme removes phenolic hydrogen to form radicals or quinines, hence catalyzes polyphenol oxidation in the presence of oxygen (O_2). These products go through nucleophilic addition reactions in the presence or absence of free-NH_2 groups with the eventual production of humic acid-like polymers (Martin and Haider 1980; Stevenson 1994). The occurrence of phenol oxidase in soil environments is essential for the formation of humic substances. Peroxidases are enzymes associated with depolymerising lignin and use H_2O_2 as electron acceptor. Matocha *et al.,* (2004) observed that after 33 year of imposed tillage and N fertilization treatments, activity of phenol oxidase under NT soil was 1.7 times higher than soil tilled with mouldboard plough in a corn/rye system. Benitez *et al.,* (2006) reported lower phenol oxidase activity under NT as compared with conventional tillage in an olive orchard in Spain. Chu *et al.,* (2016) analysed the effect of long term tillage and crop rotation practices on soil enzyme activities and observed significantly higher activity of phenol oxidase, dehydrogenase and β-glucosaminidase in the no tilled plot as compared with conventionally tilled plot. But the activity of peroxidase enzyme was significantly higher under CT plot than NT plot. Zhao *et al.,* (2016) evaluated the effect of long term (30 years) maize straw incorporation at the rate of 0, 2.25 and 4.50 t ha^{-1} on phenol oxidase activity in a wheat-maize cropping system. They observed that incorporation of maize straw at the rate of 2.25 and 4.5 t ha^{-1} decreased the activity phenol oxidase as compared with control. Mangalassery *et al.,* (2015) observed that the activities of dehydrogenase, cellulase, xylanase, β-glucosidase, phenol oxidase and peroxidase were higher in zero tillage as compared with CT after 7 years in wheat and oilseed rape crop.

Tillage and residue management practices significantly alter enzyme activity in soil in diverse cropping systems. Reduction in the intensity of tillage and residue incorporation can substantially increase enzyme activity in soil which is an indication of better soil quality and sustainability of any cropping system. Soil enzymes can be a useful tool to determine sustainability of a system under various management practices.

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