SOIL MICROBIAL COMMUNITIES AND ENZYME ACTIVITIES UNDER DIFFERENT CROPPING SYSTEMS

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ABSTRACT

Current trend in the global agriculture is to search for highly productive; sustainable and ecologically friendly cropping systems. Studies have been disclosed that some cropping systems had impacts on the microorganisms' biomass, enzyme functions, and diversity. As well, several studies investigated important differences between microorganisms rising from various long-term cropping and control systems although several researches have pointed on the problems of diverse plant species on rhizosphere microbial communities. Some microbial groups show noteworthy parts in the carbon cycling by degrading starch, cellulose, lignin, or lipids; and other microorganisms participate in both nitrogen and carbon cycles in the soil ecology. Accordingly, microbial activity greatly pays on deviations of soil biochemical possessions along with plant nutrition by enabling organic material mineralization, and aggregating nutrient accessibility and plant endorsement. In order to get improved farming techniques we have to aware the correlation between cropping methods and the resultant situations in microbial-ecosystem. Therefore, this review illustrates effect of cropping systems on soil microbial structures and enzyme activities in the soils.

Keywords: Cropping systems, Soil enzymes, Soil microorganisms, Organic fertilizer, Inorganic fertilizer

INTRODUCTION

The loss of soil biodiversity makes soils highly vulnerable to other soil degradation processes (Gaublomme et al., 2006). Soil microorganisms play a noteworthy role in ecosystems by governing a large number of crucial soil processes including soil nutrient biochemical cycling, the disintegration litters and the establishment of established soil living components (Cruz-Martinez et al., 2009; Chen et al., 2015). Therefore, controlling the components in the agricultural soils is a crucial feature of the biological component of agricultural soils is a vital aspect of bearable crop farming systems (Malherbe and Marais, 2015).

They are motorist of disease demolition which reacts to soil condition, shaping the responses of the microbial diversity to various agricultural applications (Malherbe and Marais, 2015). Both the extremes and variability in soil climate can have a dramatic impact on the assembly and role of the microorganisms (Kayler et al., 2015). Soil fertility plays key functions in sustainability of cropping methods (Ullah et al., 2013). Regarding to this, soil enzymes roles and microbial diversity has vital influence on nutrient cycling to sustain the soil fertility index (Nelson et al., 2008).

Enzyme has high role in the cycling of the nutrients and indicating specific biochemical reactions in soil because of their correlation to soil ecology and prompt reactions to alterations in soil administrations (Kandeler et al., 1999). Accordingly, Srilatha et al. (2013) addressed that their roles are deliberated as catalogue of microbiological growth and activity in the soils. More knowledge about the function of soil-enzymes in the ecosystem could provide a distinctive chance for a united biological assessment of soils owing to their decisive part in several soil biological activities (Jain & Garg, 2014). *Phosphatase* speeds up soil organic phosphorus decomposition and improves soil phosphorous concentration that is an important index to assess soil phosphorus bioavailability (Panettieri et al., 2014).

Multiple cropping methods are base for sustainable high output from the farm, countenance for yield escalation and likewise affect soil erosion, soil in organic properties, pest invasion and the carbon confiscation potential (Waha et al., 2013). The exudates from plant root through the growth age (Chou, 2010) have a major effect on the soil compositions, microbial structure and soil tasks (Haichar et al., 2014). For instance, pathogen adapted better to the accumulation of tobacco root exudates than antagonist, which might be the reason of tobacco bacterial wilt outbreak in mono-cropping system subsequently decreased beneficial microbes (Liu et al., 2015).The key mechanism of tolerances of the microbial structures have been authorized to enzymes with unique structural features that provide them to sustain extreme conditions (Ventosa et al., 2008).

Since numerous cropping methods have been carrying out (Tittonell et al., 2007), agronomic management decisions make an essential role in determining to use resource effectively and subsequently yield productivity. Soil microorganisms are responsible for performing many critical ecosystem functions and can be important biotic indicators of soil wellbeing (Jackson et al., 2003). All harmful consequences of agronomic controlling systems on soil microscopic structures would destruct the jobs that they accomplish and henceforth influence the natural phenomena by soils, for instance ecological-recycling and crop protection (Pimentel et al., 2005). Therefore, it is important to bring concrete and systematic thought on the functional variety, composition and fluctuation of microorganisms' structures beneath to various cropping methods. It may help to display the unfavorable scenario on ecosystem and to look for better management techniques.

Microbial Process in the Soil

An understanding of microbial processes is important for the management of farming systems (Melero et al., 2006). In organic management systems nitrogen is supplied in organic form via cover crops and manures, and large amounts of C are included in the mass of organic material required to achieve adequate amounts of N (Gunapala and Scow, 1998). Carbon additions of virtually any form to arable soils often increase the amount of microbial biomass (Marinari et al., 2006). Microbial biomass, rather than total organic C, has been suggested as a useful and more sensitive measure of change in organic matter status (Melero et al., 2006).

One of the factor which influence litter decomposition is soil biotic communities (Berg and McClaugherty, 2014); whereas litter decomposition is fundamental in nutrient cycling and plant nutrition (Guckland et al., 2009). As for soil biota, fungi and bacteria form unique communities and successions during the decomposition process (Romaní et al., 2006), with fungi as the main protagonists in the production of exo-enzymes capable of lignin degradation (Osono, 2007). Soil fauna, according to the size of the animals implicated, are involved in different parts of the decomposition process and soil quality (Andriuzzi et al., 2013). The presence of beneficial fungi is essential to obtain a diversified food web that guarantees nutrient retention and cycling (de Vries et al., 2011), a good soil structure (Ritz and Young, 2004) and pathogen suppression (Garbeva et al., 2006). Therefore, any detrimental effects of agricultural management systems on soil microbial communities would damage the functions that they perform and hence impact the ecological services provided by soils, such as nutrient cycling and crop protection (Pimentel et al., 2005).

Microbial activity and biochemical properties are important indicators of the impact of organic composting on soil (Vinhal-Freitas et al., 2010). Organic waste has high levels of macronutrients such as N, P, K, Ca (Giacomini et al., 2009), and micronutrients such as B, Zn and Mn. Several studies have shown that variations occur in both microbial communities and that soil microbial activity is indirectly attributable to changes in the decomposition of soil organic matter (Saison et al., 2006).

Soil Enzymes and their Applications

Soil enzymes paly role in maintaining soil ecology, physical and chemical properties, fertility, and soil health thus they play key biochemical functions in the overall process of organic matter decomposition in the soil system (Dick et al., 1994; Dick, 1997). They are constantly being synthesized, accumulated, inactivated and decomposed in the soil, consequently playing an imperative role in agriculture and particularly in nutrients cycling (Tabatabai, 1994). In addition, soil enzymes have a crucial role in C (*β-glucosidase* and *β-galactosidase*), N (*urease*), P (*phosphatase*), and S (*sulphatase*) cycles (Karaca et al., 2011). Most tests of enzyme activities (*α-galactosidase, β-galactosidase, α-glucosidase, β-glucosidase, urease, protease, phosphomonoesterase and arylsulphatase*) showed the highest activities under intercropping system (Zhang et al., 2010). According to the study of Okur et al. (2009) soil organic C and soil microbial biomass C (SMBC), and protease, urease, alkaline phosphatase, and dehydrogenase activity were significantly higher in the organic system than in the conventional system

Enzymes may respond to changes in soil management more quickly than other soil variables and therefore, enzymes might be useful as early indicators of biological change (Chen et al. 2015). *Dehydrogenase*, an indicator of microbiological activity involved in oxidative phosphorylation (Alef and Nannipieri, 1995), has been found to decrease in soils treated with herbicide (Reinecke et al., 2002).

Table 1: Soil enzymes as indicators of soil health (adopted from Das & Varma, 2010)

Soil enzyme	Enzyme reaction	Indicator of microbial activity
Dehydrogenase	Electron transport system	C-cycling
β-glucosidase	Cellobiose hydrolysis	C-cycling
Cellulase	Cellulose hydrolysis	C-cycling
Phenol oxidase	Lignin hydrolysis	C-cycling
Urease	Urea hydrolysis	N-cycling
Amidase	N-mineralization	N-cycling
Phosphatase	Release of PO_4^-	P-cycling
Arylsulphatase	Release of SO_4^-	S-cycling
Soil enzymes	Hydrolysis	General organic matter degradative enzyme activities

The enzyme levels in soil systems vary in amounts primarily due to the fact that each soil type has different amounts of organic matter content, composition and activity of its living organisms and intensity of the biological processes (Stevenson, 1986). These enzymes may include *amylase, arylsulphatases, glucosidase, cellulase, chitinase, dehydrogenase, phosphatase, protease and urease* released from plants (Miwa et al., 1937), animals (Kanfer et al., 1974), organic compounds and micro-organisms (Dick and Tabatabai, 1984; James et al., 1991).

B-glucosidase is a common and predominant enzyme in soils (Tabatabai, 1994). It plays an important role because it is involved in catalyzing the hydrolysis of various β-glucosides present in plant debris decomposing in the soil ecosystem. Its final product is glucose, an important C energy source of life to microbes in the soil (Esen, 1993). It is naturally useful as a soil quality bio-indicator, and may give a reflection of past biological activity, the capacity of soil to stabilize the soil organic matter, and can be used to detect management effect on soils (Das and Varma, 2011; Ndiaye et al., 2000).

Cellulase catalyses hydrolysis of cellulose to D-glucose (Hussain et al., 2009) and its activities affected by temperature, soil pH, water and oxygen contents, the chemical structure of organic matter and its location in the soil profile horizon (Alf and Nannipieri, 1995), quality of organic matter debris and soil mineral elements (Deng, 1989 and Tabatabai, 1994) and the trace elements from fungicides (Arinze and Yubedee 2000; Makoi and Ndakidemi, 2008).

Urease is an enzyme that catalyses the hydrolysis of urea into CO_2 and NH_3 with a reaction mechanism based on the formation of carbamate as an intermediate (Tabatabai, 1982). It is widely distributed in nature, mainly from plants and microorganisms found as both intra- and extra-cellular enzymes (Mobley and Hausinger 1989). *Urease* has been widely used to evaluate changes in soil quality related to management, since its activity increases with organic fertilization and decreases with soil tillage (Saviozzi et al., 2001). This enzyme, mostly the cases are an extra-cellular enzyme representing up to 63% of total activity in the soil. Its activity depends on microbial community, physical, and chemical properties of soil (Corstanje et al., 2007), and its stability is affected by various factors: organo-mineral complexes and humic substances make them resistant to denaturing agents such as heat and proteolytic attack (Makoi and Ndakidemi, 2008). It is used as a soil biological indicator because it is influenced by soil factors such as cropping history, organic matter content, soil depth, management practices, heavy metals and environmental factors like temperature and pH (Yang et al., 2006). Urease activity increases with increasing temperature. Subsequently, the understanding of urease activity should provide better ways to manage urea fertilizer, especially in warm high rainfall areas, flooded soils and irrigated conditions (Makoi and Ndakidemi, 2008).

Organic phosphorus (P) is rich in soils and can contribute to the P nutrition of plants and microbes following hydrolysis and the release of free phosphate (Condron et al., 2005). This process is catalyzed by *phosphatase enzymes*, which are actively secreted into the soil by many plants and microbes in response to a demand for P, or passively released from decaying cells (Quiquampoix and Mousain, 2005). Microorganisms that produce phosphates in soil includes soil fungi, particularly those belonging to the genera *Aspergillus* and *Penicillium*, along with *Pseudomonas* and *Bacillus* bacteria that produce mostly neutral phosphatase, while *Actinomycetes* produced only negligible quantities of phosphatases (Tarafdar and Chhonkar, 1979). The amount of acid phosphatase exuded by plant roots has been shown to differ between crop species and varieties (Ndakidemi, 2006), as well as crop management practices (Wright and Reddy, 2001). For instance, several studies reported that legumes secrete more phosphatase enzymes than cereal (Li et al., 2004). It might be due to a higher requirement of P by legumes in the symbiotic nitrogen fixation process as compared to cereals.

Arylsulfatase is the enzyme that catalyses the hydrolysis of organic sulfate ester (Kertesz and Mirleau, 2004) and is typically widespread in the soils (Ganeshamurthy et al., 1995). It is detected in strains of bacteria (*Actinobacteria sp.*, *Pseudomonas sp.*, *Klebsiella sp.* and *Raoultella sp.*), fungi (*Trichoderma sp. and Eupenicillium sp.*), plants and animals (Nicholls and Roy, 1971), and was first detected in soils by Tabatabai and Bremner (1970). It is very

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important to know the possible roles of soil enzymes in order to maintain soil health and its fertility management in ecosystems.

States in the Soil with Different Cropping Systems

Basing on amount and type of fertilizer, inorganic (N) fertilization can have significant effect on soil microorganisms and enzyme activity through its impact on soil pH (Ullah et al. 2013). A number of studies have shown that organic farming leads to higher soil quality and soil biological activity than conventional farming (Carpenter-Boggs et al. 2000; Fliessbach, et al. 2000). The study of Elabed et al. (2014) indicated that soils in the organic systems had higher microbial biomass, DHA, soil bases, EC and available phosphorus than soils in conventional systems. Sustainable bio-fertilizer application suppressed the *Fusarium wilt disease* might through improving soil chemical condition and manipulating the composition of soil microbial community (Shen et al. 2015).

Degraded soils may be restored if farming practices are changed to favor increase in soil organic matter and soil biological activity (Blank, 2008). Compost application and reduced tillage counteracted soil degradation as a result, increases soil microorganisms activities (Alluvione et al., 2013; Duong et al., 2013; Willekens et al., 2014) thus total microbial biomass was 44% higher under reduced compared to conventional tillage. Soil biota may be positively affected by inclusion of legumes in the rotation and animal manure application and negatively by mineral N fertilizers (Truu et al., 2008).

On the other hand, the possible increase in community size only partially explains the increase in respiratory activity (Saison et al., 2006). Compost application can decrease metabolic quotient, which could indicate greater microbial community diversity and greater energy use efficiency (Maeder et al., 2002). The metabolic quotient has been used as a stress indicator and interpreted as microbial efficiency, which is a measure of the energy required to maintain the metabolic activity in relation to the energy required to synthesize biomass (Bardgett & Saggar, 1994). Vinhal-Freitas et al. (2010) summarized that vegetation soil amended with organic compost increased microbial respiration, microbial biomass C, and β-glucosidase, phosphatase activity in the soil and decrease in qCO_2, which could indicate greater energy use efficiency by the microbial community.

Cultural practices, type of vegetation, environment and soil types are some of the factors which may influence activities of *α-amylase and β-amylase enzymes* in soil (Pancholy and Rice, 1973). For instance, amylase enzyme activities of soil can be affected by excreted compounds. Soil Sulphatases can be affected by heavy metal pollution; pH changes in the soil solution; organic matter content; the concentration of organic sulphate esters; enzymatic hydrolysis such as sorption to particles surfaces in soils, and the activity persistence of extracellular arylsulphatases in the soil (Acosta-Martinez and Tabatabai, 2000). Similarly, β-glucosidase enzyme is sensitive to changes in pH and soil management practices (Madejon et al., 2001).

Likewise roles of *cellulases* in agricultural soils affected by several factors such as soil pH, temperature, water and oxygen contents, quality of organic matter and soil mineral elements and the trace elements from fungicides (Deng and Tabatabai, 1994; Arinze and Yubedee, 2000). Also Brzezinska et al. (1998) reported that soil water content and temperature influence *dehydrogenase* activity indirectly by affecting the soil redox status which is closely connected with respiration activity of soil micro-organisms.

Cropping systems such as fertilization, weed and pest management, tillage, and crop rotation can greatly alter soil properties such as soil structure, density, pH, organic matter (OM) content, and nutrient cycling (Dorr de Quadros et al., 2012; Fierer et al., 2012). Similarly, Chu et al (2016) unveiled that pH, organic matter, and cation exchange capacity are important factors that are associated with enzyme activities and described as the amount of nitrogen applied significantly affected soil enzyme activities. Likewise, Song et al. (2011) detected that nitrogen addition suppressed soil *urease* activity and increased *invertase* activity. In addition, Chu et al (2016) explained that tillage treatment significantly decreased activities of *phenol oxidase, peroxidase, dehydrogenase,* and *β-glucosaminidase,* correspondingly, Quadros et al. (2012) said soil microbial activity and diversity decrease as tillage intensifies.

CONCLUSIONS

Maintaining soil health is one of the most vital requirements for crop production in agricultural systems. Soil microorganisms and soil enzymes play a vital role in maintaining soil ecology, physical and chemical properties, fertility and soil health. However, some cropping systems have impacts on the microorganisms' biomass, enzyme functions, and diversity. Therefore, agronomic management decisions make an essential role in determining to use highly productive; sustainable and ecologically friendly cropping systems

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