Chapter 2
Role of Enzymes in Maintaining Soil Health

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2.1 Introduction

Enzymes are the vital activators in life processes, likewise in the soil they are known to play a substantial role in maintaining soil health and its environment. The enzymatic activity in the soil is mainly of microbial origin, being derived from intracellular, cell-associated or free enzymes. A unique balance of chemical, physical, and biological (including microbial especially enzyme activities) components contribute to maintaining soil health. Evaluation of soil health therefore requires indicators of all these components. Healthy soils are essential for the integrity of terrestrial ecosystems to remain intact or to recover from disturbances, such as drought, climate change, pest infestation, pollution, and human exploitation including agriculture (Ellert et al. 1997). Deterioration of soil, and thereby soil health, is of concern for human, animal, and plant health because air, groundwater, and surface water consumed by humans, can be adversely affected by mismanaged and contaminated soil (Singer and Ewing 2000). As soil is the part of the terrestrial environment and supports all terrestrial life forms, protection of soil is therefore of high priority and a thorough understanding of soil enzymes activities is a critical factor in assuring that soil remains healthy. A better understanding of the role of this soil enzymes activity in maintaining the soil health will potentially provide a unique opportunity for an integrated biological assessment of soils due to their crucial role in several soil biological activities, their ease of measurement, and their rapid response to changes in soil management. Although there have been extensive studies on soil enzymes, little has been reported on their roles in maintaining soil health. Thus, it is authoritative to

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understand the roles of these enzymes' activity and their efficiency to maintain soil health for future betterment of soil research and soil biology.

2.2 Soil Enzymes

Soil enzymes are a group of enzymes whose usual inhabitants are the soil and are continuously playing an important role in maintaining soil ecology, physical and chemical properties, fertility, and soil health. These enzymes play key biochemical functions in the overall process of organic matter decomposition in the soil system (Sinsabaugh et al. 1991). They are important in catalyzing several vital reactions necessary for the life processes of micro-organisms in soils and the stabilization of soil structure, the decomposition of organic wastes, organic matter formation, and nutrient cycling, hence playing an important role in agriculture (Dick et al. 1994; Dick 1997).

All soils contain a group of enzymes that determine soil metabolic processes (McLaren 1975) which, in turn, depend on its physical, chemical, microbiological, and biochemical properties. 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 biological processes. In practice, the biochemical reactions are brought about largely through the catalytic contribution of enzymes and variable substrates that serve as energy sources for microorganisms (Kiss et al. 1978). These enzymes may include amylase, arylsulphatases, β-glucosidase, cellulose, chitinase, dehydrogenase, phosphatase, protease, and urease released from plants (Miwa et al. 1937), animals (Kanfer et al. 1974), organic compounds, and microorganisms (James et al. 1991; Richmond 1991; Shawale and Sadana 1981) and soils (Gupta et al. 1993; Ganeshamurthy et al. 1995).

2.2.1 Kind of Soil Enzymes

2.2.1.1 Constitutive

Always present in nearly constant amounts in a cell (not affected by addition of any particular substrate – genes always expressed).

(Pyrophosphatase)

2.2.1.2 Inducible

Present only in trace amounts or not at all, but quickly increases in concentration when its substrate is present.

(Amidase)

Both types of enzymes are present in the soil.

2.2.2 Origin and State of Soil Enzymes

Although the general origins of soil enzymes are (a) microorganisms-living and dead, (b) plant roots and plant residues and, (c) soil animals; the state of soil enzymes in the soil is different as below

State-1: Role of clays

Most activity associated with clays
Increased resistance to proteolysis and microbial attack
Increases the temperature of inactivation

State-2: Role of organic matter

Humus material provides stability to soil nitrogen compounds
Enzymes attached to insoluble organic matrices exhibit pH and temperature changes
Inability to purify soil enzymes free of soil organic matters (bound to organic matter)

State-3: Role of clay–organic matter complexes

Lignin + bentonite (clay) protect enzymes against proteolitic attack, but not bentonite alone
Enzymes are bound to organic matter which is then bound to clay

2.2.3 Importance of Soil Enzymes

Release of nutrients into the soil by means of organic matter degradation
Identification of soils
Identification of microbial activity
Importance of soil enzymes as sensitive indicators of ecological change

2.2.4 Application of Soil Enzymes

Correlation with soil fertility
Correlation with microbial activity
Correlation with biochemical cycling of various elements in soil (C, N, S)
Degree of pollution (heavy metals, SO_4)
To assess the successional stages of an ecosystem
Forensic purposes
Rapid degradation of pesticides
Disease studies
Enzyme activity in soil fluctuates with environment.

2.3 Soil Health

2.3.1 Definition

The definition of soil health must be broad enough to encompass the many functions of soil, e.g., environmental filter, plant growth, and water regulation (Doran and Safley 1997). Definitions of air and water quality standards have existed for a long time, while a similar definition does not exist for soil. A definition of soil health based on this concept would encompass only a small fraction of the many roles soil play (Singh et al. 1999). Soil health is the net result of on-going conservation and degradation processes, depending highly on the biological component of the soil ecosystem, and influences plant health, environmental health, food safety, and quality (Halvorson et al. 1997; Parr et al. 1992).

Several definitions of soil health have been proposed during the last decades. Historically, the term soil quality described the status of soil as related to agricultural productivity or fertility (Singer et al. 1999). In the 1990s, it was proposed that soil quality was not limited to soil productivity but instead expanded to encompass interactions with the surrounding environment, including the implications for human and animal health. In this regard, several examples of definitions of soil quality have been suggested (Doran and Parkin 1994). In the mid-1990s, the term *soil health* was introduced. For example, a program to assess and monitor soil health in Canada used the terms quality and health synonymously to describe the ability of soil to support crop growth without becoming degraded or otherwise harming the environment (Acton and Gregorich 1995). Others broadened the definition of soil health to capture the ecological attributes of soil, and went beyond its capacity to simply produce particular crops. These attributes are chiefly associated with biodiversity, food web structure, and functional measures (Pankhurst et al. 1997).

Several numbers have been recognized for soil health which are as follows:

1. The continued capacity of soil to function as a vital living system, within the ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health (Doran and Safley 1997).
2. Soil health is an assessment of ability of a soil to meet its range of ecosystem functions as appropriate to its environment.
3. Soil health can also be defined as the continued capacity of a specific kind of soil to function as a vital living system, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance the quality of air and water environments, and to support human health and habitation.

2.3.2 Aspects of Soil Health

The term soil health is used to assess the ability of a soil to

Sustain plant and animal productivity and diversity
Maintain or enhance water and air quality
Support human health and habitation

The underlying principle in the use of the term "soil health" is that soil is not just a growing medium; rather, it is a living, dynamic and ever-so-subtly changing environment. We can use the human health analogy and categorize a healthy soil as one

In a state of composite well-being in terms of biological, chemical, and physical properties

Not diseased or infirmed (i.e., not degraded, nor degrading), nor causing negative off-site impacts
With each of its qualities cooperatively functioning such that the soil reaches its full potential and resists degradation
Providing a full range of functions (especially nutrient, carbon, and water cycling), and in such a way that it maintains this capacity into the future.

2.3.3 Interpretation of Soil Health

Different soils will have different benchmarks of health depending on the "inherited" qualities, and on the geographic circumstance of the soil. The generic aspects defining a healthy soil can be considered as follows

"Productive" options are broad
Life diversity is broad
Absorbency, storing, recycling, and processing is high in relation to limits set by climate
Water runoff quality is of high standard
Low entropy
No damage to or loss of the fundamental components

This translates to

A comprehensive cover of vegetation
Carbon levels relatively close to the limits set by soil type and climate
Little leakage of nutrients from the ecosystem

Biological productivity relatively close to the limits set by the soil environment and climate
Only geological rates of erosion
No accumulation of contaminants
The ecosystem does not rely excessively on inputs of fossil energy

An unhealthy soil thus is the simple converse of the above.

2.3.4 Pressures on Soil Health Towards Impacts

The flow chart given below is a simple description of soil health factors and their impacts (Fig. 2.1).

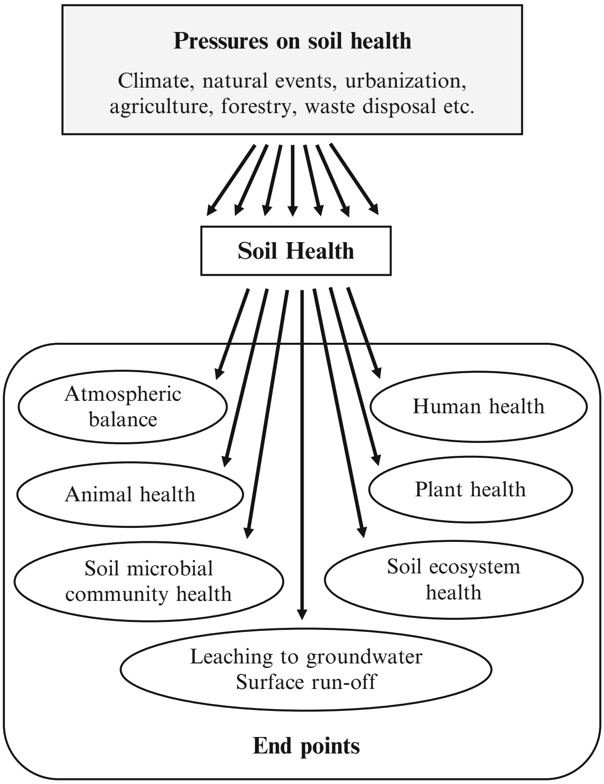

Fig. 2.1 Policy relevant end points of soil health monitoring

2.4 Indicators of Soil Health

2.4.1 Microorganism as Indicators of Soil Health

The biological activity in soil is largely concentrated in the topsoil, the depth of which may vary from a few to 30 cm. In the topsoil, the biological components occupy a tiny fraction (<0.5%) of the total soil volume and make up less than 10% of the total organic matter in the soil. These biological components consist mainly of soil organisms, especially microorganisms. Despite of their small volume in soil, microorganisms are key players in the cycling of nitrogen, sulfur, and phosphorus, and the decomposition of organic residues. Thereby they affect nutrient and carbon cycling on a global scale (Pankhurst et al. 1997). That is, the energy input into the soil ecosystems is derived from the microbial decomposition of dead plant and animal organic matter. The organic residues are, in this way, converted to biomass or mineralized to CO_2, H_2O, mineral nitrogen, phosphorus, and other nutrients (Bloem et al. 1997). Microorganisms are further associated with the transformation and degradation of waste materials and synthetic organic compounds (Torstensson et al. 1998). In addition to the effect on nutrient cycling, microorganisms also affect the physical properties of the soil. Production of extra-cellular polysaccharides and other cellular debris by microorganisms help in maintaining soil structure as well as soil health. Thereby, they also affect water holding capacity, infiltration rate, crusting, erodibility, and susceptibility to compaction (Elliott et al. 1996).

Microorganisms possess the ability to give an integrated measure of soil health, an aspect that cannot be obtained with physical/chemical measures and/or analyses of diversity of higher organisms. Microorganisms respond quickly to changes; hence they rapidly adapt to environmental conditions, and thus they can be used for soil health assessment, and changes in microbial populations and activities may therefore function as an excellent indicator of change in soil health (Kennedy and Papendick 1995; Pankhurst et al. 1995).

Microorganisms also respond quickly to environmental stress compared to higher organisms, as they have intimate relations with their surroundings due to their high surface to volume ratio. In some instances, changes in microbial populations or activity can precede detectable changes in the soil's physical and chemical properties, thereby providing an early sign of soil improvement or an early warning of soil degradation (Pankhurst et al. 1995). The impact of some chemicals on soil health is dependent on microbial activities. For example, the concentration of heavy metals in soil will not change over small time periods, but their bioavailability may. In this way, soil enzymes are acting as important indicators of soil.

2.4.2 Soil Enzymes as Indicators of Soil Health

Enzymes are the direct mediators for biological catabolism of soil organic and mineral components. Thus, these catalysts provide a meaningful assessment of

Table 2.1 Soil enzymes as indicators of soil health

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

reaction rates for important soil processes. Soil enzyme activities (1) are often closely related to soil organic matter, soil physical properties and microbial activity or biomass, (2) changes much sooner than other parameters, thus providing early indications of changes in soil health, and (3) involve simple procedures (Dick et al. 1996). In addition, soil enzyme activities can be used as measures of microbial activity, soil productivity, and inhibiting effects of pollutants (Tate 1995). Easy, well-documented assays are available for a large number of soil enzyme activities (Dick et al. 1996; Tabatabai 1994a, b). These include dehydrogenase, glucosidases, urease, amidases, phosphatases, arylsulphatase, cellulases, and phenol oxidases as shown in Table 2.1.

2.5 Potential Roles of Soil Enzymes in Maintaining Soil Health

A number of soil enzymes and their respective roles in maintaining soil health are stated below

2.5.1 Amylase

The starch hydrolyzing enzyme amylase (Ross 1976) is known to be constituted by α-amylase and β-amylase (King 1967; Thoma et al. 1971). The α-amylases are synthesized by plants, animals, and microorganisms, whereas, β-amylase is synthesized mainly by plants (Pazur 1965; Thoma et al. 1971). This enzyme is widely distributed in plants and soils so it plays a significant role in the breakdown of starch, which converts starch like substrates to glucose and/or oligosaccharides and β-amylase, which converts starch to maltose (Thoma et al. 1971). Studies have, however, indicated that the roles and activities of α-amylase and β-amylase enzymes may be influenced by different factors ranging from cultural practices, type of vegetation, environment and soil types (Pancholy and Rice 1973; Ross 1975). For example, plants may influence the amylase enzyme activities of soil by directly supplying enzymes from their residues or excreted compounds, or indirectly providing substrates for the synthetic activities of microorganisms. Greater understanding is required of the significance of these enzymes in the soil, and to enable proper management techniques to be devised to maximize the benefits that may be derived from such enzymes.

2.5.2 *Arylsulphatases*

This is due to the fact that certain proportions of sulphur in different soil profiles are bound into organic compounds and are indirectly available to plants. Arylsulphatases are typically widespread in nature (Dodgson et al. 1982) as well as in soils (Gupta et al. 1993; Ganeshamurthy et al. 1995). They are responsible for the hydrolysis of sulphate esters in the soil (Kertesz and Mirleau 2004) and are secreted by bacteria into the external environment as a response to sulphur limitation (McGill and Colle 1981). Its occurrence in different soil systems is often correlated with microbial biomass and rate of S immobilization (Klose and Tabatabai 1999; Vong et al. 2003). This enzyme has a role in the hydrolysis of aromatic sulphate esters (R–O–SO_3-) to phenols (R–OH) and sulfate, or sulfate sulfur (SO_4-2 or SO_4–S) (Tabatabai 1994a, b).

Soil is affected by various environmental factors (Burns 1982) such as heavy metal pollution (Tyler 1981); pH changes in the soil solution (Acosta-Martínez and Tabatabai 2000); organic matter content and its type (Sarathchandra and Perrott 1981); such as absorption to particles surfaces in soils, and the activity persistence of extra cellular arylsulfatases in the soil. Considering the importance of S in plant nutrition, a better understanding of the role(s) of arylsulfatases in S mobilization in agricultural soils is critical. So far, very little is known about specific microbial genera or species that play an important role in the soil organosulphur circle (Kertesz and Mirleau 2004) in which arylsulphatases is the key enzyme.

2.5.3 *β-Glucosidase*

Glucosidase is a common and predominant enzyme in soils (Eivazi and Tabatabai 1988; Tabatabai 1994a, b). It is named according to the type of bond that it hydrolyses. This enzyme plays an important role in soils because it is involved in catalyzing the hydrolysis and biodegradation of various β-glucosidase present in plant debris decomposing in the ecosystem (Ajwa and Tabatabai 1994; Martinez and Tabatabai 1997). Its final product is glucose, an important C energy source of life to microbes in the soil (Esen 1993). β-glucosidase is characteristically useful as a soil quality 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 (Bandick and Dick 1999; Ndiaye et al. 2000). This has greatly facilitated its adoption for soil quality testing (Bandick and Dick 1999). Some of the aglycons are known to be the precursors of the toxic substances, which cause soil sickness where plants are grown as monocrops (Patrick 1955; Borner 1958).

β-Glucosidase enzyme is very sensitive to changes in pH, and soil management practices (Acosta-Martínez and Tabatabai 2000; Madejón et al. 2001). Acosta-Martínez and Tabatabai 2000 reported β-glucosidase as sensitive to pH changes. This property can be used as a good biochemical indicator for measuring ecological changes resulting from soil acidification in situations involving activities of this enzyme. Consequently, more understanding of the β-glucosidase enzyme activities and factors influencing them in the ecosystem may contribute significantly to soil health studies.

2.5.4 Cellulases

Cellulose is the most abundant organic compound in the biosphere, comprising almost 50% of the biomass synthesized by photosynthetic fixation of CO_2 (Eriksson et al. 1990). Growth and survival of microorganisms important in most agricultural soils depends on the carbon source contained in the cellulose occurring in the soils (Deng and Tabatabai 1994). However, for carbon to be released as an energy source for use by the microorganisms, cellulose in plant debris has to be degraded into glucose, cellobiose and high molecular weight oligosaccharides by cellulases enzymes (White 1982). Cellulases are a group of enzymes that catalyze the degradation of cellulose, polysaccharides built up of β-1,4 linked glucose units (Deng and Tabatabai 1994). It has been reported that cellulases in soils are derived mainly from plant debris incorporated into the soil, and that a limited amount may also originate from fungi and bacteria in soils (Richmond 1991). Demonstrating the effects of increasing concentrations of fungicides on cellulases activities, Petker and Rai (1992) showed that there was a decreasing effect with fungicides captan, cosan, thiram, zinels, and sandolex. More recently, Arinze and Yubedee (2000) reported that fungicides benlate, calixin, and captan inhibited cellulase activity in *Fusarium monoliforme* isolates. Captatol inhibited cellulose activity in the sandy loam soil (Atlas et al. 1978), and chlorothalonil showed a clear reduction in cellulase activity under flooded or non-flooded conditions (Vincent and Sisler 1968). Studies have shown that activities of cellulases in agricultural soils are affected by several factors. These include temperature, soil pH, water and oxygen contents (abiotic conditions), the chemical structure of organic matter and its location in the soil profile horizon (Deng and Tabatabai 1994; Alf and Nannipieri 1995), quality of organic matter/plant debris and soil mineral elements (Sinsabaugh and Linkins 1989; Deng and Tabatabai 1994) and the trace elements from fungicides (Deng and Tabatabai 1994; Arinze and Yubedee 2000). Srinivasulu and Rangaswamy 2006 reported a significantly more stimulatory effect of cellulases in black soil than red soil. For instance, chitin in the presence of cellulose induces the synthesis of chitinase and other cell wall lytic enzymes which promote the release of the intramural β-glucosidase into the medium. All these findings suggest that activities of cellulases can be used to give preliminary indication of some of the physical chemical properties of soil, thus, easing agricultural soil management strategies. Since cellulases enzymes play an important role in global recycling of the most abundant polymer, cellulose in nature, it would be of critical importance to understand this enzyme better so that it may be used more regularly as a predictive tool in our soil fertility programs. More information on the role of this enzyme is needed since it is affected by different factors, which may jeopardize its involvement in the decomposition of cellulolytic materials in the soil for microbial use and improved soil health in agricultural ecosystems.

2.5.5 Chitinase

Chitinase or chitinolytic enzymes are key enzymes responsible for the degradation and hydrolysis of chitin (polyβ-1-4-(2-ncetamido-2-deoxy)-D-glucoside). They are also considered as the major structural component of many fungal cell walls that use the hyperparasitism mechanisms against pests/pathogen attack (Chet and Henis 1975; Chet 1987). These biological agents also reduce disease-producing agents by using other mechanisms such as antibiosis or competition mechanisms (Park 1960). This agriculturally important enzyme is produced or released by various organisms including plants and microorganisms (Deshpande 1986). Its presence in different forms in the ecosystem has demonstrated its effectiveness in the control of soil-borne diseases such as *Sclerotium rolfsii* and *Rhizoctonia solani* in beans and cotton, respectively (Ordentlich et al. 1988; Shapira et al. 1989). One of the mechanisms proposed involves lytic enzymes chitinase that cause the degradation of cell walls of pathogenic fungi (Ordentlich et al. 1988; Chet et al. 1990; Singh et al. 1999). As for its role in biological control of pests, moreover, due to environmental friendliness, there are so many avenues for the application of this enzyme for maintaining soil health and consequently, increase plant growth and final yields.

2.5.6 Dehydrogenase

The dehydrogenase enzyme activity is commonly used as an indicator of biological activity in soils (Burns 1978). This enzyme is considered to exist as an integral part of intact cells but does not accumulate extracellularly in the soil. Dehydrogenase enzyme is known to oxidize soil organic matter by transferring protons and electrons from substrates to acceptors. These processes are the part of respiration pathways of soil microorganisms and are closely related to the type of soil and soil air-water conditions (Kandeler 1996; Glinski and Stepniewski 1985). Since these processes are the part of respiration pathways of soil microorganisms, studies on the activities of dehydrogenase enzyme in the soil is very important as it may give indications of the potential of the soil to support biochemical processes which are essential for maintaining soil fertility as well as soil health. A study by Brzezinska et al. (1998) suggested that soil water content and temperature influence dehydrogenase activity indirectly by affecting the soil redox status. After flooding the soil, the oxygen present is rapidly exhausted so that a shift of the activity from aerobic to anaerobic microorganisms takes place. Such redox transformations are closely connected with respiration activity of soil microorganisms. They may serve as indicators of the microbiological redox systems in soils and can be considered a possible measure of microbial oxidative activity (Tabatabai 1982; Trevors 1984). For instance, lack of oxygen may trigger facultative anaerobes to initiate metabolic processes involving dehydrogenase activities and the use of Fe (III) forms as terminal electron acceptors (Bromfield 1954; Galstian and Awungian 1974), a process that may affect iron availability to plants in the ecosystem (Benckiser et al. 1984). Additionally, dehydrogenase enzyme is often used as a measure of any disruption caused by pesticides, trace elements or management practices to the soil (Reddy and Faza 1989; Wilke 1991; Frank and Malkomes 1993), as well as a direct measure of soil microbial activity (Trevors 1984; Garcia and Hernández 1997). It can also indicate the type and significance of pollution in soils. For example, dehydrogenase enzyme is high in soils polluted with pulp and paper mill effluents (McCarthy et al. 1994) but low in soils polluted with fly ash (Pitchel and Hayes 1990). Similarly, higher activities of dehydrogenases have been reported at low doses of pesticides, and lower activities of the enzyme at higher doses of pesticides (Baruah and Mishra 1986).

2.5.7 Phosphatases

In soil ecosystems, these enzymes are believed to play critical roles in P cycles (Speir and Ross 1978) as evidence shows that they are correlated to P stress and plant growth. Apart from being good indicators of soil fertility, phosphatase enzyme plays a key role in the soil system (Eivazi and Tabatabai 1977; Dick et al. 2000). For example, when there is a signal indicating P deficiency in the soil, acid phosphatase secretion from plant roots is increased to enhance the solubilization and remobilization of phosphate, thus influencing the ability of the plant to cope with P-stressed conditions (Karthikeyan et al. 2002; Mudge et al. 2002; Versaw and Harrison 2002). Understanding the dynamics of enzyme activities in these systems is crucial for predicting their interactions as their activities may, in turn, regulate nutrient uptake and plant growth, later on, where soil health is concerned.

2.5.8 Proteases

Proteases in the soil play a significant role in N mineralization (Ladd and Jackson 1982), an important process regulating the amount of plant available N and plant growth. This enzyme in the soil is generally associated with inorganic and organic colloids (Burns 1982; Nannipieri et al. 1996). The amount of this extra cellular enzyme activity may be indicative not only of the biological capacity of soil for the enzymatic conversion of the substrate, which is independent of the extent of microbial activity, but might also have an important role in the ecology of micro-organisms in the ecosystem (Burns 1982). There is a need to study the properties and factors affecting naturally occurring enzyme complexes such as those involving protease enzymes in the soil ecosystem as they may reveal some unknown role(s) in maintaining soil health and fertility.

2.5.9 Urease

Urease enzyme is responsible for the hydrolysis of urea fertilizers applied to the soil into NH_3 and CO_2 with the concomitant rise in soil pH (Andrews et al. 1989; Byrnes and Amberger 1989). This, in turn, results in a rapid N loss to the atmosphere through NH_3 volatilization (Simpson et al. 1984; Simpson and Freney 1988). Due to this role, urease activities in soils have received a lot of attention since it was first reported by Rotini (1935), a process considered vital in the regulation of N supply to plants after urea fertilization. Soil urease originates mainly from plants (Polacco 1977) and microorganisms found as both intra- and extra-cellular enzymes (Burns 1986; Mobley and Hausinger 1989). On the other hand, urease extracted from plants or microorganisms is rapidly degraded in soil by proteolytic enzymes (Pettit et al. 1976; Zantua and Bremner 1977). This suggests that a significant fraction of ureolytic activity in the soil is carried out by extracellular urease, which is stabilized by immobilization on organic and mineral soil colloids. Urease activity in soils is influenced by many factors. These include cropping history, organic matter content of the soil, soil depth, soil amendments, heavy metals, and environmental factors such as temperatures (Tabatabai 1977; Yang et al. 2006). For example, studies have shown that urease was very sensitive to toxic concentrations of heavy metals (Yang et al. 2006). Generally, urease activity increases with increasing temperature. It is suggested that higher temperatures increase the activity coefficient of this enzyme. Therefore, it is recommended that urea be applied at times of the day when temperatures are low. Since urease plays a vital role in the hydrolysis of urea fertilizer, it is important to uncover other unknown factors that may reduce the efficiency of this enzyme in the ecosystem.

2.6 Conclusion

It is very essential to understand the possible roles of soil enzymes in order to maintain soil health and its fertility management in ecosystems. These enzymes, usually found in the soil, may have significant effects on soil biology, environmental management, growth and nutrient uptake in plants growing in ecosystems. Their activities may, however, be influenced by unknown cultural management practices either in a major or minor amount. Studies focusing the discovery of new enzymes from microbial diversity in the soil might be the most suitable practices that may positively influence their activities for improved plant growth as well as rendering the friendly biological environments in order to sustain other living beings.

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