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EFFECT OF VARIOUS ENZYMES ON MINERALIZATION OF SOIL ORGANIC MATTER

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Abstract

Soil ecosystem has various microbial communities which provide various functions *viz.* organic matter decomposition, storage and release of nutrients for plants, regulating plant growth etc. Soil enzymes are playing an important role in nutrient cycling by enhancing decomposition of organic matter residues in the soil thus provide nutrients for the plants. Soil organic matter is an important source of nutrients in soil following the mineralization process. Soil enzymes are the main catalyst to carry out these mineralization or decomposition of organic matter in the soil. Both intracellular and extracellular soil enzymes may be intricate in biogeochemical processes but it is challenging to quantify the contribution its specific functions by each enzyme groups. Generally, all the enzymes help in chemical breakdown of organic matter, mineralization of organic matter or transformation of nutrients, identification of soil, microbial activity, indicators for change in ecology and climate change etc. These enzymes are affected by many factors like temperature, pH, nutrient concentration etc. which will determine the rate of mineralization. Enhancing the activity of enzymes in soil by providing optimum condition for its growth is the need of hour as mineralization is one of the essential processes which cannot be avoided at any cost.
***Keywords**:* mineralization, degradation, nutrient cycling, intracellular, extracellular

Introduction

Among the seventeen essential nutrients, carbon, hydrogen and oxygen are obtained from CO_2 and H_2O through photosynthesis but the rest nutrients are to be provided by organic matter mineralization (Dotaniya *et al.,* 2019). Soil ecosystem has various microbial communities which provide various functions *viz.* organic matter decomposition, storage and release of nutrients for plants, regulating plant growth etc. (Devi *et al.,* 2018; Pathma *et al*., 2019). Soil enzymes are playing vital role in nutrient cycling by augmenting decomposition of organic matter residues in the soil thus provide nutrients for the plants (Fang *et al.,* 2010). Soil organic matter (SOM) is an important source of nutrients in soil following the mineralization process. Organic matter also supplies different micro nutrients to the soil which a inorganic fertilizer cannot (Srivatsava *et al*., 2015). Mineralization is a transformation process of organic form nutrients to inorganic form of nutrients which is available to the plants. These processes of nutrient conversion are done by various groups of microorganisms by producing different enzymes and these enzymes are responsible for breakdown of different tissues of plants and animals. Study of ability of the different groups of enzymes will help us to understand the mineralization rate of organic matter and it will eventually make it possible to plan for proper mineralization process of naturally present organic matter.

On Earth, all the living members of the ecosystem are dependent on the soil for its nutrient and energy need as they lowest trophic level group of communities *viz.* microbes and plants are dependent on soil for their growth. Therefore, transformations of nutrients by microbes associated with specific enzymes are very important basis for sustaining the life on Earth. Soil enzymes are the main catalyst to carry out these mineralization or decomposition of organic matter in the soil (Dick and Kandeler, 2005). Enzymes are generally proteins which act as catalyst in reactions on substrates which reduces the energy required for activation energy of that reaction. Enzymes are occurring in extracellular and intracellular types depending on its nature to release inside or outside the cell. Both intracellular and extracellular soil enzymes may be intricate in biogeochemical processes but it is challenging to quantify the contribution its specific functions by each enzyme groups. Soil enzymes increase the area of contact for reactions by breaking down the substrate (Pankhurst *et al.,* 1995; Dotaniya *et al.,* 2017). Lignolytic enzymes are moderately active in mineralizing and solubilizing lignin, some of the Ascomycetes fungi have also been observed to be mineralizing ligin (Deighton *et al.,* 1999). Enzymes xylases, laccases and cellulases are found to be vital degrading enzyme of organic matter with combining its activity with hydrolases (Liers *et al.,* 2006). The enzyme lignin peroxidase produced by white rot fungus *Phanerochaete chrysoporium* is believed to be one of the strategic enzymes in degrading lignin (Vares *et al.,* 1994).

Mechanism of soil enzyme

Soil microorganisms are the source of soil enzymes which acts on plant nutrient kinetics in soil by carrying out decomposition of organic matter. Plant roots releases optimum amount of organic acids which is carbon source for microbes and thus enhance production of enzymes near rhizospheric region and increasing mineralization or organic compounds to inorganic ions (Dotaniya and Meena, 2013; Meena *et al.,* 2017). Soil enzymes enhance the decomposition rate of organic matter and release more ionic nutrients (Fig 1).

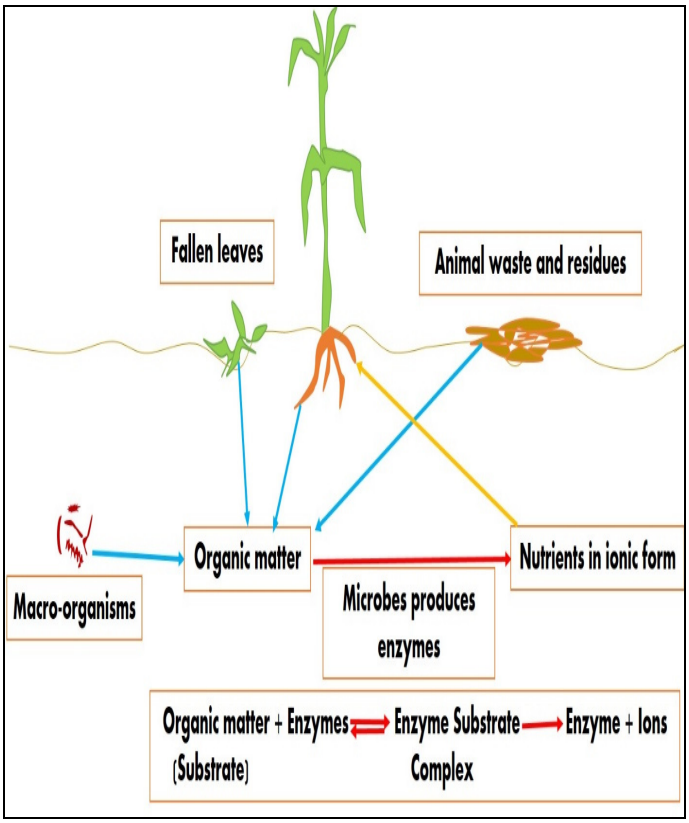

Fig 1. Mineralization of organic matter by microbes

Role of soil enzymes

Soil is having plethora of different microbial communities with different group of enzymes associated with it. Each enzymes has specific functions but generally, all the enzymes help in chemical breakdown of organic matter, mineralization of organic matter or transformation of nutrients, identification of soil, microbial activity, indicators for change in ecology and climate change etc. (Fig 2)

Some specific enzymes with their specific roles are explained in the following table (Table 1). Soil is a home to numerous enzymes, some of which are very important for nutrient recycling and other beneficial functions but there are some enzymes which are functioning against the need of the plants and microbes in the nature. Overall functions of different enzymes are resulting in decomposition of organic matter and nutrient recycling. Dehydrogenases enzyme are considered to be indicator of microbial activity in the soil because of its wide production by microbes (Gu *et al.,* 2009). Amylases are group of enzymes which act on carbon cycling influencing more on vegetation type in the land (Ross, 1975). Cellulase enzyme works on the cellulose present in organic matter which forms a major part of it. β-glucosidase enzyme breaks down the low molecular weight organic matter into simpler compounds (Tabatabai, 1994; Ajwa and Tabatabai, 1994). This particular enzyme is also vastly produced by microbes thus establishing itself as an important indicator of microbial activity in soil (Dontaniya *et al.,* 2019). Orthophosphates are acted upon by phosphatases enzymes and are adaptive and inductive type (Nannipieri, 1994). Organic nitrogen in the soil is mineralized by protease enzyme (Ladd and Jackson, 1982) and is associated with colloidal substances in soil (Nannipieri *et al.,* 1996; Burns, 1982). These enzymes break and degrade the proteins into shorter peptides and then amino acids. Urea is the most common form of nitrogenous fertilizers and it is not available to the plants as it is, it needs to be broken down to ionic forms *i.e* ammonium. Urease enzymes hydrolyse urea into NH_4 and CO_2 (Pettit *et al.,* 1976; Andrews *et al.,* 1989; Fazekasova, 2012). Urease is a common type of enzyme produced by most of the soil microbes and plant roots (Follmer, 2008), it acts as both extracellular and intracellular form (Burns, 1986; Mobley and Hausinger, 1989).

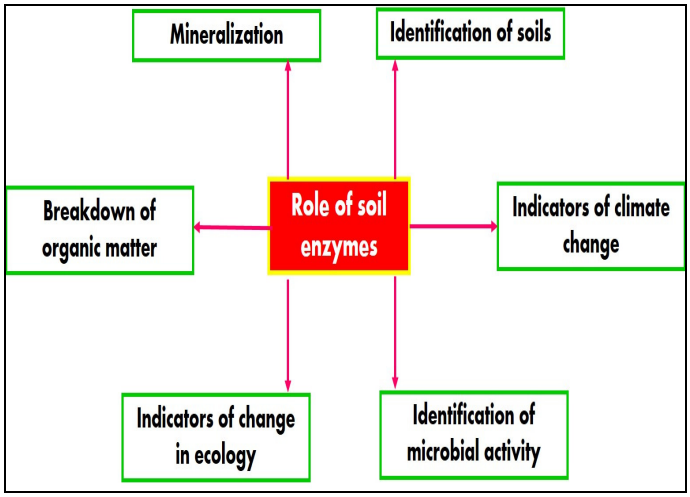

Fig. 2 : Important roles played by soil enzymes in soil

Table 1: Role of specific enzymes

Enzymes	Substrate	End Product	Importance for plants and other microbes	Function in soil
Dehydrogenase	triphenyl tetrazolium chloride	triphenyl formazan	energy and nutrients for microorganisms, soil quality and fertility indicator	biological oxidation of soil organic matter
Phosphatase	phosphorus	phosphate (PO_4)	available P for plants	nutrient recycling
Sulfatase	sulfur	sulfate (SO_4)	available S for plants	nutrient recycling
Beta glucosidase	carbon compounds	glucose (sugar)	energy for microorganisms	organic matter decomposition
Fluorescein Diacetate Hydrolysis	organic matter	carbon and various nutrients	nutrients and energy for microorganisms, measure microbial biomass	organic matter decomposition nutrient recycling
Amidase	carbon and nitrogen compounds	ammonium (NH_4)	available NH_4 for plants	nutrient recycling
Urease	nitrogen (urea)	ammonia (NH_3) and carbon dioxide (CO_2)	available NH_4 and NO_3 for plants	nutrient recycling

Lipase	lipids (fats and oils)	fatty acids and glycerol	energy for microorganisms	organic matter decomposition nutrient recycling
Gelatinase	gelatin	polypeptides, peptides, and amino acids	energy for microorganisms	organic matter decomposition nutrient recycling
Nitrate reductase	nitrate	nitrite (NO_2)	toxic end product	Loss of nutrients

Factors affecting microbial and enzymatic activity

Temperature is an important factor which is affecting microbial activity and the maximum growth as well as activity is observed within the range of temperature 25 – 35^0C (Alexander, 1997). De-polymerization of organic matter is carried out by enzymatic catalyst which is more easily accessible to microbial attack for further conversion to carbon, energy, nutrients etc. (Tian *et al.,* 2010). The utilization of these products by microbes will again cause immobilization of nutrients in the soil. The variation in pH also plays a vital role in activity of enzymes. Most of the enzyme activity increases with increase in pH except the enzyme phosphatase enzyme (Acosta-Martínez and Tabatabai, 2000). L-glutaminase enzyme was found to be the most sensitive enzyme among the 14 enzymes analyzed. The effect of nitrogen fertilization has also been observed to be affecting different enzyme activities (Ajwaa *et al.,* 1999). For increasing enzymes like carbonic anhydrase (CA) and superoxide dismutase (SOD) activities application of Zn fertilizers was found most effective in increasing chlorophyll and protein content in different crops (Mathpal *et al*., 2015). Tall grasses or pristine ecosystem are indicated by enzyme activity and burning of these residues on the soil affects the microbial biomass and its ability to produce enzymes.

Soil enzyme activities are affected by presence of phenolic compounds in the soil organic matter. A hypothesis was proposed by Freeman *et al.* (2001) called 'enzymatic latch' to show better mineralization after drainage due to increase in phenol oxidase enzyme in peaty land. They have reported decrease in C content in organic matter due to reduction in inhibitory compounds or toxic soil enzymes by draining the wet land. The relationship between C storage in till and no till practices have also been explained by the hypothesis 'enzymatic latch' (Zibilske and Bradford, 2007). In highly managed turfgrass system, it has been observed that the phenolic compound is also associated with pH of the soil and this factor can also affect the soil hydrolytic enzymes and C storage in the soil (Yao *et al.,* 2009).

Conclusion

Various enzymes are playing their specific role in mineralizing organic matter which is an essential process for nutrient cycling. These enzymes are affected by many factors like temperature, pH, nutrient concentration etc. which will determine the rate of mineralization. Some of the important soil enzymes are dehydrogenase, amylase, phosphatases, protease, hydrolases, cellulases, xylasses etc. Among the common group of enzymes inhabiting in soil, catalase, alkaline phosphatase and amidase are found to be predicting the microbial population in that particular type of soil. Instead of going additional application of chemical fertilizers to the soil, one can enhance the activity of enzymes in soil by providing optimum condition for its growth as mineralization is one of the essential process which cannot be avoided at any cost. But proper understanding of different functions of different enzymes is important to use these components in successful mineralization of organic matter for a sustainable end.

References

Acosta-Martinez, V. and Tabatabai, M.A. (2000). Enzyme activities in a limed agricultural soil. Biol. Fert. Soils., 31(1): 85-91.

Ajwa, H.A. and Tabatabai, M.A. (1994). Decomposition of different organic materials in soils. Biol. Fert. Soils., 18(3): 175-182.

Ajwa, H.A.; Dell, C.J. and Rice, C.W. (1999). Changes in enzyme activities and microbial biomass of tallgrass prairie soil as related to burning and nitrogen fertilization. Soil Biol. Biochem., 31(5): 769-777.

Alexander, M. (1977). Introduction to soil microbiology. 2nd Edn. Wiley Eastern Limited, New Delhi.

Andrews, R.K.; Blakeley, R.L. and Zerner, B. (1989). Urease: a Ni (II) metalloenzyme. The bioinorganic chemistry of nickel. VCH, New York, 141-166.

Bums, R.G. (1986). Interaction of enzymes with soil mineral and organic colloids. Interactions of soil minerals with natural organics and microbes, (interactionsofs), 429-451.

Burns, R.G. (1982). Enzyme activity in soil: location and a possible role in microbial ecology. Soil Biol. Biochem., 14(5): 423-427.

Deighton, N.; Muckenschnabel, I.; Goodman, B.A. and Williamson, B. (1999). Lipid peroxidation and the oxidative burst associated with infection of *Capsicum annuum* by Botrytis cinerea. Plant J., 20(4): 485-492.

Devi, Y.B.; Meetei, T.T. and Kumari, N. (2018). Impact of Pesticides on Soil Microbial Diversity and Enzymes: A Review. Int. J. Curr. Microbiol. App. Sci., 7(6): 952-958.

Dick, R.P. and Kandeler, E. (2005). Enzymes In Soils. Encyclopedia of Soils in the Environment, 448–456.

Dotaniya, M.L. and Meena, V.D. (2015). Rhizosphere effect on nutrient availability in soil and its uptake by plants: a review. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 85(1): 1-12.

Dotaniya, M.L.; Aparna, K.; Dotaniya, C.K.; Singh, M. and Regar, K.L. (2019). Role of soil enzymes in sustainable crop production. In Enzymes in Food Biotechnology (pp. 569-589). Academic Press.

Dotaniya, M.L.; Rajendiran, S.; Meena, V.D.; Saha, J.K.; Coumar, M.V.; Kundu, S. and Patra, A.K. (2017). Influence of chromium contamination on carbon mineralization and enzymatic activities in Vertisol. Agric. Res., 6(1): 91-96.

Fang, S.; Liu, J.; Liu, D. and Xie, B. (2010). Enzymatic activity and nutrient availability in the rhizosphere of

poplar plantations treated with fresh grass mulch. Soil Sci. Plant Nut., 56(3): 483-491.

Fazekašová, D. (2012). Evaluation of soil quality parameters development in terms of sustainable land use. Sustainable development-authoritative and leading edge content for environmental management, 435-458.

Follmer, C. (2008). Insights into the role and structure of plant ureases. Phytochemistry, 69(1): 18-28.

Freeman, C.; Ostle, N. and Kang, H. (2001). An enzymic'latch'on a global carbon store. Nature, 409(6817): 149.

Gu, Y.; Wang, P. and Kong, C.H. (2009). Urease, invertase, dehydrogenase and polyphenoloxidase activities in paddy soil influenced by allelopathic rice variety. Eur. J. Soil Biol., 45(5-6): 436-441.

Ladd, J.N. and Jackson, R.B. (1982). Biochemistry of ammonification.[w] FJ Stevenson (ed.) Nitrogen in agricultural soils. 173-228. Am. Soc. Agron., Madison.

Liers, C.; Ullrich, R.; Steffen, K.T.; Hatakka, A. and Hofrichter, M. (2006). Mineralization of 14 C-labelled synthetic lignin and extracellular enzyme activities of the wood-colonizing ascomycetes *Xylaria hypoxylon* and *Xylaria polymorpha*. Appl. Microbial. Biotechnol., 69(5): 573-579.

Mathpal, B.; Srivastava, P.C.; Shankhdhar, D. and Shankhdhar, S.C. (2015). Improving key enzyme activities and quality of rice under various methods of zinc application. Physiol. Mol. Boil. Pla., 21(4): 567-572.

Meena, V.S.; Meena, S.K.; Verma, J.P.; Kumar, A.; Aeron, A.; Mishra, P.K. and Dotaniya, M.L. (2017). Plant beneficial rhizospheric microorganism (PBRM) strategies to improve nutrients use efficiency: a review. Ecol. Eng., 107: 8-32.

Mobley, H.L. and Hausinger, R.P. (1989). Microbial ureases: significance, regulation, and molecular characterization. Microbiol. Mol. Biol. Rev., 53(1): 85-108.

Nannipieri, P.; Sequi, P. and Fusi, P. (1996). Humus and enzyme activity. In Humic substances in terrestrial ecosystems (pp. 293-328). Elsevier Science BV.

Pankhurst, C.E.; Hawke, B.G.; McDonald, H.J.; Kirkby, C.A.; Buckerfield, J.C.; Michelsen, P. and Doube, B.M. (1995). Evaluation of soil biological properties as potential bioindicators of soil health. Aus. J. Exp. Agric., 35(7): 1015-1028.

Pathma, J.; Raman, G. and Sakthivel, N. (2019). Microbiome of Rhizospheric Soil and Vermicompost and Their Applications in Soil Fertility, Pest and Pathogen Management for Sustainable Agriculture. In Soil Fert. Manag. Sustain. Dev. Springer, Singapore. 189-210.

Pettit, N.M., Smith, A.R.J.; Freedman, R.B. and Burns, R.G. (1976). Soil urease: activity, stability and kinetic properties. Soil Biol. Biochem., 8(6): 479-484.

Ross, D.J. (1975). Studies on a climosequence of soils in tussock grasslands. 5. Invertase and amylase activities of topsoils and their relationships with other properties. NZJ Sci.

Srivatsava, P.K.; Maruthi Sankar, G.R.; Kumar, P.V.; Singh, S.P.; Rani, N.; Singh, A. and Agarwal, V.K. (2015). Effects of organic and inorganic fertilizers on soil and plant nutrients and yields of pearl millet and wheat under semi-arid Inceptisols in India. Commun. Soil Sci. Plan., 46(20): 2595-2614.

Tabatabai, M.A. (1994). Soil enzymes. Methods of soil analysis: part 2—microbiological and biochemical properties, (methodsofsoilan2), 775-833.

Tian, L.; Dell, E. and Shi, W. (2010). Chemical composition of dissolved organic matter in agroecosystems: correlations with soil enzyme activity and carbon and nitrogen mineralization. Appl. Soil Ecol., 46(3): 426-435.

Vares, T.; Niemenmaa, O. and Hatakka, A. (1994). Secretion of ligninolytic enzymes and mineralization of 14C-ring-labelled synthetic lignin by three *Phlebia tremellosa* strains. Appl. Environ. Microbiol., 60(2): 569-575.

Yao, H.; Bowman, D.; Rufty, T. and Shi, W. (2009). Interactions between N fertilization, grass clipping addition and pH in turf ecosystems: implications for soil enzyme activities and organic matter decomposition. Soil Biol. Biochem., 41(7): 1425-1432.

Zibilske, L.M. and Bradford, J.M. (2007). Oxygen effects on carbon, polyphenols, and nitrogen mineralization potential in soil. Soil Sci. Soc. Am. J., 71(1): 133-139.