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Potentials for Soil Enzyme Activities as Indicators of Ecological Management

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Abstract

Activity measurements of selected soil enzymes (cellulase, glucosidase, amidohydrolase, phosphatase, arylsulfatase) involved in carbon, nitrogen, phosphorus, and sulfur cycling in the biosphere, hold potential as early and sensitive indicators of soil ecological stress and restoration, These measurements are advantageous, because the procedures are simple, rapid, and reproducible over time. Enzyme activities are also sensitive to short-term changes in soil and kind-use management. Enzyme activities have also been observed to be closely related to soil organic matter proposed as an index of soil quality.

Introduction

Public concerns about soil, water, and environmental degradations have increased significantly and agricultural practices are criticized as a major contributor. The activity measurements of some selected soil enzymes (cellulase, α- or β- glucosidase, amidohydrolase, acidic or alkaline phosphatase, and arylsulfatase) involved in carbon, nitrogen, phosphorus, and sulfur cycling in the biosphere, are being considered as potential indicators of soil management practices, soil quality/health, ecological stress and restoration. Soil enzyme activities have recently been considered among the most efficient and cost-effective tools for analyzing changes in various land management practices such as residue management, soil compaction, tillage, and crop rotation (Dick, 1994, Deng, 1994, Senwo, 1995),

Soil enzyme activities can be used: (1) to test and/or generate hypotheses to improve understanding of soil biological, chemical, and physical processes; (ii) to provide guidelines in identifying gaps in knowledge and stimulate new research initiatives; (iii) to integrate basic knowledge of various biochemical and physical attributes of the biosphere; (iv) to make long-term predictions of the impacts of agricultural practices on soil, water, and environmental quality; and (v) to select the best alternative practices fitting the desired soil, water, and environmental quality goals.

Enzyme activities in soils have been shown to be closely related to other proposed indexes (organic matter, pi-Q of soil quality (Table 1).

Table 1. Correlation coefficients for linear regressions of enzymatic activities and organic C or pH of soil under tillage and residue management.

	Correlation Coefficient	
Enzyme activity	Organic C	pH
	------------------------ r†	------------------------------
Aspartase	0.84***	0.41**
Amidase	0.90***	0.24
L-asparaginase	0. SO***	0.74***
L-glutaminase	0.70***	0.77***
Urease	0.80***	0.72***

‘**, ***, Significant at P <0.01, and 0.001 respectively (From Senwo, 1995).

Soil organic matter decomposes very slowly and many years may be required to measure changes from decomposition activities. The accumulation of organic and inorganic nutrients in soils stimulates microbial growth and activity, and therefore, enzyme synthesis. High organic matter levels from residue applications may provide more favorable environment for the accumulation of enzymes in the soil matrix (Burns, 1982). Enzymes in soils may be polymerized, entrapped, and/or adsorbed giving rise to a stable active enzyme-soil colloid associations (Burns, 1982) and their activities in soils are also closely related (Table 2).

Table 2. Correlation coefficients for linear regressions of between enzyme activities.

	Correlation Coefficient			
	Aspartase	Cellulase	α-Gluco	β- Gluco
	$r^{\dagger}$			
Arylsulfatase	na	0.33*	0.74***	0.46**
Amidase	0.44**	0.66***	0.67***	0.61***
L-asparaginase	0.94***	0,43**	0.76***	0.53***
L-glutaminase	0.88***	0.40**	0.66***	0.48**
Urease	0. SO***	0.40**	0.87***	0.50**

†*,**, ***, Significant at $P < 0.05$, 0.01, and 0.001 respectively. (From Deng, 1994; Senwo, 1995). na = not available, Glu = glucosidase.

Various soil management practices have profound effects on enzyme activities (Dick, 1994; Deng, 1994; Senwo, 1995). Gupta and Germida (1988) observed that cultivation depressed phosphatase and arylsulfatase activities by 49 and 65%, respectively. Senwo (1 995) observed aspartase activity in soils were affected by tillage and management practices (Fig. 1).

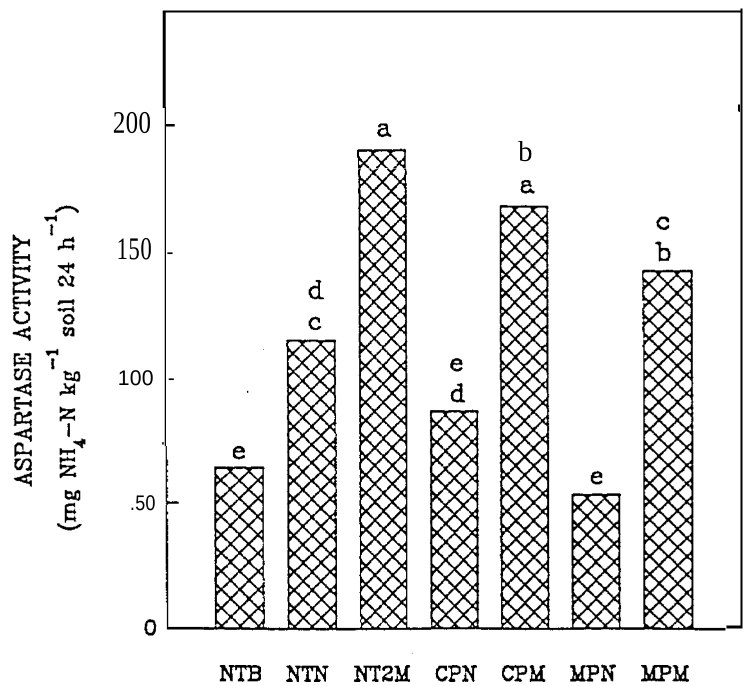

Fig. 1. Bars with the same letter are not significantly different ($P < 0.05$). NTB = not tilled but bared, NTN = not

tilled but not bared, NT2M = not till but doubled mulch, CPN = chisel plowed and not mulched, CPM= chisel plowed and mulched, MPN = moldboard plowed and not mulched, MPM = mold board plowed and mulched (adapted from Senwo, 1995).

Deng (1994) also reported that the activities of 14 enzymes involved in C, N, P, and S cycling in soils were greater in four replicated plots that were not tilled but doubled mulched, than in those treated with other tillage systems and residue placement. The activities decreased significantly with increasing soil depth, accompanied by a decrease in organic C content and pH. Eivazi and Bayan (1994) observed that the activities of et- and β-glucosidase, and acid phosphatase were significantly reduced by burning treatments.

Activity Measurement

There has been little or no success in extracting enzymes from soils (Tabatabai, 1982), however, several procedures exist for measuring enzyme activities in soils (Tabatabai, 1994; Alef and Nannipieri, 1995; Senwo and Tabatabai, 1996). The measurement of most soil enzyme activities involve the quantitative measurement of the appearance or disappearance of a product when soil has been treated with a microbial inhibitor (usually toluene) and incubated with buffered solution at a fixed temperature and time. The pertinent parameters measured for most enzyme assays include: the optimal pH (Fig. 2), "

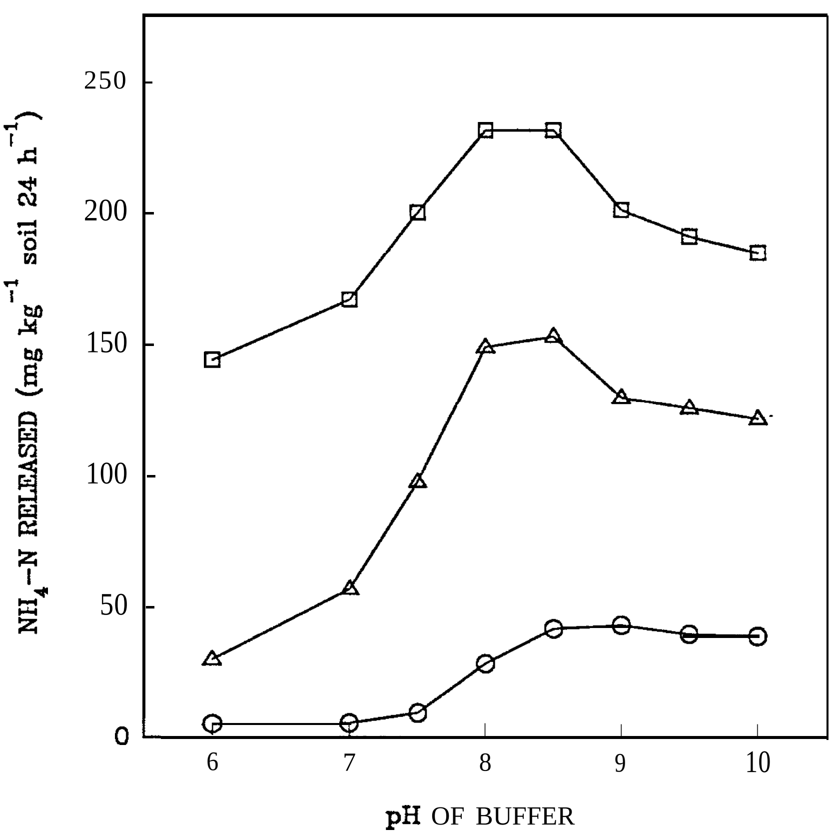

Fig. 2. Effect of pH of buffer on aspartase activity in soils. (From Senwo and Tabatabai, 1996).

substrate concentration at which the reaction essentially follows a zero-order kinetics, amount of soil needed to obtain maximum activity without limiting the substrate concentration, temperature

(Fig. 3) and time of incubation to obtain maximum activity.

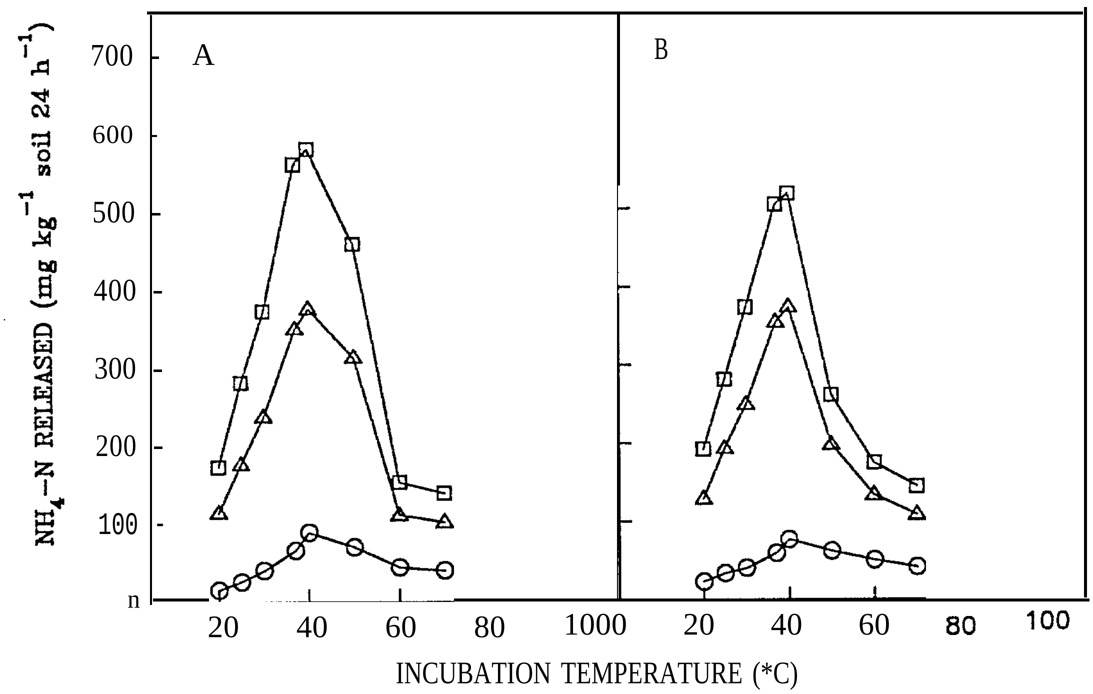

Fig. 3. Effect of incubation temperature on aspartase activity in soils. A, Field-moist soils; B, air-dried soils (From Senwo and Tabatabai, 1996).

Summary and Conclusion

The potential exist for use of soil enzyme assays in identifying positive or negative effects of land management practices within periods, long before there are measurable changes in soil organic matter. Most soil enzyme assays are simple, rapid, and reproducible.

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