Soil Quality Indicators

Soil Enzymes

Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate.

Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells. It is thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes.

Factors Affecting

Inherent - Soil enzymes have varying optimum pH and temperature values at which they function most effectively. For example, the activity of phosphatase, aryl sulfatase, and amidase involved in phosphorus, sulfur, and nitrogen cycling, respectively, is strongly correlated to variations in soil pH. Since enzyme structure and substrate binding can be altered by heat and extreme cold temperature, enzyme activity decreases above and below the optimum temperature. The activity of many enzymes often correlates with soil moisture content, as well. Drought may suppress enzyme activity. Soil texture influences enzyme activity, and normally enzyme activities are significantly and positively correlated with clay content. Clayey soils have greater ability to store organic matter that promotes microbial communities, and clay forms clay-enzyme complexes. In contrast, sandy soils tend to exhibit low rates of enzyme activity because they are naturally low in organic matter and have poor water holding capacity which results in lower microbial biomass and therefore lower enzyme activity.

Dynamic - Addition of organic amendments and adoption of management practices that increase soil organic matter lead to increased enzyme activity (figs 1 and 2). Plant roots stimulate enzyme activity because of their positive effect on microbial activity and production of exudates rich in substrates acted on by enzymes.

Elevated soil concentrations of chemical compounds that are end products of enzymatic reactions can inhibit enzyme activity by feedback inhibition. For example, phosphatase activity increases in phosphorus deficient soil, but its activity decreases in soil with high phosphorus concentration. Similarly, urease activity may be suppressed by ammonia-based nitrogen fertilizer because ammonium is the product of urease activity (fig 2).

Compaction may limit the activity of enzymes involved in nutrient mineralization because of decreased oxygen in the soil for those reactions or organisms requiring an aerobic environment. Conversely, anaerobic conditions from compaction or water saturation increase enzymatic reaction rates related to denitrification. Application of materials containing heavy metals can reduce enzyme activity (e.g., amidase) due to their toxic effect on soil organisms and roots or direct inhibition of enzyme reactions.

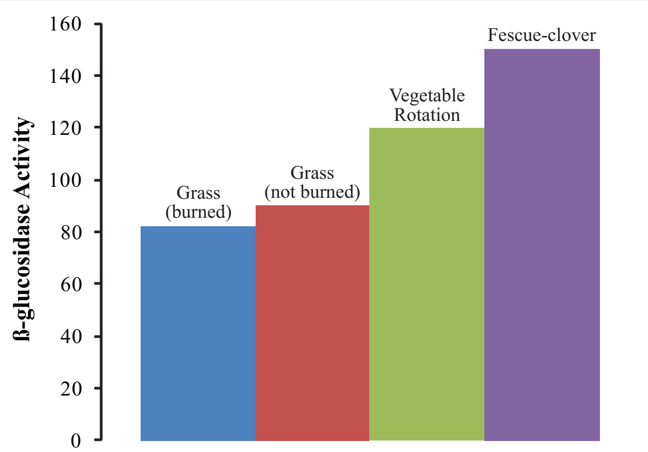

Figure 1. Effects of cropping systems on ß-glucosidase (adapted from Dick 1994).

Relationship to Soil Function

Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling (table 1). Some enzymes only facilitate the breakdown of organic matter (e.g., hydrolase, glucosidase), while others are involved in nutrient mineralization (e.g., amidase, urease, phosphatase, sulfates). With the exception of phosphatase activity, there is no strong evidence that directly relates enzyme activity to nutrient availability or crop production. The relationship may be indirect considering nutrient mineralization to plant available forms is accomplished with the contribution of enzyme activity.

Problems with Poor Activity

Absence or suppression of soil enzymes prevents or reduces processes that can affect plant nutrition. Poor enzyme activity (e.g., pesticide degrading enzymes) can result in an accumulation of chemicals that are harmful to the environment; some of these chemicals may further inhibit soil enzyme activity.

Improving Enzyme Activity

Organic amendment applications, crop rotation, and cover crops have been shown to enhance enzyme activity (figs 1 and 2). The positive effect of pasture (fig 2) is associated with the input of animal manure and less soil disturbance. Agricultural methods that modify soil pH (e.g., liming) can also change enzyme activity.

Measuring Enzyme Activity

Enzymes are measured indirectly by determining their activity in the laboratory using biochemical assays. Enzyme assays reflect potential activity and do not represent true in situ activity levels and must be viewed as an index.

Interpretation and Assessment

When possible, compare the site of interest to samples taken from an adjacent, undisturbed site on the same soil type. Alternatively, for a newly implemented land management system, track changes from time zero to five or more years with annual sampling to detect temporal changes in activity of soil enzymes.

Specialized equipment, shortcuts, tips:

A spectrophotometer, and in some cases a fume hood, centrifuge, and/or shaker. For better results, use the enzyme optimum temperature and pH.

Time needed: variable, 30 to 60 minutes

References:

Bandick AK and Dick RP. 1999. Field management effects on enzyme activities. Soil Biology and Biochemistry 31:1471-1479.

Dick RP. 1994. Soil Enzyme Activity as an Indicator of Soil Quality. In: Doran JW et al., editors. Defining soil quality for a sustainable environment.. Madison, WI. p107-124.

Tabatabai MA. 1994. Soil Enzymes. In: Weaver RW et al., editors. Methods of soil analysis. Part 2. Microbiological and Biochemical Properties. p 775-833.

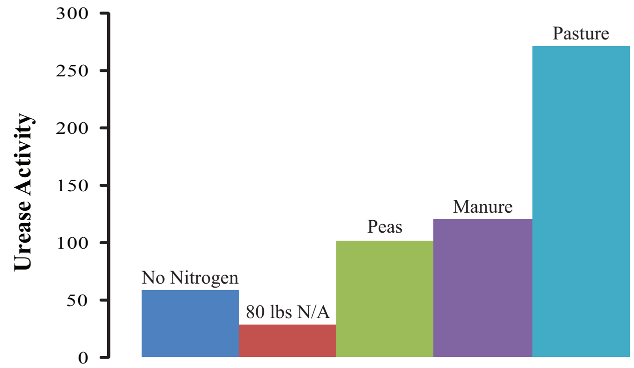

Figure 2. Effects of management on urease activity (adapted from Bandick and Dick 1999).

Table 1. Role of soil enzymes

Enzyme	Organic Matter Substances Acted On	End Product	Significance	Predictor of Soil Function
Beta glucosidase	carbon compounds	glucose (sugar)	energy for microorganisms	organic matter decomposition
FDA hydrolysis	organic matter	carbon and various nutrients	energy and nutrients for microorganisms, measure microbial biomass	organic matter decomposition nutrient cycling
Amidase	carbon and nitrogen compounds	ammonium (NH_4)	plant available NH_4	nutrient cycling
Urease	nitrogen (urea)	ammonia (NH_3) and carbon dioxide (CO_2)	plant available NH_4	nutrient cycling
Phosphatase	phosphorus	phosphate (PO_4)	plant available P	nutrient cycling
Sulfatase	sulfur	sulfate (SO_4)	plant available S	nutrient cycling