Effects of Texture and Tillage on Soil Enzyme Activities

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Introduction

Biochemical processes in soil are mediated by enzymes. Measurements of soil enzyme activity have most often been used as general indices of microbial activity, in combination with other biochemical properties. Kinetic parameters (K_m and V_{max}) have been measured to provide indirect information about amount, source and location of enzymes in soil.

More recently, enzyme assays have been used to study macronutrient cycling in soils (Sinsabaugh 1994). This approach may provide information about functional diversity of microbial communities in soil (cf. Zak et al. 1994), if enzyme activities are indicative of rates of macronutrient transformation in situ. Such information would be useful in assessing soil quality.

Objective

The objective of this study was to test for effects of tillage and texture on six different enzyme activities.

Materials and Methods

Site description and sampling procedure

Soil samples were collected from a soybean field in SW Ontario on 4 dates in 1994, from sites with and without conventional tillage, on fine (SiCL) and coarse (FSL) textured soils (Gray Brown Luvisol-Humic Gleysol complex). Soil was sampled at 2 depths (0-8cm, and 8cm to the bottom of the Ap horizon), at 2 locations within each of the 4 sites.

Soil Analyses

Field moist samples were analyzed for dehydrogenase, urease, alkaline (pH 11) phosphatase, B-glucosidase and arylsulfatase activities as described by Tabatabai (1982). Glutaminase activity was determined as described by Frankenberger and Tabatabai (199 1). Kinetic constants (K_m and V_{max}) were determined for selected air-dried (<2mm) samples from the first sampling date.

Statistical Analysis

Enzyme activities of field moist samples were analyzed as a split-plot design with texture and tillage as main plots, and kinetic constants of air-dried samples were calculated by a nonlinear estimation procedure, using SYSTAT (Wilkinson 1988).

Results

We tested for treatment effects in two ways, by measuring activity of field moist samples and kinetic constants of air-dried (<2mm) samples. For field moist samples, effects of tillage and texture were measured against background variation deriving from sampling

depth and date. Comparison of responses of six different enzymes indicated whether responses were enzyme-specific, or were a general characteristic of microbial activity.

Texture

Four enzymes showed a similar response to texture (Table 1). Phosphatase, B-glucosidase and arylsulfatase activities were greater in coarse textured soil (Fig. la,b,c). Glutaminase was greater in coarse textured soil, within the lower layer of the Ap horizon (Fig. 1d).

Table 1. Summary of analysis of variance of five[Z] enzyme activities of field moist samples of the Ap horizon of a soybean field in SW Ontario (significant effects at P 0.05)

Treatment	Dehydrogenase[Y]	Urease[X]	Glutaminase	Phosphatase	B-glucosidase
	%SS[W]	%SS	%SS	%SS	%SS
Texture (T)			25	31	23
Tillage (P)			13	18	5
Layer (L)	33	13			11
Date (D)	23	42	8	15	17
Interactions	P*L	P*L T*L D*T D*P*T	P*L T*L D*T D*L	D*T	P*L

Z there appeared to be two different populations for arylsulfatase activity, associated with soil texture (mean values of 0.95 and 0.44 moles -nitrophenol $g^{-1}h^{-1}$ for coarse and fine textured soil, respectively); for homogeneity of variance, arylsulfatase activities were analyzed separately for coarse and fine textured soil; the only significant effect was that of tillage (%SS = 35; P = 0.015) for fine textured soil

Y data transformed by square root

X data log-transformed

W percent of sum of squares associated with treatment in ANOVA

Figure. 1. Effect of texture and tillage on (a) phosphatase, (c) B-glucosidase, (c) arylsulfatase, (d) glutaminase, (e) dehydrogenase and (f) urease activities of field moist samples of the Ap horizon, collected on 4 dates during 1994 from a soybean field in SW Ontario (averaged over sampling dates)

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Tillage

All enzymes responded to tillage (Table 1). Activity of dehydrogenase, urease, glutaminase and B-glucosidase was greater in no-till versus conventionally tilled soil, within the surface layer (Fig. le,f,d,b). Arylsulfatase activity in fine textured soil, and phosphatase activity were greater for no-till plots at both depths (Fig. lc,a).

Date

Activity of all enzymes except arylsulfatase varied temporally (Table 1). Over the four sampling dates, activity of urease varied more than that of other enzymes. The significant interactions indicated that sampling date sometimes influenced other effects (Table 1).

Kinetics

In the surface layer, V_{max} of B-glucosidase was greater for coarse textured soil and no-till plots (Table 2). For phosphatase, V_{max} was greater in coarse textured soil. Within tillage treatments, Km of B-glucosidase was greater in coarse textured soil; within textural classes, K_m of B-glucosidase was greater for conventional tillage.

Table 2. Kinetic constants for B-glucosidase and phosphatase activity of air-dried (<2mm) surface samples collected on May 13 from a soybean field in SW Ontario

Tillage	Texture	B-glucosidase		Phosphatase	
		K_m [Z]	V_{max} [Y]	K_m	V_{max}
Conventional	coarse	5.5 +/- 0.5[X]	1.3 +/- 0.04	2.3 +/- 0.5	1.5 +/- 0.07
No-till	coarse	2.5 +/- 0.3	1.5 +/- 0.03	4.8 +/- 0.4	1.6 +/- 0.03
Conventional	fine	2.6 +/- 0.4	0.8 +/- 0.03	3.7 +/- 1.0	0.8 +/- 0.06
No-till	fine	1.3 +/- 0.1	0.9 +/- 0.01	2.6 +/- 0.6	0.8 +/- 0.04

Z mM

Y mole -nitrophenol $g^{-1} h^{-1}$

X standard deviation

Discussion

All six enzymes responded similarly to tillage in the surface layer. Greater activity in the surface layer of no-till soil was most likely due to increased organic C content and microbial activity. The fact that dehydrogenase activity has frequently been used as an index of general microbial activity in soil (Tabatabai 1982) supports this conclusion.

Four enzymes responded similarly to texture. Increased activity of phosphatase, B-glucosidase, arylsulfatase and glutaminase in coarse textured soil was difficult to explain. In the absence of an effect on dehydrogenase, it could not be attributed to greater microbial activity. It may have been related to stabilization of extracellular enzymes. Within the

surface layer, greater V_{max} of B-glucosidase and phosphatase in coarse compared with fine textured soil indicated greater amounts of active enzyme. At the same time, the greater K_m of B-glucosidase in coarse textured soil (within tillage treatments) indicated decreased substrate affinity.

The larger K_m of B-glucosidase in conventionally tilled plots (within textural classes) contrasted with the decrease in K_m of arylsulfatase resulting from cultivation of native soils reported by Farrell et al. (1994).

Conclusions

1. Tillage decreased activity of all six enzymes in the surface layer. Activity of four of six enzymes was greater in coarse textured soil.
2. Variability due to sampling depth and time must be taken into account, when making comparisons between treatments such as texture and tillage.
3. Activity measurements and determination of V_{max} provided similar information for B-glucosidase, but only in part for phosphatase.

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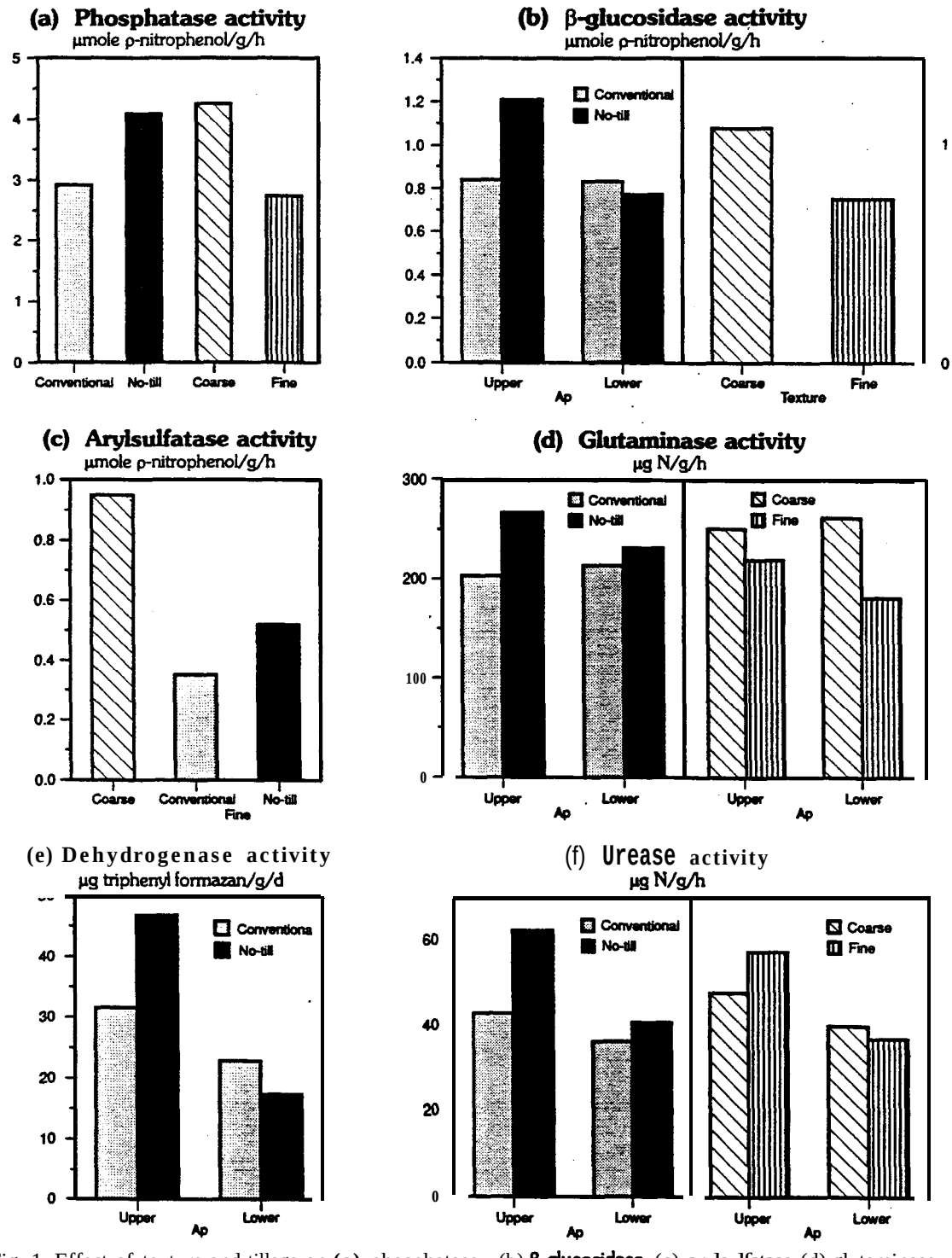

Fig. 1. Effect of texture and tillage on **(a)** phosphatase, (b) **β-glucosidase,** (c) arylsulfatase, (d) glutaminase (e) dehydrogenase and (f) urease activities of field moist samples of the Ap horizon, collected on 4 dates during 1994 from a soybean field in SW Ontario (averaged over sampling dates)