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Original Research

Effects of Soil Conservation Management Systems on Soil Enzyme Activities under Wheat Cultivation

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Abstract

Soil management systems such as conservation tillage practices and the cultivation of cover crops have various positive effects on soil environment. These practices help to increase or maintain an adequate level of soil organic matter, thus improve soil properties. The aim of the study was to determine the effects of cover crops and tillage systems on soil enzyme activity (urease, alkaline phosphatase, catalase) at different soil depths following wheat. According to the results, the cover crops affected all the enzyme activities while tillage systems affected only urease activity in the soil. The highest urease (8.09 and 6.90 µg g N soil^{-1} h^{-1}), alkaline phosphatase (74.53 and 69.08 µg g p-nitrophenol soil^{-1} h^{-1}) and catalase (41.56 and 48.62 ml O_2 3 min^{-1} g soil^{-1}) activities were observed in common vetch plots in minimum and conventional tilled plots. Another observation was that enzyme activities were decreased with the increase of soil sampling depths. These results showed that the incorporation of cover crops into rotations may increase soil enzyme activities and common vetch can be used as an alternative cover crop.

Keywords: cover crops, urease activity, alkaline phosphatase activity, catalase activity, soil properties, tillage

Introduction

Soils, which are the main components of agricultural production, are constantly subjected to human-induced practices. These practices generally disrupt the physical, chemical or biological structure or quality of soils. Whereas, in recent years, practices entitled conservation soil management practices aimed to protect and sustain soil quality have been developed worldwide.

Soil quality is important for all living organisms. Researchers have defined soil quality in different ways. According to the definition of researchers, soil quality is “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health” [1]. According to this definition, the biological productivity of soils must also be sustainable. Therefore, it is necessary to determine the biological productivity status of soils. In other words, microbial biomass, soil respiration, potential mineralization and earthworm population must be determined in soils to detect soil biological productivity [2].

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Enzymes which are the biological properties of soils are of plant, animal or microbial origin and they are found in the aqueous phase of the soil [3]. Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. Enzymes cannot be isolated from soil since they are absorbed by soil colloids. They are stabilized in soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells. 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. 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 and sulphates).

The 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 and some of these chemicals may further inhibit soil enzyme activity [4].

Therefore, soil enzyme activities are determined instead of their amounts and affected by physico-chemical properties such as pH, soil moisture, temperature and organic matter in soils [5, 6]. Recent studies have shown that the applications made to the soils affect the biological properties as well as the physical and chemical properties of soils [7, 8]. For instance, organic amendment applications, crop rotation, and cover crops have been shown to enhance enzyme activity.

Applying minimum tillage and cover crops, which are within the conservation soil practices, has positive effects on soil properties such as increasing soil organic matter, soil nitrogen, soil phosphorus, soil aggregation, soil microbial activity, soil porosity and decreasing soil compaction, runoff and water erosion [9, 10]. In addition, the integrated use of cover crops and conservation soil tillage systems increases their positive effects on soil properties [11].

In recent years, studies researching soil enzymes have been manifold. Some of these were done on the effect of organic materials applied to the soil [8, 12], some soil tillage systems [13-15], some fertilization applications [16-17] some cover crops or different mulch materials [10,18-21] on the enzyme activity, while very few of them were carried out in the form of double or triple combinations [7, 9, 22]. In this study, the enzyme activity was investigated in a semi-arid region, which can be considered problematic (pH 8.5), the application of 3 different cover crops after the main product of wheat (which has no practical application in the region) at 3 different soil depths of two different tillage (traditional and minimum) systems (0- 10, 10-20, 20-30 cm).

Material and Methods

Study Site

The study was established in the research area of Igdır University Agricultural Research and Application Center.

Igdır has a microclimate feature and the elevation of the region is 850 m. Summers are hot and winters are mild. The highest rainfall in the plain falls in May and the lowest in August. In the plain, the annual average rainfall is 254.2 mm, and the evaporation is 1094.9 mm. The coldest month is January and the warmest is July [23]. Some soil properties are shown in Table 1.

Table 1. Results of some soil properties.

Tillage practice	Cover crops	Soil properties				
		SOM, %	AS, %	P, kg da^{-1}	EC, µmhos cm^{-1}	pH
Minimum tillage	Control	1.47±0.00	19±2.00	5.13±0.13	474±4.35	8.51±0.05
	Common vetch	1.76±0.09	27±0.38	9.20±0.25	401±54.83	8.44±0.03
	Common vetch-fodder beet	1.66±0.04	24±0.92	8.12±0.75	382±7.54	8.45±0.0
	Fodder beet	1.62±0.06	23±1.01	6.89±0.81	417±10.50	8.44±0.01
Conventional tillage	Control	1.42±0.03	16±0.56	4.99±0.25	400±10.01	8.53±0.01
	Common vetch	1.70±0.06	24±2.63	6.06±0.13	343±5.50	8.46±0.02
	Common vetch-fodder beet	1.60±0.01	23±1.25	5.76±0.09	371±1.00	8.46±0.02
	Fodder beet	1.45±0.03	23±0.78	5.56±0.11	412±3.60	8.46±0.02

*SOM: soil organic matter; AS: aggregate stability; P: plant available phosphorus; EC: electrical conductivity; pH: soil pH.

Experimental Design

The study consists of cultivation of wheat and cover crops in conventional tillage (moldboard plow with the depth of 30 cm, spring tine harrow) and minimum-tillage (no tillage before planting) and the cultivation of cover crops after wheat harvesting. Vetch, fodder beet, vetch and fodder beet mixtures were used as cover crops. In the study, wheat variety was common wheat (*Triticum aestivum* L.). Common vetch (*Vicia sativa* L.) was used as vetch and fodder beet (*Beta vulgaris var.* rapacea) was used as beet.

The research was planned according to randomized blocks design and it consisted of 24 parcels: two different tillage methods, three different cover crops applications with no cover crops (control, C) and three replicates (2 x 4 x 3). The size of each experiment plot was taken 6 x 4 m. Service blanks with a width of 2 m was taken between the blocks and 1 m between the plots.

Starting from 2016, wheat was grown in spring. After harvesting wheat, cover crops (common vetch, fodder beet) were planted under conventional tillage and minimum tillage. Cover crops were left on the land surface until wheat sowing period in each year. The same processes were repeated till 2020.

Soil Sampling and Analysis

For soil physical and chemical analyses, disturbed soil samples were taken after wheat was planted in 2020 to determine the soil properties of the research area from the depth of 0-30 cm. For enzyme analysis, disturbed soil samples were taken from the depth of 0-10, 10-20 and 20-30 cm after wheat was planted in 2020. The samples were brought to the laboratory and sieved through a 2 mm sieve and then stored at 4°C at the refrigerator for enzyme analyses.

Organic matter, aggregate stability, soil pH, plant available phosphorus and electrical conductivity were determined in disturbed soil samples. Soil organic matter, aggregate stability, plant available phosphorus, electrical conductivity was determined [24-27]. Soil pH was tested with a soil/water ratio of 1:2.5 using a compound electrode [28]. Soil urease, alkaline phosphatase and catalase activity were tested [29-31].

Statistical Analysis

The data were analysed using the statistical software program *SPSS* (SPSS Inc., USA). The comparison of the mean values of each group was tested by using the ANOVA (Analysis of variance) test. The differences between each group were detected for statistical significance ($p<0.05$) and the differences between specified groups were determined by Duncan multiple comparison test ($p<0.05$).

Results

Generally, cover crops significantly ($P<0.05$) affected soil urease, alkaline phosphatase and catalase activity in soil. Alkaline phosphatase and catalase activity were not significantly affected by tillage systems but by urease activity. Regarding the tow-way interactions; tillage x cover crop, significantly affected only urease activity while tillage x soil sampling depth significantly affected alkaline phosphatase and catalase activity. Cover crops x soil sampling depth was the only interaction that significantly affected all enzyme activities. The three-way interaction significantly affected only catalase activity.

It has been determined that tillage systems have a significant effect on urease activity. While the urease activity was 7.14 μg g N soil^{-1} h^{-1} in the minimum tillage block, it was measured as 6.10 μg g N soil^{-1} h^{-1} in the conventional tillage block. Although the effect of different tillage systems was statistically insignificant, phosphatase activity was higher at minimum tillage. Average phosphatase activity was measured at 65.90 μg g p-nitrophenol soil^{-1} h^{-1} at minimum tillage and 62.94 μg g p-nitrophenol soil^{-1} h^{-1} at conventional tillage. The catalase activity was higher in the traditional tillage block than in the minimum tillage block but it was statistically insignificant. The means of catalase activity in the minimum tilled plots were 32.96 and 37.97 ml O_2 3 min^{-1} g soil^{-1} in conventional tilled plots (Table 2).

The results showed that soil urease, alkaline phosphatase and catalase activity were significantly ($P<0.05$) influenced by cover crops. When viewed on the general average, the use of different cover crops significantly changed the urease activity. The highest value (7.49 μg g N soil^{-1} h^{-1}) was measured in common vetch plots and the lowest value (5.73 μg g N soil^{-1} h^{-1}) was measured in control plots. When minimum tillage and conventional tillage are considered separately, the highest urease activity values were measured in common vetch and the lowest in control plots. Likewise, phosphatase activity reached the highest value in both the minimum tillage and conventional tillage and general in the common vetch plots, and the lowest values were measured in the control plots. The maximum phosphatase value was 71.81 μg g p-nitrophenol soil^{-1} h^{-1} (in common vetch) and minimum value was 55.78 μg g p-nitrophenol soil^{-1} h^{-1} (in control). According to our findings, cover crops had a significant ($p<0.05$) effect on catalase activity in both the minimum tillage and the traditional tillage. Catalase activity of cover crop plots was higher than in control plots. As the average of both tillage systems, catalase activity was measured as 41.56 ml O_2 3 min^{-1} g soil^{-1}, 34.15 ml O_2 3 min^{-1} g soil^{-1}, 29.10 ml O_2 3 min^{-1} g soil^{-1}, 27.04 ml O_2 3 min^{-1} g soil^{-1} in common vetch plots, common vetch + fodder beet plots, fodder beet plots and control plots, respectively (Table 2). The increases in common vetch plots may be caused by crops which release nutrients and high rates of N after decomposing

Table 2. Effects of cover crops and tillage systmes on soil enzyme activities at different depths.

Soil urease activity (µg g N soil^{-1} h^{-1})							
Tillage	Depth, cm	Cover crops				Means of depths	Means of tillage systems
		Control	Common vetch	Common vetch-fodder beet	Fodder beet		
Minimum tillage	0-10	6.64±0.57A	10.13±0.92A	9.04±0.77A	7.57±0.38A	8.35±1.51A	7.14±1.39A
	10-20	6.22±0.65AB	7.66±0.53B	7.45±0.85B	7.02±0.14A	7.09±0.77B	
	20-30	5.44±0.44B	6.47±0.19B	6.13±0.23B	5.91±0.43B	5.98±0.48C	
Means of cover crops		6.10±0.72cA	8.09±1.70a	7.54±1.39aA	6.83 ±0.79bA		
Conventional Tillage	0-10	5.42±0.42	8.43±0.58A	7.32±0.37A	6.62±0.55	6.95±1.21A	6.10±1.07B
	10-20	5.51±0.32	6.69±0.80B	5.79±0.81B	5.89±0.58	5.97±0.72B	
	20-30	5.14±0.19	5.56±0.16B	5.41±0.69B	5.34±0.85	5.37±0.50B	
Means of cover crops		5.36±0.32cB	6.90±1.34a	6.18±1.04bB	5.95±0.80bB		
Overall means of cover crops		5.73±0.66c	7.49±1.61a	6.86±1.38ab	6.39±0.90bc	6.62±1.34	
Alkaline phosphatase activity (µg g p-nitrophenol soil^{-1} h^{-1})							
Minimum tillage	0-10	61.86±0.11A	92.07 ±2.80A	83.09±2.82A	75.08±0.66A	78.03±11.76A	65.90±14.33
	10-20	54.87±1.83B	78.88±2.64B	75.32±0.73B	64.98±5.07B	68.51±10.13B	
	20-30	49.44±1.58C	52.64±2.73C	53.12±3.09C	49.44±1.77C	51.16±2.71C	
Means of cover crops		55.39±5.74d	74.53±17.54a	70.51±13.63b	63.17±11.50c		
Conventional tillage	0-10	59.49±3.34A	82.74 ±3.08A	74.20±1.92A	69.24±1.95A	71.42±9.07A	62.94±10.51
	10-20	57.95±1.51A	71.74±1.98B	68.65±1.26B	65.74±0.97A	66.02±5.49B	
	20-30	51.04±1.80B	52.77±1.27C	49.82±2.06C	51.85±2.67B	51.37±2.05C	
Means of cover crops		56.16±4.39c	69.08±13.27a	64.22±11.17b	62.28±8.15b		
Overall means of cover crops		55.78±4.97c	71.81±15.34a	67.37±12.51ab	62.72±9.68bc		64.42±12.57
Catalase activity (ml O_2 3 min^{-1} g soil^{-1})							
Minimum tillage	0-10	31.05±2.19A	58.27±6.91A	39.72±3.62A	35.22±2.15A	41.06±11.43A	32.96±10.35
	10-20	27.87±1.09A	39.93±1.89B	34.02±6.19AB	32.37±4.09A	33.55±5.59B	
	20-30	22.19±3.58B	26.47±3.49C	28.72±4.50B	19.70±4.27B	24.27±5.01C	
Means of cover crops		27.04±4.45b	41.56±14.38a	34.15 ±6.37ab	29.10±7.81b		
Conventional tillage	0-10	32.70±2.64A	85.37±5.59A	67.48±13.79A	49.82±2.74A	58.84±21.53A	37.97±19.85
	10-20	28.44±9.12AB	34.13±3.84B	33.73±3.55B	30.72 ±3.46B	31.76±5.31B	
	20-30	21.24±1.25B	26.35±2.91B	23.86±2.13B	21.84 ±4.74C	23.32±3.33B	
Means of cover crops		27.46±6.93d	48.62±28.01a	41.69 ±21.08b	34.12±2.79c		
Overall means of cover crops		27.25±5.65d	45.09±21.90a	37.92 ±15.95b	31.61±10.60c		35.47±15.92

*Lower case letters are used for horizontal indicate significant differences, capital letters are used for vertical indicate significant differences according to Duncan multiple comparison test at *p*<0.05 significance level.

and accordingly increasing soil N content and microbial activity and may also be caused by an increase in soil nitrogen through nodules in the roots [12].

It was determined that there was a statistically significant (p<0.05) relationship between soil depth and enzyme activity except for fodder beet and control plots in the conventional tillage block. The activities of all enzymes reached the highest value at 0-10 cm soil depth while the lowest value was at 20-30 cm depth in both soil cultivation systems. Similarly, the highest urease, phosphatase and catalase activity values were determined at 0-10 cm soil depth and the lowest at 20-30 cm soil depth in all cover crop applications.

Discussion

Agricultural management practices such as tillage affect markedly soil organic carbon (SOC) contents [32]. Conservation tillage with fewer disturbances has been recommended as an effective method to enhance the accumulation of SOC. As a result of reduced tillage, soil organic matter increase with remain of plant residues on the surface, retention of root biomass below the surface, and lower decomposition rates. Similar to this, one of the most common goals of the research with cover crops is to increase or maintain soil organic matter [33]. Additional root growth of cover crops may provide benefits to soil including increases in soil organic carbon content, available nutrients, as well as soil aggregation. Enzymes have a positive relationship with soil organic matter content. SOC serves as a substrate for a diverse set of soil microorganisms, promoting enzymatic activity [34]. The increase of organic matter in the soil has a positive effect on the diversity and number of soil microorganisms, and as a result, it causes an increase in enzyme activity. The increased diversity of the soil prokaryotic community, particularly soil bacteria, under minimum tillage with cover crops is in agreement with previous studies [35-36].

Different tillage systems were effective on urease, phosphatase and catalase activity in the soil. In agreement with previous research, it was determined that conservation tillage increased soil enzyme activities [14, 15]. Dissimilarity between tillage practices in enzyme activity may be caused by the increase in organic matter associated with minimum tilled plots, the less oxidative atmosphere that can stabilize the extracellular enzymes pool [13] (Table 1). Another finding of our study was that cover crops had increased enzyme activities in the soil. The highest values of urease, phosphatase and catalase enzymes were found in common vetch applications, and the lowest values were found in non-cover crop (control) applications. This may be because the microbial population and microbial biomass C or N increase with plant residues providing the organic matter used as a substrate for soil enzymes. Researchers stated that increased arylsulfatase, L-asparaginase, acid phosphatase, and b-glucosidase enzyme activity with a hairy vetch cover crop in subtropical Tennessee, USA [37].

Other researchers observed that in subtropical humid North Carolina, USA, where cover crops increased soil enzyme activities as well as bacterial populations and microbial biomass carbon [19, 22, 38-40]. Our results clearly suggested that enzyme activities were influenced by the presence of common vetch and therefore, common vetch could be used to monitor soil quality under the arid and semi-arid conditions. In fact, it is reported that leguminous can produce large amounts of vegetative parts and can be decomposed in a short time, so that causes an increase in soil organic matter [41]. In addition, the positive effect of minimum tillage with cover crops on the phosphatase enzymatic activity can be explained by the effect of minimum tillage to increase the P concentration in the upper soil layers.

Another result that emerges from the study findings is that urease, phosphatase and catalase activity decreases depending on the increase in soil depth in all treatments. The reason for the decrease in enzyme activity may be that soil organic matter and soil organic C decrease with depth and, accordingly, microbial activity decreases. Regardless of treatments, the decrease in soil enzyme activities with depth was probably due to reduced root growth and lower organic matter inputs from the root residue in lower depths. In conformity with prior studies enzyme activity decreased with soil depth [20, 42].

Conclusions

Our research indicated that enzyme activities were very reactive to the cover crops. The activities were not sensitive to tillage treatments except urease activity. Individual use of common vetch can stimulate urease, phosphatase and catalase activity in minimum tilled and conventional tilled soils. While urease and phosphatase activity were lower in conventional tilled plots than in minimum tilled plots, it was observed that the activity in conventional tillage plots increased with the cultivation of common vetch in the soil and the activities were higher in common vetch plots under conventional tillage than fodder beet and control plots under minimum tilled. Common vetch is a legume type crop which can produce high dry matter yields and can be decomposed in a short time so that provides soil organic matter accumulation and sustainability. Besides, common vetch forms nodules centre intense N fixation activities in soil; thus, increase soil organic N. For these reasons, common vetch is important in improving soil health and quality and can be used as an alternative cover crop. Our research suggests that soil management practices that incorporate cover crops improve soil enzyme activities.

Conflict of Interest

The authors declare no conflict of interest.

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