Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 12(2): 1134-1142, 2022
Journal of the Institute of Science and Technology, 12(2): 1134-1142, 2022
ISSN: 2146-0574, eISSN: 2536-4618
Soil Science and Plant Nutrition **DOI: 10.21597/jist.1009439**
Research Article
Received:14.10.2021 **Accepted:11.04.2022**

To Cite: Erdel E, 2022. Soil Enzyme Activities Affecting by Different Tillage Systems and Cover Crops Following Corn Cultivation. Journal of the Institute of Science and Technology, 12(2): 1134-1142.

Soil Enzyme Activities Affecting by Different Tillage Systems and Cover Crops Following Corn Cultivation

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ABSTRACT: Cover crops and minimum tillage or zero- tillage practices are the soil conservation management practices. These practices improve or sustain soil properties especially soil organic matter. In the study, we investigated the effects of cover crops and tillage practices on soil urease, alkaline phosphatase and catalase activities at different soil depths following corn. The corn was planted in May, and the cover crops (common vetch, fodder beet, mix of common vetch and fodder beet) were planted in late summer under minimum and conventional tillage. Soil samples were collected at 0-10, 10-20 and 20-30 cm soil depths in 2018. With respect to results of the study, cover crops affected all the enzyme activities while tillage systems affected urease and catalase activities in soil. The highest urease (9.91 and 7.48 µg g N soil^{-1} h^{-1}), alkaline phosphatase (99.29 and 84.61 µg g p-nitrophenol soil^{-1} h^{-1}) and catalase (58.73 and 64.82 ml O_2 3 min^{-1} g soil^{-1}) activities were in common vetch plots in minimum and conventional tilled plots and all the enzyme activities were decreased with increasing soil depth. The results suggest that cover crops and minimum tillage practices increase soil enzyme activities.

Keywords: Tillage, urease activity, phosphatase activity, catalase activity, cover crops, corn

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INTRODUCTION

Soil is the key element of plant production. As a result of excessive and unconscious practices in areas which intensive agriculture is made, soil degradation has occurred, it also causes reductions in crop fertility and productivity. For these reasons, new practices have been developed under the name of soil conservation management practices to maintain the sustainability of soils.

Soil conservation management practices have many positive impacts on soil properties. Such as; increasing soil organic matter, increasing transpiration and infiltration so that decreasing runoff and water erosion, increase soil nutrients (Lal, 2015; Pareja-Sánchez et al., 2017). However, it has positive effects as well as some negative effects. Due to intense machinery traffic, it has been observed that soil compaction and penetration resistence increased as a result of long-term no-till or reduced till (Nunes et al., 2015). In addition, water flows in soils are also negatively affected as a result of compaction. Some researchers have suggested deep tillage to eliminate these negative effects (Stavi et al., 2011).

Cover crops and minimum tillage practices are some of the soil conservation management practices. Cover crops remaining on the land during the winter affect soil properties by covering the soil surface, reducing evaporation and preserving soil moisture, reducing surface flow, reducing nutrient loss, and thus ensuring aggregate stability and organic matter accumulation in soils (Locke et al., 2015; Mitchell et al., 2017). On the other hand, in minimum tillage, however, by decreasing the tillage frequency, the decomposition of organic matter in the soil decreases and the stability of aggregates increases. So, it has been determined that these applications have many positive impacts (increase of soil organic matter, aggregate stability and nutrient content) on soils (Fourie et al., 2007). Besides, legume-based cover crops effects of soil carbon and soil nitrogen and availability of carbon substrates largely controls microbial growth and activity in soil (Elfstrand et al., 2007).

Soil enzymes are essential for soil health and also play an important role in the decomposition of organic matter and in the cycling of nutrients. Soil enzymes, as a result of soil microbial activity affects by the applications on soils. Since they are very sensitive to agricultural practices, they can be used as an index for microbial activity and productivity in soil (Benitez et al., 2000). Some researchers have determined that cover crops and minimum tillage practices increase enzyme activities in soils (Balota et al., 2014; Mbuthia et al., 2015). Although the effects of tillage systems and cover crops on soil properties are well studied, the effects of different types of cover crops on soil properties are different. In addition, this difference varies according to regional characteristics (climatic and topographic conditions). So, in this study, I investigated how cover crops and minimum tillage practices influenced soil catalase, urease and alkaline phosphatase activity at different depths (0-10, 10-20, 20-30 cm) following corn cultivation.

MATERIALS AND METHODS

Study Site

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

The region has a microclimate feature and the elevation of the plain is 850 m. It is hot in summers and mild in winters, the highest rainfall 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 (data of Turkish State Meteorological Service, 2). Some physical and chemical soil properties have shown in Table 1.

Table 1. Some physical and chemical soil properties

Tillage practices	Cover crops	Soil properties				
		SOM, %	AS,%	P, kg da^{-1}	EC, µmhos cm^{-1}	pH
Minimum tillage	Control	1.42±0.03	19±0.59	4.79±0.20	427±3.51	8.51±0.02
	Common vetch	1.74±0.01	24±1.40	5.57±0.38	398±2.64	8.43±0.02
	Common vetch-Fodder beet	1.61±0.02	23±0.89	5.36±0.07	389±10.01	8.47±0.05
	Fodder beet	1.50±0.02	22±0.51	5.32±0.08	342±2.00	8.46±0.04
Conventional tillage	Control	1.41±0.04	18±0.43	4.26±0.05	430±8.00	8.54±0.03
	Common vetch	1.68±0.01	23±1.53	4.56±0.23	361±16.50	8.44±0.03
	Common vetch-Fodder beet	1.55±0.02	21±0.63	4.30±0.07	365±8.08	8.43±0.01
	Fodder beet	1.46±0.02	20±1.05	4.34±0.11	371±3.00	8.49±0.06

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

Experimental Design

The research contains of cultivation of corn (hybrid silage) 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 corn harvesting. Vetch (*Vicia sativa* L.), fodder beet (*Beta vulgaris var.* rapacea), vetch and fodder beet mixtures were used as cover crops.

The experimental design was randomized blocks and it included of 24 parcels: two different tillage methods, three different cover crops applications with no cover crops (control, C) and three replications (2 x 4 x 3). The size of each experiment plot was taken 6 x 4 m.

In may 2016, corn was planted at 7500 seeds da^{-1} rate under conventional tillage and minimum tillage. After corn harvesting, cover crops were sowed under conventional tillage and minimum tillage (common vetch 12 kg da^{-1} seeds rate, fodder beet 4 kg da^{-1} seeds rate). Cover crops were left on the land surface until the corn sowing period. The same procedures were replicated in 2017 and 2018.

Soil Sampling and Analysis

For soil physical and chemical analysis, disturbed soil samples were collected after corn planted in 2018 for determining the soil properties of the research area from the depth of 0-30 cm. For enzyme analysis; disturbed soil samples were collected from the depth of 0-10 cm, 10-20 cm and 20-30 cm after corn planted in 2018. The samples were brought to the laboratory and sieved through a 2 mm sieve and then stored at 4 ^{o}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 and pH were determined according to Walkley and Black (1934), Kemper and Rosenau (1986), Olsen et al. (1954), Rhoades (1983) and McLean (1982), respectively.

Soil urease, alkaline phosphatase and catalase activity were tested by Hoffmann and Teicher (1961), Hofmann and Hoffmann (1966) and Beck (1971), respectively.

Statistical Analysis

The data were analyzed using the statistical software program *SPSS* (SPSS Inc., USA). For comparison of means to each group were tested by using ANOVA (Analysis of variance) tests. 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 AND DISCUSSION

The activities of soil urease, alkaline phosphatase and catalase were significantly ($P < 0.05$) influenced by cover crops and sampling depths in the region soils following corn cultivation. However, tillage systems significantly ($P < 0.05$) affected soil urease and catalase activities. The two-way interactions: tillage x cover crops were significantly affected soil urease and phosphatase activities; tillage x sampling depths were significantly affected soil phosphatase and catalase activities; cover crops x sampling depths were significantly affected soil urease and catalase activities. The three-way interaction was found to be statistically insignificant ($P < 0.05$).

Urease Activity

Findings showed that tillage systems significantly ($P < 0.05$) affected soil urease activity. The average of soil urease activity in the minimum tilled plots was 6.23 µg g N soil^{-1} h^{-1} and 4.86 µg g N soil^{-1} h^{-1} on the conventional tilled plots (Table 2). This means that soil urease activity was greater under minimum tilled plots than conventional tilled plots. The differences between tillage systems may be caused by higher organic matter content under minimum tilled plots (Table 1) and some other researchers (Zhao et al., 2014; Zhang et al., 2016) reported that organic matter increases soil enzyme activity. Similarly with previous research, our findings demonstrated that conservation tillage increased soil enzyme activities (Pandey et al., 2014; Nivelle et al., 2016; Vazquez et al., 2017).

Table 2. Cover crops and tillage systems effect on soil urease activity (µg g N soil^{-1} h^{-1}) at different depths

Tillage Practices	Depths, cm	Cover Crops				Means of Depths	Means of tillage systems
		Control	Common vetch	Common vetch-Fodder beet	Fodder beet		
Minimum Tillage	0-10	4.90±0.97	9.91±0.51A	8.91±0.14A	6.50±0.78A	7.55±2.13A	6.23±1.88A
	10-20	4.50±0.82	7.75±0.58B	7.13±0.51B	5.88±0.66AB	6.32±1.41B	
	20-30	4.14±0.57	5.11±0.86C	5.32±0.70C	4.67±0.52B	4.81±0.74C	
Means of Cover Crops		4.51±0.77c	7.59±2.16aA	7.12±1.61aA	5.68±0.98b		
Conventional Tillage	0-10	4.68±0.59A	7.48±0.27A	6.60±0.12A	6.04±0.40A	6.20±1.11A	4.86±1.28B
	10-20	3.44±0.50B	5.19±0.10B	4.90±0.93B	4.53±0.37B	4.52±0.84B	
	20-30	3.55±0.48B	3.92±0.30C	3.94±0.05B	4.08±0.57B	3.87±0.40C	
Means of Cover Crops		3.89±0.75c	5.53±1.57aB	5.15±1.25abB	4.88±0.97b		
Overall Means of Cover crops		4.20±0.80c	6.56±2.11a	6.13±1.73ab	5.28±1.03b		5.54±1.74

* – differences between means of treatments were tested by using Duncan multiple comparison test at $p < 0.05$ significance level.

Soil sampling depths significantly ($P < 0.05$) affected urease activity. The activities were 7.55 µg g N soil^{-1} h^{-1}, 6.32 µg g N soil^{-1} h^{-1} and 4.81 µg g N soil^{-1} h^{-1} at 0-10 cm, 10-20 cm and 20-30 cm soil depths in minimum tilled plots. In conventional tilled plots, the activities were 6.20 µg g N soil^{-1} h^{-1}, 4.52 µg g N soil^{-1} h^{-1} and 3.87 µg g N soil^{-1} h^{-1} at 0-10 cm, 10-20 cm and 20-30 cm soil depths, respectively. Soil urease activity decreased with increasing soil depths (Green et al., 2007).

Urease activity in cover crops was significantly ($P < 0.05$) greater than control plots. At 0-10 cm soil depth, urease activities were 9.91 µg g N soil^{-1} h^{-1}, 8.91 µg g N soil^{-1} h^{-1}, 6.50 µg g N soil^{-1} h^{-1} and 4.90 µg g N soil^{-1} h^{-1} in common vetch, common vetch-fodder beet, fodder beet and control under minimum tilled plots, respectively. Urease activity was also higher in cover crops (7.48 µg g N soil^{-1} h^{-1}, 6.60 µg g N soil^{-1} h^{-1}, 6.04 µg g N soil^{-1} h^{-1}; common vetch, common vetch-fodder beet, fodder beet, respectively) than control (4.68 µg g N soil^{-1} h^{-1}) plots under conventional tillage.

Findings showed that at 0-10 cm and 10-20 cm soil depth, the highest urease activities were in common vetch plots under both minimum and conventional tilled plots. The increases in common vetch plots may be caused by turning over soil nutrients (soil C, soil N, etc.) to the soil and increasing soil organic matter (Marschner et al., 2015). In conclusion, we determined that cover crops increased soil enzyme activity (Nautiyal et al., 2010; Nivelle et al., 2016).

Alkaline Phosphatase Activity

Statistical analyses suggested that tillage systems affected soil phosphatase activity statistically insignificant ($P< 0.05$), however the values of phosphatase activities were higher in minimum tilled than conventional tilled plots. The mean values of phosphatase activity in minimum tilled plots were 67.14 µg g p-nitrophenol soil^{-1} h^{-1} and 663.89 µg g p-nitrophenol soil^{-1} h^{-1} in the conventional tilled plots (Table 3). It is clear of that minimum tillage increased soil enzyme activity (Deng and Tabatabai, 1997; Wang et al., 2011). The changes in soil enzyme activities may be caused by higher rates of soil plant available phosphorus in minimum tilled plots (Table 1). Prior research reported that higher concentrations of total P and plant available P were in no-tilled than conventional tilled soils (Saavedra et al., 2007; Qin et al., 2010). In addition, the higher values of phosphatase activities were in minimum tilled plots could be because minimum tillage with a cover of plant residues can provide more substrate available for phosphatases and therefore support phosphatase activities.

Table 3. Effects of cover crops and tillage systems on alkaline phosphatase activity (µg g p-nitrophenol soil^{-1} h^{-1}) at different depths

Tillage Practices	Depths, cm	Cover Crops				Means of Depths	Means of tillage systems
		Control	Common vetch	Common vetch-Fodder beet	Fodder beet		
Minimum Tillage	0-10	64.49±9.59A	99.29±2.63A	89.90±6.64A	75.07±5.53A	82.19±15.06A	67.14±17.20
	10-20	58.98±5.34A	78.99±6.26B	73.13±4.71B	65.71±1.01B	69.20±8.87B	
	20-30	42.56±4.23B	57.78±2.68C	56.95±1.30C	42.79±2.37C	50.02±8.05C	
Means of Cover Crops		55.34±11.50d	78.69±18.34a	73.33±14.85b	61.19±14.70c		
Conventional Tillage	0-10	64.61±1.87A	84.61±7.28A	71.66±6.34A	67.32±2.17A	72.05±9.09A	63.89±10.75
	10-20	61.11±8.29A	72.53±4.05B	67.41±0.25A	65.36±4.84A	66.60±6.18B	
	20-30	44.49±3.35B	59.10±1.28C	53.14±3.25B	55.37±3.44B	53.02±6.15C	
Means of Cover Crops		56.74±10.36c	72.08±11.82a	64.07±9.13b	62.68±6.38b		
Overall Means of Cover Crops		56.04±10.64c	75.38±15.35a	68.70±12.87ab	61.94±11.02bc		65.51±14.33

* – differences between means of treatments were tested by using Duncan multiple comparison test at $p < 0.05$ significance level.

The phosphatase activities were significantly different with respect to soil depths. The activities were 82.19 and 72.05 µg g p-nitrophenol soil^{-1} h^{-1} at 0-10 cm depth, 69.20 and 66.60 µg g p-nitrophenol soil^{-1} h^{-1} at 10-20 cm depth, 50.02 and 53.02 µg g p-nitrophenol soil^{-1} h^{-1} at 20-30 cm depth in minimum tillage and conventional tillage, respectively. The results showed that phosphatase activity decreased with soil depth (Shi et al., 2013; Cai et al., 2018) and the decrease may be associated with a decrease in organic carbon content (Deng and Tabatai, 1997).

Statistical analyses revealed that cover crops affected soil phosphatase activity statistically significant (P< 0.05). Phosphatase activity was 99.29 µg g p-nitrophenol soil^{-1} h^{-1}, 89.90 µg g p-nitrophenol soil^{-1} h^{-1} and 75.07 µg g p-nitrophenol soil^{-1} h^{-1} in cover crops (common vetch, common vetch-fodder beet, fodder beet, respectively) and 64.49 µg g p-nitrophenol soil^{-1} h^{-1} in control at 0-10 cm depth under minimum tilled plots. And it was 84.61 µg g p-nitrophenol soil^{-1} h^{-1}, 71.66 µg g p-nitrophenol soil^{-1} h^{-1} and 67.32 µg g p-nitrophenol soil^{-1} h^{-1} in cover crops (common vetch, common vetch-fodder beet, fodder beet, respectively) and 64.61 µg g p-nitrophenol soil^{-1} h^{-1} in control at 0-10 cm depth under conventional tilled plots. It is obvious according to findings that cover crops increased activity of phosphatase in soil (Fernandez et al., 2016; Zhao et al., 2016). This may be caused by increasing soil phosphorus, soil organic matter and turning over crop residues with cover crops (Neilsen et al., 2014; Wei et al., 2014).

Catalase Activity

Catalase activity was significantly (P< 0.05) affected by tillage systems. The average values of catalase activity in the minimum tilled plots were 28.32 and 41.83 ml O_2 3 min^{-1} g soil^{-1} in conventional tilled plots (Table 4). It was clear that catalase activity was higher in conventional tillage than minimum tillage. Rodriguez-Kabana, Truelove (1982) reported that increasing aerobic microbial activity with tillage practices increases catalase activity in soil. Similar to our findings, previous investigations (Luo et al., 2011; Meng et al., 2016) reported that catalase activity was higher in conventional tillage than conservation tillage practices.

It was found to be statistically significant (P< 0.05) with respect to sampling depths in both tillage systems. In minimum tilled plots, the activity was 41.36, 27.56 and 16.04 ml O_2 3 min^{-1} g soil^{-1} at 0-10, 10-20 and 20-30 cm soil depths, respectively. Besides, it was 54.22, 46.56 and 24.72 ml O_2 3 min^{-1} g soil^{-1} in conventional tilled plots at 0-10, 10-20 and 20-30 cm soil depths, respectively (Table 4). Our findings suggested that catalase activity decreased with increasing soil depths (Ulrich et al., 2010; Cai et al., 2018).

Table 4. Effects of cover crops and tillage systems on catalase activity (ml O_2 3 min^{-1} g $soil^{-1}$) at different depths

Tillage Practices	Depths, cm	Cover Crops				Means of Depths	Means of tillage systems
		Control	Common vetch	Common vetch-Fodder beet	Fodder beet		
Minimum Tillage	0-10	24.90±5.20A	58.73±0.97A	47.42±2.22A	34.37±5.30A	41.36±13.80A	28.32±14.02B
	10-20	16.95±1.09B	35.15±6.80B	31.29±4.78B	26.85±3.88A	27.56±8.11B	
	20-30	15.31±3.76B	18.39±4.93C	18.87±3.61C	11.57±0.47B	16.04±4.32C	
Means of Cover Crops		19.05±5.51d	37.43±18.05a	32.53±12.80b	24.26±10.58c		
Conventional Tillage	0-10	46.55±3.26A	64.82±9.99A	56.01±4.24A	49.49±7.09A	54.22±9.28A	41.83±14.70A
	10-20	43.01±1.70A	52.45±8.91A	46.42±7.62A	44.37±10.25A	46.56±7.67B	
	20-30	24.09±3.51B	24.45±7.87B	27.30±0.82B	23.02±9.04B	24.72±5.59C	
Means of Cover Crops		37.88±10.76b	47.24±19.52a	43.24±13.39ab	39.96±14.39b		
Overall Means of Cover Crops		28.47±12.75c	42.33±18.92a	37.88±13.85ab	31.61±14.40bc		35.07±15.80

* – differences between means of treatments were tested by using Duncan multiple comparison test at $p < 0.05$ significance level.

Statistical analyses suggested that cover crops affected significantly (P< 0.05) catalase activity. At 0-10 cm soil depth, catalase activity was higher in cover crops (58.78, 47.42 and 34.37 ml O_2 3 min^{-1} g $soil^{-1}$; common vetch, common vetch-fodder beet and fodder beet, respectively) than control (24.90 ml O_2 3 min^{-1} g $soil^{-1}$) in minimum tilled plots. In conventional tilled plots, significantly higher values of catalase activity were found in cover crops (64.82, 56.01 and 49.49 ml O_2 3 min^{-1} g $soil^{-1}$; common vetch, common vetch-fodder beet and fodder beet, respectively) than control (46.55 ml O_2 3 min^{-1} g $soil^{-1}$) plots at 0-10 cm soil depth. The findings of this research showed that cover crops increased catalase activity and the increase may be caused by an increase in organic matter via cover crops (Zhao et al., 2014; Zhang et al., 2016). These results are in agreement with those obtained by Navas et al. (2011), Zhao et al. (2016), who concluded that cover crops increased soil catalase activity.

CONCLUSION

In the study, I investigated the effects of cover crops and tillage treatments on soil urease, alkaline phosphatase and catalase activities. As a result of the experiment, I detected that cover crops effected all enzymes but tillage treatments effected soil urease and catalase activities following corn. The higher rates of soil urease, phosphatase activities were determined in minimum till practices, while the higher rates of soil catalase activities were in conventional till. The greater values of soil enzyme activities were found in cover crops than control under all tillage treatments. In cover crops, the higher rates of enzyme activities were observed in common vetch under both minimum and conventional tilled plots. It is clear that growing a legume cover crop like vetch, soil enzyme activities are increased. Furthermore, the vetch cover crop improves soil properties such as (soil organic matter, aggregate stability, soil available phosphorus) and fixes nitrogen to the soil with root nodules. Consequently, the use of common vetch as a cover crop is important tool for improving soil properties.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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