Turkish Journal of Agriculture and Forestry

Volume 48 | Number 1 Article 11

2-1-2024

The effect of organic and chemical fertilizers on the activity of soil enzymes in soils of different compositions

Elif Yağanoğlu
elifyaganoglu@atauni.edu.tr

ADİL AYDIN
adil@atauni.edu.tr

Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2024) 48: 116-128
© TÜBİTAK
doi:10.55730/1300-011X.3167

The effect of organic and chemical fertilizers on the activity of soil enzymes in soils of different compositions

Elif YAĞANOĞLU*, **Adil AYDIN**
Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Atatürk University, Erzurum, Turkiye

Received: 03.07.2023 • **Accepted/Published Online:** 07.12.2023 • **Final Version:** 01.02.2024

Abstract: In this study, the effects of chemical (20:20:0 compound) and organic (barnyard) fertilizers applied to different textured soils on several soil enzyme (urease, acid phosphatase, alkaline phosphatase, and dehydrogenase) activities were investigated. The research was conducted under greenhouse conditions with (beans and corn) and without crops. Considering the results of the preexperiment analysis of the soils, a 40-g pot^{-1} of farmyard manure was placed into the pots in which organic fertilizer would be applied in clay and silty loam soils, and a 50-g pot^{-1} of farmyard manure was added to sandy loam soil; in addition, a 0.25-g pot^{-1} of 20:20:0 compound fertilizer was mixed into the clay, silty, and sandy loam samples where chemical fertilizer would be applied. Soil chemical properties such as soil reaction (pH), electrical conductivity, lime, organic matter, useful phosphorus, total nitrogen, exchangeable cations (Ca, Mg, Na, K), cation exchange capacity, microelements (Fe, Cu, Mn, Zn), and soil enzymes (urease, acid phosphatase, alkaline phosphatase, and dehydrogenase) were determined. According to the results, fertilizers applied to the soil increased the soil's pH, organic matter, and macro and micronutrient contents and decreased the exchangeable Na content. The lime content of the soils did not show any decrease or increase. Organic and chemical fertilizers applied to the soil increased the activity of soil enzymes (urease, acid phosphatase, alkaline phosphatase, and dehydrogenase).

Key words: Soil, plant, farmyard manure, chemical fertilizer, enzyme activity

1. Introduction

Obtaining high quality and high yield in plant cultivation is determined by many factors, the most important of which is fertilizer (Azadi et al., 2022; Lavic et al., 2023). While using mineral fertilizers results in a high-yield increase, it adversely affects soil's physical, chemical, and biological properties and leads to soil pollution and inefficiency (Uyanöz et al., 2004; Jia et al., 2022). Due to rapid population growth worldwide and in Türkiye, chemical fertilizers are widely and inadvertently used to obtain additional yield from the unit area; as a result, human health deteriorates, and environmental pollution occurs. Considering these drawbacks, the use of fertilizers of organic origin for sustainable agriculture has increased (Altindag et al., 2006; Channabasana et al., 2008; Erturk et al., 2012; Naghman et al., 2023).

Although organic fertilizers contain lower nutrient levels compared to commercial ones, they are made up of many different nutrients, improve the soil physically, chemically, and biologically, protect it against erosion, provide a suitable environment for plant growth, and improve the water-holding capacity and aggregate structure of the soil (Kılıç and Korkmaz, 2012; Asri et al., 2013; Gülser et al., 2015; Namlı et al., 2017; Asri et al., 2023).

Although maize (*Zea mays* L.) grows in hot climates, the plant does not require too much heat. Maize is primarily used in human food and as an industrial raw material; the leaves of the maize plant are also used in the animal feed sector, the paper industry, and straw handicrafts. Its other uses include its presence in snack foods and oil and biofuel-bioethanol production (Öztürk et al., 2019; Azam et al., 2022).

The bean (*Phaseolus vulgaris* L.) plant has a high vegetable protein content and is produced all over the world; it is important in terms of nutrition but also provides nutrients (N) to the soil by binding free nitrogen in the air (Nadeem et al., 2021; Cilesiz et al., 2023).

Soil enzymes play important roles in the nutrient cycling and mineralization of organic matter. Because determining enzyme activity in soil provides information about chemical and biological changes occurring in soil, enzyme activities are determined in addition to soil chemical and physical parameters (Lemanowicz, 2020).

The amounts and types of enzymes in soil are affected by the content and quantity of postharvest plant and

* Correspondence: elifyaganoglu@atauni.edu.tr

animal residues in soil and the various fertilizers added to it. In addition to inappropriate pH and temperature, soil mismanagement, decreased organic matter content, and fertility negatively affect enzymes (Kadalli et al., 2000).

Dehydrogenase enzyme activity (DEA) indicates microbial activity because these enzymes are present in all living cells. Dehydrogenases are very sensitive to external applications. Dehydrogenase enzymes also convert organic carbon (Tejada et al., 2008).

The urease enzyme is an extracellular soil enzyme adsorbed by organic and inorganic colloids in soil; it catalyzes the hydrolysis of urea to carbon dioxide and ammonia and is involved in the decomposition of nitrogenous compounds in soil and the nitrogen cycle (Chen et al., 2004).

The phosphatase enzyme is involved in converting organic phosphorus compounds into inorganic phosphorus form. Phosphatases are divided into 2 categories: alkaline and acid. The mineralization of phosphorus indicates soil biological activity and plant roots can secrete phosphatase enzymes (Bielinska et al., 2009).

Many researchers have found that fertilizer (organic and chemical) application to soil increases the activity of soil enzymes (urease, acid phosphatase, alkaline phosphatase, dehydrogenase, L-asparaginase, β-glucosidase phosphodiesterase, arylsulfatase, and amylase) (Marinari et al., 2000; Laic et al., 2002; Chang et al., 2007; Okur et al., 2007; Wang et al., 2008; Srivastava et al., 2012; Ergün, 2017; Chen et al., 2018).

Soil enzymes and microorganisms play an important role in plant nutrient cycling, and enzyme activities related to C, N, and P nutrient cycling in soil generally increase after adding organic fertilizers to soil (Debosza et al., 1999; Garcia-Gil et al., 2000; Böhme et al., 2005; Bilen and Turan, 2022).

This study aimed to determine the effect of organic and chemical fertilizers on several physical, chemical, and biological properties and several enzyme (urease, phosphatase, and dehydrogenase) activities of soils with different textures.

2. Materials and methods

The experiment was conducted under greenhouse conditions using soil samples of different textures (coarse, medium, and fine) from the Erzurum plains. It was conducted in 81 pots (3 × 3 × 3 × 3 = 81 pots) with varying soil textures (coarse, medium, and fine) × 2 types of fertilizers (organic, chemical, and control) × 2 types of plants (bean, maize, and control) × 3 replications. In the experiment, 0.25 g of chemical fertilizer was mixed into clay, silty loam, and sandy loam soils with 10 kg N and P_2O_5 per decare, a 40-g pot^{-1} of matured farm manure was mixed into clay and silty loam soil, and a 50-g pot^{-1} of matured farm manure was mixed into sandy loam soil with 4% organic matter in organic fertilizer pots. After adding organic and chemical fertilizers to the pots, 4 bean (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) seeds were sown in each pot. After 10 days of germination, the seeds were thinned, and 2 plants were left in each pot. The plants in the experimental pots were harvested 70 days after germination by measuring plant height; harvested, dried, and dry matter content was also determined (Liu et al., 2016). Total nitrogen was determined using the micro-Kjeldahl method from Kacar and Inal (2008); phosphorus was determined with the vanadate-molybdate yellow color method in the plant samples subjected to wet digestion with a nitric-perchloric acid mixture; other elements (K, Ca, Mg, Fe, Mn, Zn, and Cu) were determined with an an atomic absorbtion spectroscopy reading after wet digestion with a nitric-perchloric acid mixture (Kacar and Inal, 2010).

The pH of the soil samples (Hortensius and Welling, 2008), organic matter content (Bond et al., 2006), $CaCO_3$ content (Loeppert and Suarez, 1996), total nitrogen (Bremner et al., 1965), available P_2O_5 content (Jackson, 2005), cation exchange capacity (Knudsen et al., 1982), exchangeable Ca, Mg, K, and Na content (Udo et al., 2009), electric conductivity (EC) (Sonmez et al., 2008), plant available Fe, Zn, Mn, and Cu content with DTPA (Jones, 2001), mechanical structure (Gee and Or, 2002), soil enzymes urease, acid phosphatase, alkaline phosphatase, and dehydrogenase (Tabatabai, 1982) were determined. Analysis of variance and Duncan's multiple comparison tests were applied in the statistical analysis of the numerical values of soil properties determined according to the soil analysis results (SPSS, 2016).

3. Results and discussion

The numerical values of several soil properties of the soils used before the experiment are given in Table 1, and the changes in several soil properties after the experiment due to fertilizer application and plant growth are shown in Tables 2 and 3.

The pH of the experimental soils was slightly alkaline and showed a decreasing trend with both organic fertilizer and chemical fertilizer application. The electrical conductivity of the soils was salt-free and increased with fertilizer application. With the fertilizer applications, organic matter, available phosphorus, KDK, exchangeable Ca^{+2}, Mg^{+2}, K^{+1}, Na^{+1}, and the microelement (Fe^{+2}, Mn^{+2}, Zn^{+2}, and Cu^{+2}) contents of the soils were determined to have increased. These changes in soil properties were more pronounced in the organic fertilizer used.

Effect of fertilizer application on soil enzyme activity

The results of the enzyme activity analysis of the soil samples used before and after the experiment, depending on fertilizer applications, are given in Tables 1–4.

Table 1. Analysis results of the soil textures.

	Sandy loam	Silty loam	Clay
Sand (%)	53	30	22
Silt (%)	32	44	33
Clay (%)	15	26	45

Table 2. Changes in various physical, chemical, and biological properties of the noncrop soil samples due to fertilizer applications.

Analyzed soil properties	Sandy loam			Silty loam			Clay		
	C.	**O.F.**	**C.F.**	**C.**	**O.F.**	**C.F.**	**C.**	**O.F.**	**C.F.**
pH (1:2.5)	7.65	7.49	7.56	7.45	7.39	7.42	7.57	7.54	7.53
EC. dS m^{-1}	0.65	0.74	0.70	0.58	0.64	0.63	0.66	0.74	0.71
CaCO3. %	6.74	6.74	6.74	2.78	2.77	2.77	2.18	2.18	2.18
OM. %	1.28	1.77	1.64	2.14	2.81	2.66	2.18	2.88	2.68
N. %	0.06	0.08	0.06	0.09	0.13	0.10	0.09	0.12	0.13
P_2O_5 kg/ da^{-1}	6.32	8.12	8.61	7.31	8.94	9.31	7.44	9.12	9.19
K. cmol kg^{-1}	1.96	2.16	2.07	2.73	2.95	2.85	2.93	3.37	3.18
Ca. cmol kg^{-1}	8.20	9.64	8.49	13.1	14.51	14.39	17.1	19.1	11.8
Mg.cmol kg^{-1}	2.65	2.97	2.86	4.45	4.66	4.60	5.75	5.99	5.80
Na. cmol kg^{-1}	0.55	0.47	0.53	0.71	0.66	0.67	0.74	0.55	0.55
KDK. cmol kg^{-1}	14.8	16.8	15.5	22.9	25.3	23.5	28.6	31.4	30.2
Fe. ppm	1.94	2.24	2.16	2.15	2.38	2.18	2.70	2.82	2.76
Mn. ppm	1.70	1.79	1.76	0.65	0.69	0.66	2.11	2.16	2.13
Zn. ppm	0.46	0.87	0.73	0.54	0.98	0.84	0.66	0.97	0.83
Cu. ppm	0.14	0.20	0.17	0.16	0.18	0.17	0.23	0.25	0.23
Urease µg NH_4^+-N g soil $2h^{-1}$	17.1	24.4	21.8	25.6	32.7	28.8	34.8	46.8	44.0
Acid phosphatase µg pNP g soil h^{-1}	8.20	10.0	10.1	9.07	9.91	9.56	7.15	8.09	7.60
Alkaline phosphatase µg pNP g soil h^{-1}	12.2	13.2	12.5	17.2	19.3	17.5	14.5	15.7	15.0
Dehydrogenase µg TPF g soil 24 h^{-1}	14.5	23.1	17.1	20.0	27.2	26.1	22.1	28.4	25.2

C.: Control; O.F.: Organic fertilizer; C.F.: chemical fertilizer.

Effect on urease enzyme activity

The urease enzyme activities (UEAs) of the soils before the experiment are shown in Table 2. According to the analysis, the UAEs were determined as 17.1 µg $NH4^+$ – N g soil $2h^{-1}$ in sandy loam, 25.6 µg $NH4^+$ – N g soil $2h^{-1}$ in silty loam, and 34.8 µg $NH4^+$ – N g soil $2h^{-1}$ in clay soil.

When the UEAs of the soil samples after the research were examined in Tables 2–4, averages of 17.1 µg NH_4^+ – N g soil $2h^{-1}$ in the control (no fertilizer applied and no plant grown) samples, 24.4 µg NH_4^+ – N g soil $2h^{-1}$ in the farm manure-applied samples, and 21.8 µg NH_4^+ – N g soil $2h^{-1}$ in chemical fertilizer-applied samples in the sandy loam soil were determined (Table 2). UEA was 22.9, 28.2, and 26.6 µg NH_4^+ – N g soil $2h^{-1}$ in the control, farmyard manure, and chemical fertilizer treatments, respectively (Table 3), and 23.9, 28.7, and 27.9 µg NH_4^+ – N g soil $2h^{-1}$ in the maize pots (Table 4).

Similar variation in UEA was observed in the silty loam soil, with an average of 25.6 µg NH_4^+ – N g soil $2h^{-1}$ in the control (no fertilizer and no cultivation), 32.7 µg NH_4^+

– N g soil 2h^{-1} in the farmyard manure, and 28.8 µg NH_4^+ – N g soil 2h^{-1} in the chemical fertilizer-treated samples (Table 2). UEA was 29.8, 35.1, and 33.4 µg NH_4^+ – N g soil 2h^{-1} in the bean, farmyard manure, and chemical fertilizer treatments in the silty loam soil, respectively (Table 3), and 28.7, 37.2, and 35.3 µg NH_4^+ – N g soil 2h^{-1} in the maize samples (Table 4).

The average UEA was 34.8 µg NH_4^+ – N g soil 2h^{-1} in the control (no fertilizer and no plant cultivation) samples in clay soil, 46.8 µg NH_4^+ – N g soil 2h^{-1} in the farmyard manure, and 44.0 µg NH_4^+ – N g soil 2h^{-1} in the chemical fertilizer (Table 2). In the controls of the soil samples in which beans were grown in clay soil, urease activity averaged 41.5 µg NH_4^+ – N g soil 2h^{-1}, 47.9 µg NH_4^+ – N g soil 2h^{-1} in the farmyard manure, and 45.6 µg NH_4^+ – N g soil 2h^{-1} in the chemical fertilizers. In Table 4, 6 µg NH_4^+ – N g soil 2h^{-1} (Table 3), 40.5 µg NH_4^+ – N g soil 2h^{-1}, 46.9 µg NH_4^+ – N g soil 2h^{-1}, and 44.9 µg NH_4^+ – N g soil 2h^{-1} levels can be seen in the control pots where maize was grown; therefore, farmyard manure and chemical fertilizers were applied. The changes in UEAs of the experimental soils depending on fertilizer applications are clearly seen in Figure 1.

These results showed that soil texture, plant cultivation, and fertilizer application increased the UAE of the soils. The highest proportional increase was observed in the sandy loam soil (40%). This was followed by clay soil (35%) and silty loam soil (28%) (Tables 2–4). Similar increasing results were observed in the cultivated samples and fertilizer application. The UAE was higher in the organic

Table 3. Changes in various physical, chemical, and biological properties of bean soil samples due to fertilizer applications.

Analyzed soil properties	Sandy loam			Silty loam			Clay		
	C.	O.F.	C.F.	C.	O.F.	C.F.	C.	O.F.	C.F.
pH (1:2.5)	7.60	7.45	7.55	7.43	7.38	7.40	7.54	7.53	7.52
EC. dS m^{-1}	0.66	0.73	0.71	0.57	0.63	0.63	0.67	0.74	0.74
CaCO3. %	6.73	6.73	6.74	2.77	2.78	2.77	2.18	2.19	2.18
OM. %	0.98	1.41	1.34	1.65	1.72	1.65	1.70	2.00	1.90
N. %	0.04	0.06	0.06	0.07	0.05	0.03	0.08	0.06	0.08
P_2O_5. kg da^{-1}	4.30	5.24	5.38	4.71	5.24	4.82	5.10	5.27	5.15
K. cmol kg^{-1}	1.95	2.15	2.11	2.58	2.62	2.61	2.71	2.99	2.82
Ca. cmol kg^{-1}	7.87	8.08	8.07	13.73	13.24	13.14	17.20	18.52	18.45
Mg.cmol kg^{-1}	2.57	2.88	2.77	4.29	4.38	4.39	5.64	5.87	5.85
Na. cmol kg^{-1}	0.42	0.34	0.44	0.56	0.54	0.54	0.54	0.53	0.52
KDK. cmol kg^{-1}	14.8	16.7	15.2	22.8	25.2	23.9	28.3	31.0	29.6
Fe. ppm	1.83	2.20	2.11	2.13	2.33	2.25	2.52	2.59	2.54
Mn. ppm	1.68	1.76	1.74	0.63	0.67	0.64	2.09	2.14	2.11
Zn. ppm	0.40	0.66	0.58	0.44	0.73	0.72	0.62	0.90	0.80
Cu. ppm	0.12	0.18	0.15	0.15	0.16	0.15	0.20	0.20	0.19
Urease µg NH_4^+ -N g soil 2h^{-1}	22.9	28.2	26.6	29.8	35.1	33.4	41.5	47.9	45.6
Acid phosphatase µg pNP g soil h^{-1}	9.42	11.6	12.2	9.42	10.1	9.74	8.17	8.41	8.29
Alkaline phosphatase µg pNP g soil h^{-1}	12.8	14.2	13.1	17.9	18.8	17.9	14.8	15.9	15.9
Dehydrogenase µg TPF g soil 24 h^{-1}	16.4	24.5	18.2	21.5	28.6	28.3	23.6	29.4	26.2

C: Control; O.F.: Organic fertilizer; C.F.: Chemical fertilizer

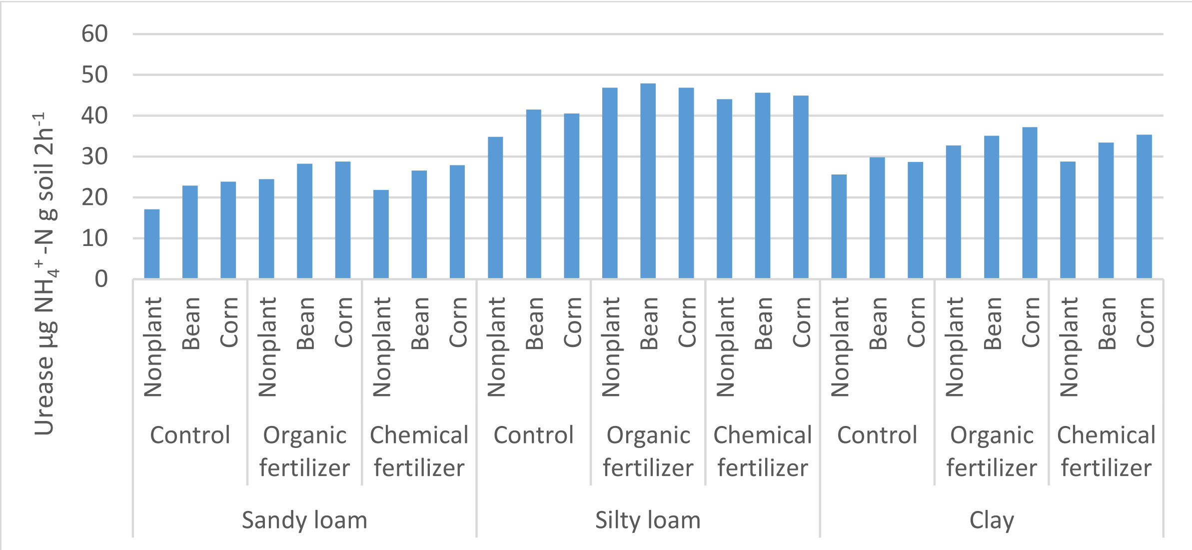

Figure 1. Changes in urease enzyme activity of soils due to fertilizer applications.

fertilizer application. Many researchers have suggested that organic and chemical fertilizer applications added to the soil increase its enzyme activity, and organic fertilizers are more effective in this increase (Debosza et al., 1999; Bilen et al., 2011; Islam et al., 2011; Liang et al., 2014; Jabborova et al., 2021).

According to the results of the analysis of variance and Duncan multiple comparison tests of the UAE values obtained, fertilizer application, soil texture, plant type, and plant cultivation were found to be very significant ($p < 0.01$) on the UAE of the soils, and the averages were found to be different (Tables 5 and 6).

Effect on acid phosphatase enzyme activity

When the acid phosphatase enzyme activity (AcdPEA) of the experimental soils before the experiment was examined from Table 2, it was 8.20 µg pNP g soil h^{-1} in sandy loam soil, 9.07 µg pNP g soil h^{-1} in silt soil, and 7.15 µg pNP g soil h^{-1} in clay soil.

The AcdPEA of the soils is shown before the experiment in Table 2. According to the analysis results, the phosphatase enzyme activities of the soil were determined at 8.20 µg pNP g soil h^{-1} in the control (no fertilizer applied and no plant cultivated) samples in sandy loam soil, 10.00 µg pNP g soil h^{-1} in the farm fertilizer-applied samples, and 10.10 µg pNP g soil h^{-1} in the chemical fertilizer-applied samples.

The AcdPEA of the soil samples in which beans were grown in the control, farmyard manure, and chemical fertilizer treatments were 9.42 µg pNP g soil h^{-1}, 11.60 µg pNP g soil h^{-1}, and 12.20 µg pNP g soil h^{-1}, respectively (Table 3), while in the pots in which maize was grown, averages of 9.29 µg pNP g soil h^{-1}, 11.40 µg pNP g soil h^{-1}, and 11.60 µg pNP g soil h^{-1} were observed (Table 4).

The AcdPEA in the silty loam soil after the research is shown before the experiment in Tables 2–4. According to the results, average phosphatase enzyme activities were determined as 9.07 µg pNP g soil h^{-1} in the control (no fertilizer application and no plant cultivation), 9.91 µg pNP g soil h^{-1} in the organic fertilizer applications, and 9.56 µg pNP g soil h^{-1} in the chemical fertilizer applications (Table 2).

The AcdPEA of the soil samples of bean cultivated plants was 9.42 µg pNP g soil h^{-1} in the control, 10.10 µg pNP g soil h^{-1} in the farm manure treatments, and 9.74 µg pNP g soil h^{-1} in the chemical fertilizer treatments (Table 2). In Table 3, the amount is shown as 74 µg pNP g soil h^{-1}, while in pots in which maize was grown, the average was 9.37 µg pNP g soil h^{-1} in the controls, 10.10 µg pNP g soil h^{-1} in the farmyard manure treatments, and 9.30 µg pNP g soil h^{-1} in the chemical fertilizer treatments (Table 4).

The AcdPEA of the clay soil was determined as 7.15 µg pNP g soil h^{-1} in the control (no fertilizer applied and no plant grown), 8.09 µg pNP g soil h^{-1} in the farmyard manure, and 7.60 µg pNP g soil h^{-1} in the chemical fertilizer (Table 2). The AcdPEA was 8.17 µg pNP g soil h^{-1} in the control pots, 8.41 µg pNP g soil h^{-1} in the farmyard manure, and 8.29 µg pNP g soil h^{-1} in the chemical fertilizers (Table 2). In Table 3, the amounts correspond to 29 µg pNP g soil h^{-1}, 8.01 µg pNP g soil h^{-1}, 8.52 µg pNP g soil h^{-1}, and 8.49 µg pNP g soil h^{-1} in pots without fertilizer, farmyard manure, and chemical fertilizer, respectively (Table 4). The changes in the AcdPEA of the experimental soils depending on fertilizer applications are shown in Figure 2.

According to the results obtained from the experiment, soil texture, plant cultivation, and fertilizer applications

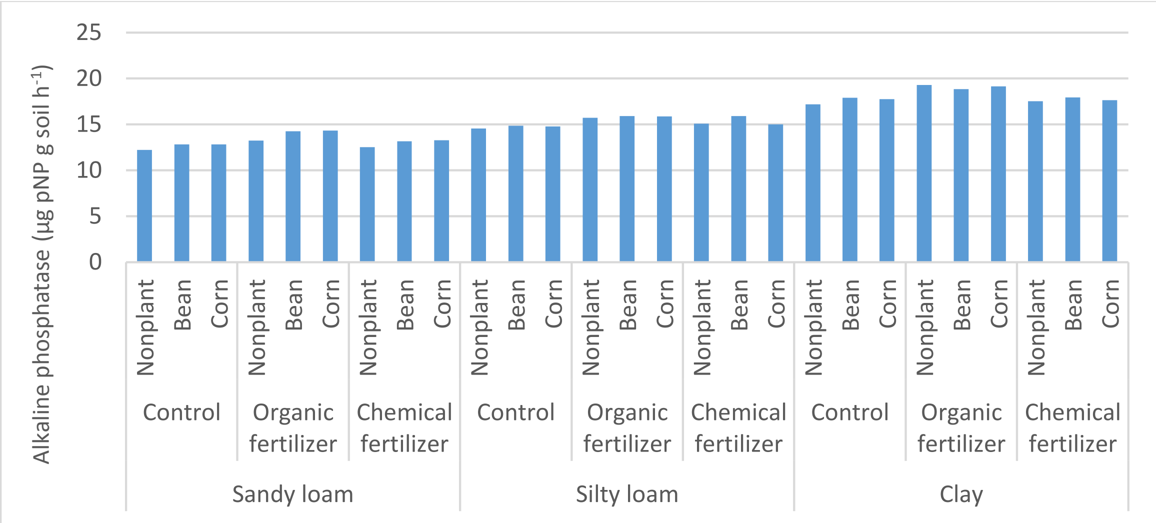

Figure 2. Changes in acid phosphatase enzyme activity of soils caused by fertilizer applications.

increased the AcdPEA of the soils. The highest proportional increase was observed in the sandy loam soil (25 %). This increase was around 10–15 % in the silty loam and clay-textured soils (Tables 2–4). Similar results in terms of increase were observed in the samples in which plants were grown and in the fertilizer application. The AcdPEA was higher in the organic fertilizer application. Numerous researchers have suggested that organic and chemical fertilizers added to the soil increase AcdPEA enzyme activity, and organic fertilizers are more effective in this increase. (Kandeler et al., 1999; Böhme et al., 2005; Bilen et al., 2011; Giacometti et al., 2014; Islam et al., 2011; Liang et al., 2014).

According to the results of the analysis of variance and Duncan's multiple comparison tests of the AcdPEA values obtained in the study, the effect of fertilizer application, soil texture class, and plant cultivation on the AcdPEA of the soils was found to be very significant ($p < 0.01$); the averages were different, while the effect of fertilizers and plant species was found to be insignificant (Tables 5 and 6).

Effect on alkaline phosphatase enzyme activity

In the initial soil samples, the alkaline phosphatase enzyme activity (AlkPEA) of the sandy loam soil was 12.20 µg pNP g soil h^{-1}, the silty loam soil was 17.20 µg pNP g soil h^{-1}, and the clay soil was 14.50 µg pNP g soil h^{-1} (Table 2).

According to Tables 2–4, in estimating the AlkPEA of soils after the experiment, the activity was 12.20 µg pNP g soil h^{-1}, 13.20 µg pNP g soil h^{-1}, and 12.50 µg pNP g soil h^{-1} in the soil sample taken from the control (no fertilizer applied and no plants grown) pots in the sandy loam soil (Table 2). The AlkPEA in the bean-cultivated samples was determined as 12.80 µg pNP g soil h^{-1}, 14.20 µg pNP g soil h^{-1}, and 13.10 µg pNP g soil h^{-1} in the control, farmyard manure, and chemical fertilizer-applied samples, respectively (Table 3), and 12.80 µg pNP g soil h^{-1}, 14.30 µg pNP g soil h^{-1}, and 13.20 µg pNP g soil h^{-1} in the corn-cultivated samples (Table 4).

In the silty loam soil, the AlkPEA was similar and averaged 17.20 µg pNP g soil h^{-1} in the control, 19.30 µg pNP g soil h^{-1} in the farmyard manure, and 17.50 µg pNP g soil h^{-1} in the chemical fertilizer treatments (Table 2). The AlkPEA was 17.90 µg pNP g soil h^{-1}, 18.80 µg pNP g soil h^{-1}, and 17.90 µg pNP g soil h^{-1} in the bean grown control, farmyard manure, and chemical fertilizer treatments, respectively (Table 3), and 17.70 µg pNP g soil h^{-1}, 19.10 µg pNP g soil h^{-1}, and 17.60 µg pNP g soil h^{-1} in the maize-grown sample (Table 4).

The average AlkPEA of the clay soil was 14.50 µg pNP g soil h^{-1} in the control samples, 15.70 µg pNP g soil h^{-1} in the farmyard manure treatments, and 15.00 µg pNP g soil h^{-1} in the chemical fertilizer treatments (Table 2). The average AlkPEA of the control samples in which bean plants were grown was 14.80 µg pNP g soil h^{-1}, 15.90 µg pNP g soil h^{-1} in the farm manure, and 15.90 µg pNP g soil h^{-1} in the chemical fertilizers. In Table 3, the amounts are 90 µg pNP g soil h^{-1}, 14.70 µg pNP g soil h^{-1}, 15.80 µg pNP g soil h^{-1}, and 14.90 µg pNP g soil h^{-1} in the maize-grown controls, farmyard manure, and chemical fertilizer treatments, respectively (Table 4 and Figure 3).

According to the findings, soil texture, plant cultivation, and fertilizer applications increased the AlkPEA of the soils. The proportional increase in AlkPEA was highest in the sandy soil (10–15%), 10–12 % in the silty soil, and

Table 4. Changes in various physical, chemical, and biological properties of maize soil samples due to fertilizer applications.

Analyzed soil properties	Sandy loam			Silty loam			Clay		
	C.	O.F.	C.F.	C.	O.F.	C.F.	C.	O.F.	C.F.
pH (1:2.5)	7.61	7.49	7.54	7.42	7.37	7.40	7.55	7.52	7.51
EC, dS m^{-1}	0.66	0.75	0.71	0.57	0.64	0.63	0.67	0.75	0.73
CaCO3, %	6.74	6.73	6.73	2.77	2.78	2.78	2.19	2.18	2.18
OM, %	0.79	1.39	1.18	1.40	1.51	1.46	1.55	1.73	1.63
N %	0.02	0.05	0.05	0.03	0.01	0.01	0.06	0.06	0.07
P_2O_5 kg da^{-1}	3.53	4.46	4.45	4.40	4.18	5.18	4.89	5.10	5.29
K, cmol kg^{-1}	1.82	2.04	1.99	2.48	2.60	2.55	2.61	2.92	2.79
Ca, cmol kg^{-1}	7.79	7.94	7.95	13.6	14.19	14.10	16.87	17.90	17.31
Mg, cmol kg^{-1}	2.55	2.85	2.74	4.25	4.35	4.32	5.59	5.79	5.71
Na, cmol kg^{-1}	0.35	0.31	0.35	0.54	0.43	0.46	0.48	0.44	0.44
KDK, cmol kg^{-1}	14.9	15.9	15.5	22.7	24.8	23.5	28.4	31.5	29.2
Fe, ppm	1.89	2.18	2.08	2.10	2.34	2.25	2.42	2.58	2.51
Mn, ppm	1.66	1.76	1.74	0.62	0.66	0.64	2.07	2.14	2.10
Zn, ppm	0.37	0.65	0.56	0.40	0.72	0.69	0.60	0.76	0.66
Cu, ppm	0.11	0.16	0.14	0.14	0.16	0.15	0.18	0.20	0.18
Urease µg NH_4^+-N g soil $2h^{-1}$	23.9	28.7	27.9	28.7	37.2	35.3	40.5	46.9	44.9
Acid phosphatase µg pNP g soil h^{-1}	9.29	11.4	11.6	9.37	10.1	9.93	8.01	8.52	8.49
Alkaline phosphatase µg pNP g soil h^{-1}	12.8	14.3	13.2	17.7	19.1	17.6	14.7	15.8	14.9
Dehydrogenase µg TPF g soil 24 h^{-1}	16.5	24.1	19.1	21.7	29.3	28.0	23.8	30.1	26.3

O.F.: Organic fertilizer; C.F.: Chemical fertilizer

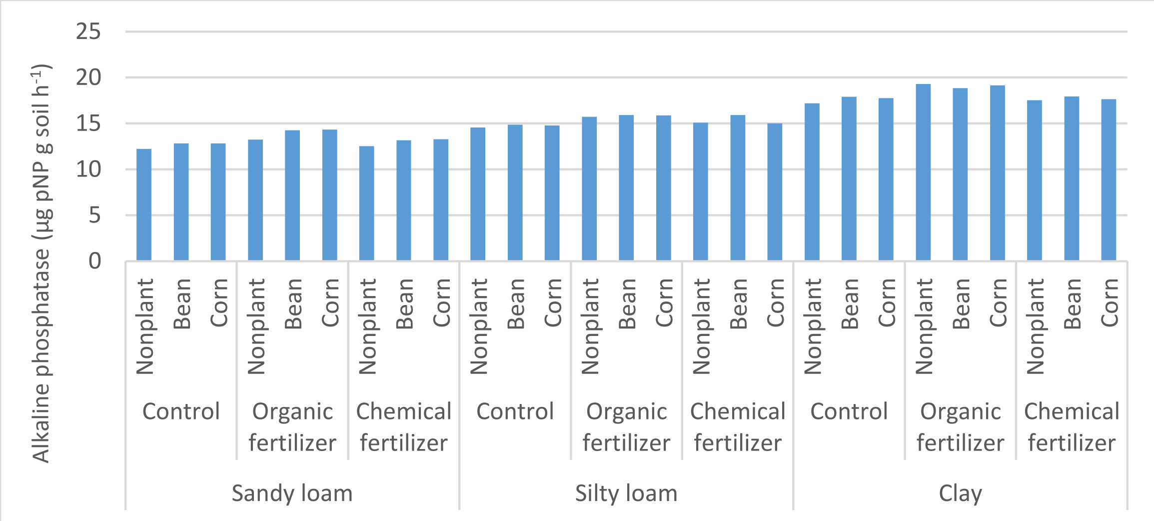

Figure 3. Changes in alkaline phosphatase enzyme activity of soils caused by fertilizer applications.

5–10 % in the clay soil (Tables 2–4). An increased change was also observed in the cultivated samples and fertilizer applications. AlkPEA was higher in the organic fertilizer application. Many researchers have reported that organic and chemical fertilizer applications added to soil increase AlkPEA, and organic fertilizers are more effective in this increase. (Garcia-Gil et al., 2000; Böhme et al., 2005; Bilen et al., 2011, Islam et al., 2011; Giacometti et al., 2014; Liang et al., 2014).

According to the analysis of variance and Duncan's multiple comparison tests of the AlkPEA values obtained from the research, the effect of fertilizer application soil texture class on the AcdPEA of the soils was found to be very significant ($p < 0.01$). The averages were different, and the effect of plant and type was insignificant (Tables 5 and 6).

Effect on dehydrogenase enzyme activity

The DEA of the soil samples before the experiment was 14.50 µg TPF g soil 24 h^{-1} in the sandy loam soil, 22.10 µg TPF g soil 24 h^{-1} in the silty loam soil, and 22.20 µg TPF g soil 24 h^{-1} in the clay soil. When the DEA of the soils after the experiment is examined in Tables 2–4, it shows variance according to the structure of the soil samples; it was 14.50 µg TPF g soil 24 h^{-1} in the sandy loam soil in the control group, 23.10 µg TPF g soil 24 h^{-1} in the farm manure treatments, and 17.1 µg TPF g soil 24 h^{-1} in the chemical fertilizer treatments (Table 2). DEA increased with the cultivation of the plant at levels of 20.00 µg TPF g soil 24 h^{-1}, 27.00 µg TPF g soil 24 h^{-1}, 27.00 µg TPF g soil 24 h^{-1}, and 27.00 µg TPF g soil 24 h^{-1} in the control, farmyard manure, and chemical fertilizer treatments, respectively (Table 2). In Table 2, 20 µg TPF g soil 24 h^{-1}, 26.10 µg TPF g soil 24 h^{-1}, 22.10 µg TPF g soil 24 h^{-1}, 28.40 µg TPF g soil 24 h^{-1}, and 25.20 µg TPF g soil 24 h^{-1} in the maize grown can be observed (Table 4).

When the DEA of the soils after the research is examined in Tables 2–4, it was found that the average was 20.00 µg TPF g soil 24 h^{-1} in the control group (no fertilizer application and no plant cultivation) samples, 27.20 µg TPF g soil 24 h^{-1} in the farm manure-added samples, and 26.10 µg TPF g soil 24 h^{-1} in the chemical fertilizer-added samples in the silty loam-textured soil (Table 2). Similar changes were also observed in the soil samples in which beans were grown, and 21.50 µg TPF g soil 24 h^{-1}, 28.60 µg TPF g soil 24 h^{-1}, and 28.30 µg TPF g soil 24 h^{-1} levels were found in the control, farmyard manure, and chemical fertilizer treatments, respectively (Table 3), while 21.50 µg TPF g soil 24 h^{-1}, 28.60 µg TPF g soil 24 h^{-1}, and 28.30 µg TPF g soil 24 h^{-1} levels were found in maize (Table 4).

The DEA in the clay soil was 22.10 µg TPF g soil 24 h^{-1} in the control group (no fertilizer application and no plant cultivation), 28.40 µg TPF g soil 24 h^{-1} in the farmyard manure application, and 25.20 µg TPF g soil 24 h^{-1} in the chemical fertilizer application (Table 2). The DEA of the soil samples in which beans were grown was 23.60 µg TPF g soil 24 h^{-1} in control pots, 29.40 µg TPF g soil 24 h^{-1} in farmyard manure, and 26.20 µg TPF g soil 24 h^{-1} in chemical fertilizers. In Table 3, 20 µg TPF g soil 24 h^{-1}, 23.80 µg TPF g soil 24 h^{-1}, 30.10 µg TPF g soil 24 h^{-1}, and 26.30 µg TPF g soil 24 h^{-1} in pots without fertilizer, farmyard manure, and chemical fertilizers can be observed, respectively (Table 4 and Figure 4).

According to the research findings, soil texture, plant cultivation, and fertilizer applications increased the DEA of the soils. Among the enzymes examined in the experiment, the highest increase in activity was observed in

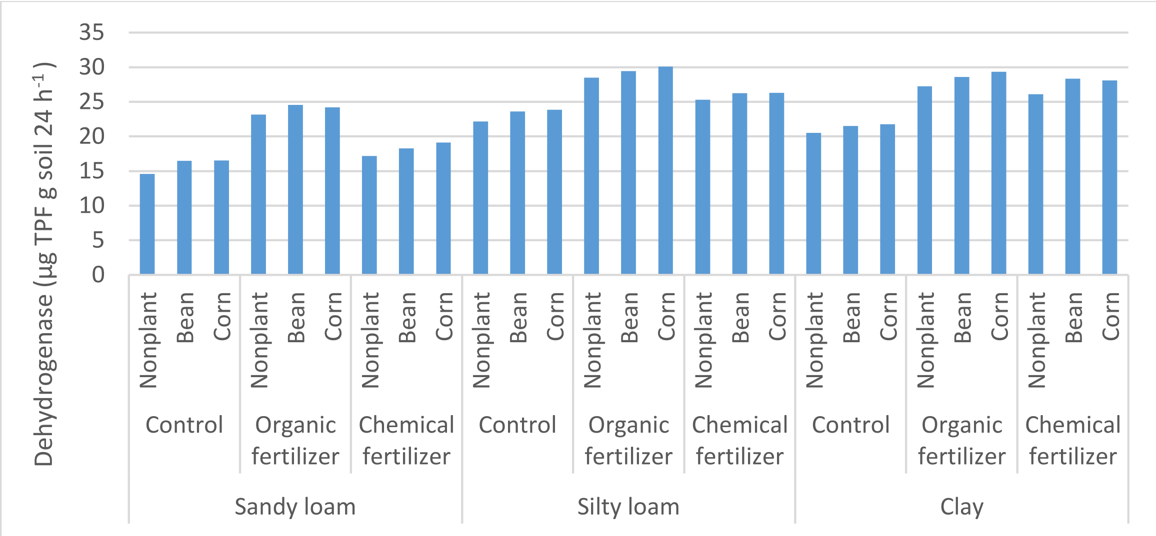

Figure 4. Changes in dehydrogenase enzyme activity of soils caused by fertilizer applications.

the DEA. The highest increase in DEA was observed in the sandy soil (50–55%), followed by silty soil (35–40%) and clay soil (25–30%) (Tables 2–4). Similar increasing results were observed in the cultivated samples and fertilizer application. DEA was higher in organic fertilizer-applied samples than in chemical fertilizer-applied samples. Many researchers have suggested that organic and chemical fertilizers added to the soil increase DEA enzyme activity, and organic fertilizers are more effective in this increase. (Marinari et al., 2000; Dodor and Tabatabai, 2003; Böhme et al., 2005; Bilen et al., 2011; Islam et al., 2011; Liang et al., 2014; Jabborova et al., 2021).

According to the results of the analysis of variance and Duncan's multiple comparison tests of the DEA values obtained in this study, it was found that the effect of fertilizer application and soil structure on the DEA of soils was very significant ($p < 0.01$), the effect of plant and plant type was significant ($p < 0.05$), and the averages were different (Tables 5 and 6).

Table 5. Multiple comparison test results of urease, acid phosphatase, alkaline phosphatase, and dehydrogenase enzyme activity values of the experimental soils for fertilizer applications and cultivation (with and without plants) conditions.

Variation Source		Urease	Acid phosphatase	Alkaline phosphatase	Dehydrogenase
		Mean ± S.Error	Mean ± S.Error	Mean ± S.Error	Mean ± S.Error
Soil	Sandy loam	24.66 ± 3.63^{c}	10.45 ± 1.33^{a}	13.19 ± 0.69^{c}	19.33 ± 3.56^{b}
	Silty loam	31.88 ± 3.68^{b}	9.68 ± 0.34^{b}	17.77 ± 2.15^{a}	25.72 ± 3.34^{a}
	Clay	43.70 ± 3.98^{a}	8.08 ± 0.43^{c}	15.30 ± 0.53^{b}	26.17 ± 2.63^{a}
Application	Control	29.45 ± 7.88^{c}	8.67 ± 0.78^{b}	14.99 ± 2.10^{b}	20.11 ± 3.26^{c}
	Org. manure	36.48 ± 8.56^{a}	9.80 ± 1.23^{a}	16.30 ± 2.18^{a}	27.23 ± 2.49^{a}
	Che. fertilizer	34.30 ± 8.48^{b}	9.73 ± 1.46^{a}	14.97 ± 2.42^{b}	23.88 ± 4.23^{b}
Plant	Nonplant	30.72 ± 9.56^{b}	8.85 ± 1.08^{b}	15.27 ± 2.32^{a}	22.74 ± 4.48^{b}
	Bean	34.59 ± 8.41^{a}	9.73 ± 1.40^{a}	15.74 ± 2.07^{a}	24.12 ± 4.44^{a}
	Corn	34.92 ± 7.80^{a}	9.63 ± 1.22^{a}	15.25 ± 2.53^{a}	24.36 ± 4.44^{a}

Table 6. Results of the multiple comparison tests of urease, acid phosphatase, alkaline phosphatase, and dehydrogenase enzyme activity values for soil texture class, fertilizer application, plant type, and cultivation conditions (with or without plant cultivation).

	Application	Alkaline phosphatase			Dehydrogenase		
		Sandy loam	Silty loam	Clay	Sandy loam	Silty loam	Clay
Nonplant	Control	12.23 ± 0.15^{b}	17.20 ± 0.01^{b}	14.57 ± 0.19^{c}	14.57 ± 0.19^{c}	20.50 ± 0.01^{b}	22.18 ± 0.01^{c}
	Or. fertilizer	13.26 ± 0.03^{a}	19.30 ± 0.01^{a}	15.74 ± 0.05^{a}	23.17 ± 0.11^{a}	27.24 ± 0.02^{a}	28.47 ± 0.03^{a}
	Ch. fertilizer	12.55 ± 0.03^{b}	17.55 ± 0.02^{b}	15.08 ± 0.02^{b}	17.18 ± 0.03^{b}	26.12 ± 0.01^{a}	25.29 ± 0.01^{b}
Bean	Control	12.84 ± 0.03^{c}	17.92 ± 0.01^{b}	14.88 ± 0.01^{b}	16.48 ± 0.03^{c}	21.53 ± 0.02^{b}	23.61 ± 0.02^{c}
	Or. fertilizer	14.27 ± 0.03^{a}	18.86 ± 0.01^{a}	15.92 ± 0.01^{a}	24.56 ± 0.01^{a}	28.61 ± 0.03^{a}	29.44 ± 0.04^{a}
	Ch. fertilizer	13.17 ± 0.03^{b}	17.96 ± 0.01^{b}	15.90 ± 0.01^{a}	18.26 ± 0.03^{b}	28.36 ± 0.06^{a}	26.27 ± 0.03^{b}
Corn	Control	12.83 ± 0.04^{c}	17.74 ± 0.02^{b}	14.77 ± 0.02^{b}	16.55 ± 0.01^{c}	21.77 ± 0.01^{b}	23.86 ± 0.01^{c}
	Or. fertilizer	14.35 ± 0.02^{a}	19.15 ± 0.02^{a}	15.87 ± 0.01^{a}	24.18 ± 0.01^{a}	29.35 ± 0.02^{a}	30.10 ± 0.01^{a}
	Ch. fertilizer	13.28 ± 0.01^{b}	17.63 ± 0.01^{b}	14.99 ± 0.02^{b}	19.10 ± 0.02^{b}	28.07 ± 0.02^{a}	26.32 ± 0.01^{b}
	Application	Urease			Acid phosphatase		
		Sandy loam	Silty loam	Clay	Sandy loam	Silty loam	Clay
Nonplant	Control	17.16 ± 0.59^{c}	25.61 ± 0.22^{c}	34.86 ± 0.17^{c}	8.20 ± 0.01^{b}	9.07 ± 0.01^{c}	7.15 ± 0.03^{c}
	Or. fertilizer	24.47 ± 0.36^{a}	32.78 ± 0.17^{a}	46.88 ± 0.20^{a}	10.01 ± 0.23^{a}	9.91 ± 0.07^{a}	8.09 ± 0.02^{a}
	Ch. fertilizer	21.88 ± 0.34^{b}	28.83 ± 0.21^{b}	44.06 ± 0.16^{b}	10.13 ± 0.06^{a}	9.56 ± 0.03^{b}	7.60 ± 0.03^{b}
Bean	Control	22.93 ± 0.33^{c}	29.86 ± 0.17^{c}	41.52 ± 0.38^{c}	9.42 ± 0.02^{b}	9.42 ± 0.02^{c}	8.17 ± 0.02^{c}
	Or. fertilizer	28.29 ± 0.41^{a}	35.14 ± 0.03^{a}	47.93 ± 0.20^{a}	11.67 ± 0.31^{a}	10.18 ± 0.01^{a}	8.41 ± 0.03^{a}
	Ch. fertilizer	26.60 ± 0.21^{b}	33.45 ± 0.31^{b}	45.66 ± 0.30^{b}	12.29 ± 0.10^{a}	9.74 ± 0.02^{b}	8.29 ± 0.02^{b}
Corn	Control	23.92 ± 0.16^{c}	28.71 ± 0.20^{c}	40.53 ± 0.24^{c}	9.29 ± 0.03^{b}	9.37 ± 0.01^{b}	8.01 ± 0.00^{b}
	Or. fertilizer	28.77 ± 0.24^{a}	37.22 ± 0.03^{a}	46.91 ± 0.23^{a}	11.47 ± 0.04^{a}	10.02 ± 0.05^{a}	8.52 ± 0.02^{a}
	Ch. fertilizer	27.96 ± 0.09^{b}	35.33 ± 0.04^{b}	44.97 ± 0.20^{b}	11.62 ± 0.03^{a}	9.93 ± 0.02^{a}	8.49 ± 0.01^{a}

4. Conclusion and suggestions

This study investigated the effects of farmyard manure and chemical fertilizer applied to soils of different textures on some soil properties, soil urease, and phosphatase and dehydrogenase enzyme activities.

Organic and chemical fertilizers applied to the soils positively affected the physical and chemical properties of the soils and increased the activity of soil enzymes. Farm manure was more effective in the soils' chemical properties and enzyme activities.

Both farm manure and chemical fertilizer applications decreased the pH value of the soils. Farm manure and chemical fertilizer applications increased the EC value of the soils. The effect of fertilizer applications on the lime content of soils of different textures used in the experiment was insignificant. The organic matter content of the soils increased with farmyard manure and chemical fertilizer applications. The highest increase in organic matter was observed in the clay-textured soil and farmyard manure. The useful phosphorus content of the test soils increased with fertilizer applications. This is a natural result of organic fertilizer and chemical (compound 20:20:0 NP) fertilizer applications.

Although the microelement contents (Fe, Cu, Zn, Mn) of the soils showed unstable increasing and decreasing changes with farm manure and chemical fertilizer applications, the changes were generally increased and more pronounced in the farm manure applications. This is due to the content of the farm manure.

The effect of the fertilizers applied to the soil on soil enzyme activity was significant, and an increase was observed. This increase in soil enzyme activity was more significant in the farm manure. The fact that the increase was more pronounced in the farm manure can be explained by the fact that organic fertilizers more significantly increase soil enzyme activities in the N, P, and S cycles. The highest proportional increase in UAE was observed in the sandy loam soil, followed by clay and silty loam soil. AcdPEA and DEA were highest in the sandy loam soil. An increase in enzyme activity in the soil increases the soil's nutrient content. An increase in soil nutrient availability can be considered an indicator of soil fertility.

The study results show that farm and chemical fertilizer applications affected soil properties and soil enzyme activity. In evaluating the results of the research and analysis, farm fertilizer was found to be more effective than chemical fertilizer, and soil texture was effective in the efficiency of the fertilizers.

Applying organic matter to the soil improves its physical and biological properties and increases its fertility and productivity and, thus, overall quality. Chemical fertilizers increase soil fertility and productivity by adding nutrients to the soil.

The fertilization of soils, especially with organic materials, will reduce chemical fertilizer costs, increase profitability in crop production, and ensure sustainability in agricultural production by improving soil quality in farming areas, thus increasing crop production and quality.

Acknowledgment

This article was produced from the PhD thesis of the corresponding author and funded by Atatürk University's Coordination Unit of Scientific Research Projects [grant no.: FDK-2021-8656].

References

Altindag M, Sahin M, Esitken A, Ercisli S, Guleryuz M et al. (2006). Biological control of brown rot (*Moniliana laxa* Ehr.) on apricot (*Prunus armeniaca* L. cv. Hacihaliloglu) by *Bacillus, Burkholderia* and *Pseudomonas* application under *in vitro* and *in vivo* conditions. Biological Control 38: 369-372. https://doi.org/10.1016/j.biocontrol.2006.04.015

Asri FÖ, Özkan CF, Demirtaş EI, Arı N (2013). Effects of organic and chemical fertilizer on soil properties and nutrient up take of cucumber. Soil Water Journal 2 (1): 337-342.

Asri FO, Erturk ME, Simsek V, Vuran FA, Bayar FU (2023). Conventional and organic fertilization improve the growth responses and essential oil content of Salvia fruticosa Mill. Turkish Journal of Agriculture and Forestry 47 (5): 761-771. https://doi.org/10.55730/1300-011X.3125

Azadi MS, Shokoohfar A, Mojdam M, Lak S, Fazel MA (2022). Investigation of changes in corn hybrids grain protein, proline, and micronutrient content under the influence of drought and fertilizers. Turkish Journal of Agriculture and Forestry. 46 (4): 413-423. https://doi.org/10.55730/1300-011X.3014

Azam MD. G, Sarker U, Uddin MD. S (2022). Screening maize (Zea mays L.) genotypes for phosphorus deficiency at the seedling stage. Turkish Journal of Agriculture and Forestry. 46 (6): 802-821. https://doi.org/10.55730/1300-011X.3044

Bielinska EJ, Mocek-Plociniak A (2009). Impact of uncontrolled waste dumping on soil chemical and biochemical properties. Archives of Environmental Protection, 35 (3): 101-107.

Bilen S, Bilen M, Bardhan S (2011). The effects of boron management on soil microbial population and enzyme activities. African Journal of Biotechnology 10 (27): 5311-5319. https://doi.org/10.5897/AJB10.1376

Bilen S, Turan V (2022). Enzymatic analyses in soils. In: Amaresan N, Patel P, Amin D (editors). Practical Handbook on Agricultural Microbiology. Part VI-Assessment of Soil Microbial Activity by Soil Respiration. New York, NY, USA: Humana Press. https://doi.org/10.1007/978-1-0716-1724-3_50

Böhme L, Langer U, Böhme F (2005). Microbial biomass, enzyme activities and microbial community structure in two European long-term field experiments. Agriculture, Ecosystems & Environment 109 (1-2): 141-152.

Bond CR, Maguire RO, Havlin JL (2006). Change in soluble phosphorus in soils following fertilization is dependent on initial Mehlich-3 phosphorus. Journal of Environmental Quality 35: 1818-1824. https://doi.org/10.2134/jeq2005.0404

Bremner JM (1965). Total nitrogen. In: Black, CA (editor). Methods of Soil Analysis: Part 2-Chemical and Microbiological Properties. Wisconsin, USA: American Society of Agronomy, p.1149-1178.

Channabasanagowda NK, Patil B, Patil BN, Awaknavar JS et al. (2008). Effect of organic manures on growth, seed yield and quality of wheat. Karnataka Journal of Agricultural Science 21 (3): 366-368.

Chang EH, Chung RS, Tsai YH (2007). Effect of different application rates of organic fertilizer on soil enzyme activity and microbial population. Soil Science and Plant Nutrition 53 (2): 132-140. https://doi.org/10.1111/j.1747-0765.2007.00122.x

Carreiro MM, Sinsabaugh RL, Repert DA, Pankhurst DF (2004). Microbial enzyme shifts explain litter decay responses to simulated nitrogen deposition. Ecology 81: 2359-2365. https://doi.org/10.1890/0012-9658(2000)081[2359:meseld]2.0.co;2

Chen Y, Liu J, Liu S (2018). Effect of long-term mineral fertilizer application on soil enzyme activities and bacterial community composition. Plant, Soil and Environment 64 (12): 571-577.

Cilesiz Y, Nadeem MA, Gursoy N, Kul R, Karakoy T (2023). Assessing the cooking and quality traits diversity in the seeds of faba bean germplasm. Turkish Journal of Agriculture and Forestry 47 (4): 448-466. https://doi.org/10.55730/1300-011X.3101

Debosza K, Rasmussen PH, Pedersen AR (1999). Temporal variations in microbial biomass C and cellulolytic enzyme activity in arable soils: effects of organic matter input. Applied Soil Ecology 13 (3): 209-218. https://doi.org/10.1016/S0929-1393(99)00034-7

Dick RP, Sandor JA, Eash NS (1994). Soil enzyme activities after 1500 years of terrace agriculture in the Colca Valley, Peru. Agriculture Ecosystems & Environment 50 (2): 123-131. https://doi.org/10.1016/0167-8809(94)90131-7

Dodor DE, Tabatabai MA (2003). Effect of cropping systems on phosphatases in soils. Journal of Plant Nutrition and Soil Science 166 (1): 7-13. https://doi.org/10.1002/jpln.200390016

Ergün YA (2017). The effect of biochar and animal manure application on some enzyme activities in soil, CO_2 production, content of nutrients, and the growth of tomato plants. MA, Ordu University, Ordu, Türkiye.

Erturk Y, Ercisli S, Cakmakci R (2012). Yield and growth response of strawberry to plant growth-promoting rhizobacteria inoculation. Journal of Plant Nutrition 35 (6), 817-826. https://doi.org/10.1080/01904167.2012.663437

Garcia-Gil JC, Plaza C, Soler-Rovira P, Polo A (2000). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. Soil Biology and biochemistry 32 (13): 1907-1913. https://doi.org/10.1016/S0038-0717(00)00165-6

Gee GW, Or D (2002). Methods of soil analysis: Part 4-Physical Methods, Particle Size Analysis 5: 255-293.

Giacometti C, Cavani L, Baldoni G, Ciavatta C, Marzadori C et al. (2014). Microplate scale fluorometric soil enzyme assays as soil quality assessment tools in a long-term agricultural field experiment. Application Soil Ecology 75: 80-85. https://doi.org/10.1016/j.apsoil.2013.10.009

Gülser C, Kızılkaya R, Aşkın T, Ekberli I (2015). Changes in soil quality by compost and hazelnut husk applications in a hazelnut orchard. Compost Science Utilization 23 (3): 135-141. https://doi.org/10.1080/1065657X.2015.1013584

Hortensius D, Welling R (2008). International standardization of soil quality measurement. Communications in Soil Science and Plant Analysis 27. pp. 387-402.

IBM SPSS statistics (2016). Version 24. Armonk, NY, USA: IBM Analytics.

Islam M, Singh Chauhan P, Kim Y, Kim M, and Sa T (2011). Community level functional diversity and enzyme activities in paddy soils under different long-term fertilizer management practices. Biology and Fertility of Soils 47 5: 599-604. https://doi.org/10.1007/s00374-010-0524-2

Jackson ML (2005). Soil Chemical Analysis: Advanced course. Madison, WI, USA: UW-Madison Libraries Parallel Press.

Jabborova D, Seyyid RZ, Azimov A, Cabbarov Z et al. (2021). Impact of mineral fertilizers on mineral nutrients in the ginger rhizome and on soil enzymes activities and soil properties. Saudi Journal of Biological Sciences 28 (9): 5268-5274. https://doi.org/10.1016/j.sjbs.2021.05.037

Jia S, Yuan D, Li W, He W, Raza S, Kuzyakov Y, Zamanian K, Zhao X (2022). Soil chemical properties depending on fertilization and management in China: A meta-analysis. Agronomy 12 (10): 2501. https://doi.org/10.3390/agronomy12102501

Jones JB (2001). Laboratory guide for conducting soil tests and plant analysis. Washington, DC, USA: CRC Press, pp. 115-119. https://doi.org/10.1201/9781420025293

Kacar B, Inal A (2008). Plant analysis. Nobel Press, 1241, 891.

Kacar B, İnal A (2010). Bitki Analizleri. Nobel Akademik Yayıncılık, Türkiye. (in Turkish).

Kadalli GG, Devi LS, Siddaramappa R, John E (2000). Characterization of humic fractions extracted from coir dust-based composts. Journal of the Indian Society of Soil Science 48: 51-55.

Karaca A, Kızılkaya R, Horuz H, Arcak S (1998). The relationships between biochemical activity characteristics and soil properties of hazelnut grown soils. Pamukkale University Journal of Engineering Sciences 4 (3): 813-822.

Kandeler E, Stemmer M, Klimanek E (1999). Soil microbial biomass response of urease and xylanase to long-term soil management in particle size fractions. Soil Biology and Biochemistry 31: 261-273. https://doi.org/10.1016/S0038-0717(98)00115

Kılıç R, Korkmaz K (2012). Residual effects of chemical fertilizers on agricultural soils. Journal of Biological Sciences Research 5 (2): 87-90.

Knudsen D, Peterson GA, Pratt PF (1982). Lithium, sodium and potassium. In: Page, AL (editor). Methods of Soil Analysis Part 2. Chemical and Microbiological Properties. Second Edition. Wisconsin, USA: ASA, Inc., pp. 225-246.

Laic CM, Liu KL, Jeng GL, Helen W (2002). Effects of fertilization management on soil enzyme activities related to the C. N. P and S cycles in soils. Symposium 12; Thailand, p. 1382.

Lavic D, Radovic M, Aliman J, Badzak N, Kulina M et al. (2023). Influence of cultivar and fertilization treatment on bioactive content of some apple (*Malus domestica* Borkh.) cultivars. Turkish Journal of Agriculture and Forestry. 47 (3): 345-356. https://doi.org/10.55730/1300-011X.3091

Lemanowicz J, Brzezinska M, Siwik-Ziomek A, Koper J (2020). Activity of selected enzymes and phosphorus content in soils of former sulphur mines. Science of The Total Environment 708: 1-11.

Liang Q, Chen H, Gong Y, Yang H, Fan M et al. (2014). Effects of 15 years of manure and mineral fertilizers on enzyme activities in particle-size fractions in a North China Plain soil. European Journal of Soil Biology 60: 112-119. https://doi.org/10.1016/j.ejsobi.2013.11.009

Liu XR, Mei CR, Yan DZ, Gong YQ, Zhang (2016). Effects of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes. Agricultural Water Management 167: 75-85.

Loeppert RH, Suarez DL (1996). Carbonate and gypsum. Methods of Soil Analysis: Part 3 Chemical Methods 5: 437-474. https://doi.org/10.2136/sssabookser5.3.c15

Lu RK (1999). Analysis Methods of Soil Agricultural Chemistry. Beijing China: China Agricultural Science and Technology Press. p. 474-490

Marinari S, Masciandaro G, Ceccanti B, Grego S (2000). Influence of organic and mineral fertilisers on soil biological and physical properties. Bioresource Technology 72 (1): 9-17. https://doi.org/10.1016/S0960-8524(99)00094-2

Nadeem MA, Yeken, MZ, Shahid MQ, Habyarimana H, Yılmaz H et al. (2021). Common bean as a potential crop for future food security: an overview of past, current and future contributions in genomics, transcriptomics, transgenics and proteomics, Biotechnology & Biotechnological Equipment 35 (1): 759-787. https://doi.org/10.1080/13102818.2021.1920462

Naghman R, Bhatti MT, Najabat Z, Hyder S, Rizvi ZF et al. (2023). Organic amendments: a natural way to suppress phytopathogens: a sustainable approach to go green. Turkish Journal of Agriculture and Forestry. 47 (5): 602-622. https://doi.org/10.55730/1300-011X.3113

Namlı A, Akça MO, Akça H (2017). The effects of biochars obtained from agricultural wastes on wheat plant growth and some soil properties. Journal of Soil Science and Plant Nutrition 5 (1): 39-47

Okur N (2007). The effect of some organic amendments using in organic agriculture on microbial activity in soil. Journal of Agriculture Faculty of Ege University 44 (2): 65-80.

Öztürk Y, Özata E, Erdal Ş, Pamukçu M (2019). Utilization and future of special corn types in Turkey. International Journal of Eastern Mediterranean Agricultural Research 2 (1): 75-90.

Srivastava PK, Gupta M, Upadhyay RK, Sharma S et al. (2012). Effects of combined application of vermicompost and mineral fertilizer on the growth of *Allium cepa* L. and soil fertility. Journal of Plant Nutrition and Soil Science 175 (1): 101-107. https://doi.org/10.1002/jpln.201000390

Sonmez S, Buyuktas D, Okturen F, Citak S (2008). Assessment of different soil to water ratios (1:1, 1:2.5, 1:5) in soil salinity studies. Geoderma. 144: 361-369.

Tejada M, Gonzalez JL, García-Martínez AM, Parrado J (2008). Application of a green manure and green manure composted with beet vinasse on soil restoration: Effects on soil properties. Bioresource Technology 99 (11): 4949-4957.

Tabatabai MA (1982). Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties. Madison, WI, USA: American Society of Agronomy.

Udo EJ, Ibia TO, Ogunwale JO, Ano AO, Esu I (2009). Manual of Soil, Plant and Water Analysis. Lagos, Nigeria: Sibon Books Limited, p. 183.

Uyanöz R, Çetin Ü, Karaarslan E (2004). Effect of different organic materials on mineral composition of wheat plant. Selcuk Journal of Agriculture and Food Sciences 18 (34): 20-27.

Wang QK, Wang SL, Liu YX (2008). Responses to N and P fertilization in a young *Eucalyptus dunnii* plantation: Microbial properties, enzyme activities and dissolved organic matter. Applied Soil Ecology 40 (3): 484-490. https://doi.org/10.1016/j.apsoil.2008.07.003