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Phosphatase enzyme activity in different soils formed on bazaltic parent material under semi humid climate conditions

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Abstract

Soil enzymes have an important role in determining the function of microorganism in soil ecosystem. In addition, the enzyme activities give much knowledge on the biochemical processes occurring in soil. Therefore, soil enzymes such as dehydrogenase, phosphatase and urease are indicators of soil biological productivity and activity. This study was carried out to determine phosphatase activity in different land use of Bafra-Engiz Basin, Samsun and to investigate the relations between soil pedogenetic processes, land use, elevation and phosphatase activities. For this purpose, soil samples taken from the four soil profiles classified as Typic Haplustert and Lithic Ustorthent. The analysis results related to phosphatase activity of soils in the study area changed between 8.1-177.3 µg p-nitrophenol. Moreover, according to statistical analysis results different profiles and different elevation were found to be important at 1% level of effect on phosphatase enzyme activity in the soils. Finally, it was also determined that the effect of different land use type on the activity of phosphatase enzyme activity in the soil was insignificant as statistically.

Keywords: Phosphatase enzyme activity, Soil development, Soil classification

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Introduction

Soil is a dynamic environment that differs in both time and space and contains many living species. These living species in the soil play an important role in bringing the vitamins and hormones that promote plant growth by storing plant nutrients dissolved in water. Soil microorganisms and some other macroscopic organisms increase soil fertility so they provide vegetation enhancement especially in natural ecosystems. These living species which help to form the soil by separating rocks and minerals are influential in the formation and development processes of the soils with the parent material, topography, climate and time factors. For this reason, microorganisms have significant functions on soil fertility and quality.

Microbial activity is also important in bio-chemical soil processes as well as it is also associated with the presence of soil enzymes (Kiss et al., 1975; Nakas et al., 1987; Martens et al., 1992; Elliott et al., 1993). Soil enzymes are related with other biological properties of soil and play a vital role in mineralization processes (Frankberger and Dick, 1983; Tate, 1987). In addition to that, enzymes such as urease, phosphatase and β-glycosidase are involved in the mineralization of organic matter in the soil and have also more effect for soil fertility (Burns, 1978). Some researcher indicated that many factors such as organic matter and agricultural practices influence the present populations of microorganisms in the soil (Coxson and Parkinson, 1987; Kowalenko et al., 1978). Thus, determination for amounts of these existing microorganisms in the soil can also reflect the activity of microorganisms with enzymes such as CO_2 production and dehydrogenase activity, together with different counting techniques (Nannipieri et al., 1990).

One of the most important indicators for soil development is structural growing (strong granular or block structure in surface and in subsurface horizons) stem from aggregate formation and aggregate size fractions. Dengiz et al. (2013) carried out an investigation to determine changes in microbial response in natural soil aggregates for soil characterization in different fluvial land shapes. The majority soils of in their study area were classified as Typic Ustifluvent and Typic Haplustept in Soil Taxonomy. Results of this study showed that the aggregate size distribution and some microbial properties and activities in aggregates varied significantly in different developed soil types formed on different fluvial landscape positions. Especially macroaggregates (diameter >250 μm) found high content in Typic Haplustept are important for soil porosity, microbial habitats and their activities and soil development. The main effects of the macroaggregates on the microbial response may be increasing by the accumulation and decomposition of organic matter. Consequently, researches indicated that this study evidenced contrasting microbial habitats in different soil aggregate sizes formed in various developed soils.

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In this present study, it was aimed to determine some physical and chemical properties with phosphatase enzyme activity of the soils developed on the bazaltic parent material in semi-humid temperate climatic conditions and to determine the relationships between phosphatase enzyme activity and different elevations and different land uses in the Engiz Basin located at Bafra district of Samsun province. Thus, it was planned that the effects of these parameters discussed on the formation and development processes of the soil in the study area.

Materials and Methods

General Description of Study Area

This study was carried out in Samsun-Bafra delta plain and its near district. The Bafra Plain found in the Kızılırmak Delta and located in the Central Black Sea Region of Turkey (Figure 1). The study area is far 30 km from west of the Samsun province and coordinated as 4554000-4558000 N and 751000-758000E UTM (37 Zone m). It covers about 1762 ha and its lies at an elevation from sea level between 10 and 300 m.

According to Soil Taxonomy (1999), the study site has mesic soil temperature regime and ustic moisture regime. Major physiographic units of the study area are four landscape features (foot slope, back slope, lowland plateau and shoulder) representing changes in geomorphology, topographic gradient, parent material and soil characteristics. The underlying bedrock consists primarily of Quaternary-age basaltic, colluvial deposits on the foot slope, lowland plateau, and Mesozoic-age basalt and marl-limestone on the back slope and highland plateau. The study area is covered mostly by forest and pasture land. A minority of the study area consists of a slightly sloped (0.0 to 2.0%) low plateau, while other sections are hilly and moderately to severely slope (3 to 20%). Only a small part of the foot slope and lowland plateau is agricultural land.

The Engiz Stream plays a major role in the formation and development of the study area's landscape. In the soils formed on the basalt material considered, there are pasture and dry farming areas, and although there are very few forest areas formed of oaks. The main herbaceous families that are common in pasture areas are; *Cruciferae, Gramineae, Umbelliferae, Compositae, Fabaceae and Rosaceae'*dır. In addition, in areas where dry agriculture is carried out, generally wheat agriculture has been cultivated.

The current climate in the region is semi-humid. The summers are warmer than winters (the average temperature in July is 22.2 and in January is 6.9 °C). The coldest month of the year is February in the study area (5.6 ºC). Average temperatures in four months of the year (December, January, February, and March) are below 10 °C but after April average temperatures raise. The mean annual temperature, rainfall and evaporation are 13.6◦C, 764.3 mm and 726.7 mm, respectively. When the distribution of rainfall according to the season is examined, it is seen that the most rainfall is in the autumn season and the least rainfall is in the summer season. According to this, it is possible to say that the rainfall is distributed all the year though it is not very regular.

Method

In this study based on the hypothesis that topography, parent material and vegetation cover might be the main controlling factors for biological activity in soil development, soils have been studied along a transverse section (diagonally in the southwestern to northwestern direction) using four representative profiles (Figure 2). The morphological features of these four profiles from the field were identified and sampled by genetic horizons and classified in accordance with Soil Survey Staff (1993, 1999). Twelve disturbed and undisturbed the samples of soil were taken to the laboratory to search for their physical, chemical features. The soil samples were first air-dried and then passed through a 2 mm sieve to be ready for laboratory analysis.

Four profiles were opened on the Southwest-Northeast transect section and from the horizons of each profile disturbed and undisturbed soil samples were made according to the horizon basis (Figure 2).

Physical and Chemical Analyses

Texture by hydrometer method (Bouyoucos 1951), pH and electrical conductivity (EC) in 1:1 (w/v) in soil: water suspension by pH-meter and EC-meter (Soil Survey Staff 1992), $CaCO_3$ by Scheibler calcimetric method (Soil Survey Staff 1992), total nitrogen by Kjeldahl method (Bremner and Mulvaney 1982), available P by 0.5 M $NaHCO_3$ extraction method (Olsen 1954), exchangeable cations (Na, K, Ca and Mg) by 1 N NH_4OAc extraction method, cation exchange capacity (CEC) by Soil Survey Staff (1992), soil organic matter by a modified Walkley-Black method (Jackson, 1958).

Phosphatase Enzyme Activity

Alkaline phosphatase activity (APA) was determined according to Tabatabai and Bremner (1969). 4 ml phosphate buffer (pH 11.0) and 1 ml of 0.025 M p-nitrophenyl phosphate (disodium salt hexahydrate) solution were added to the 1 g sample and the samples were incubated for 1 h at 37 ºC. The formation of p-nitrophenol was determined spectrophotometrically at 410 nm and results were expressed as µg p-nitrophenol g^{-1} dry soil h^{-1}. The results of alkaline phosphatase enzyme activity reported with the mean value of three replicates determinations calculated on an oven-dry basis; moisture was determined from loss in weight after drying the soil at 105 ºC for 24 h.

Statistical Analyses

SPSS 17.0 package program was used to determine the relationships between phosphatase enzyme activity and different profiles, land use and height in the soil samples of the study area.

Results and Discussions

Physical, Chemical Properties and Classification of Soils

Four profiles opened on southwest-northeast (SW-NE) section and soil samples were taken from the horizons belonging to each profile according to the horizon basis. Some physico-chemical analyses results of the profiles located on SW-NE transect are given in Table 1 and Table 2. In addition the majority soils of the study area were classified as Typic Ustifluvent and Typic Haplustept in Soil Taxonomy (1999).

The profile coded as PIV and classified as Typic Haplusert formed on the footslope position and has deep soil. All profile has clay texture and clay content of the profile varies between %56.2 and %78.4. This case directly affects the saturation of soils so, especially the increase in the amount of clay along with soil depth it also increases the saturation conditions of the soil. The cation exchange capacity (CEC) is 42.8 cmol(c). kg^{-1} due to the amount

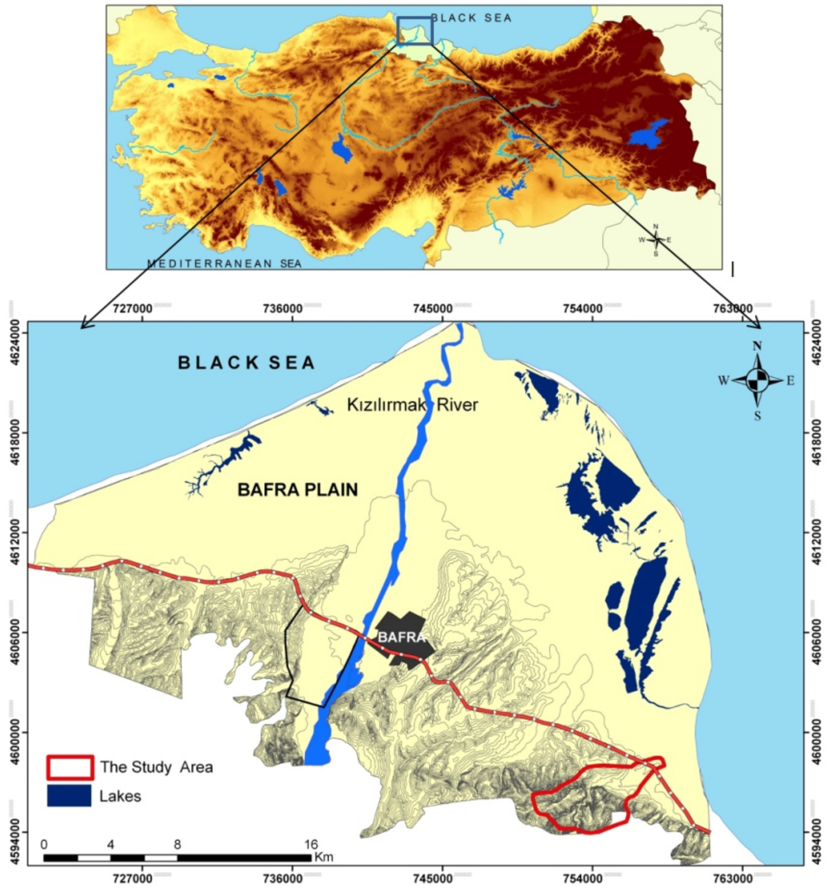

Figure 1. Location of the study area

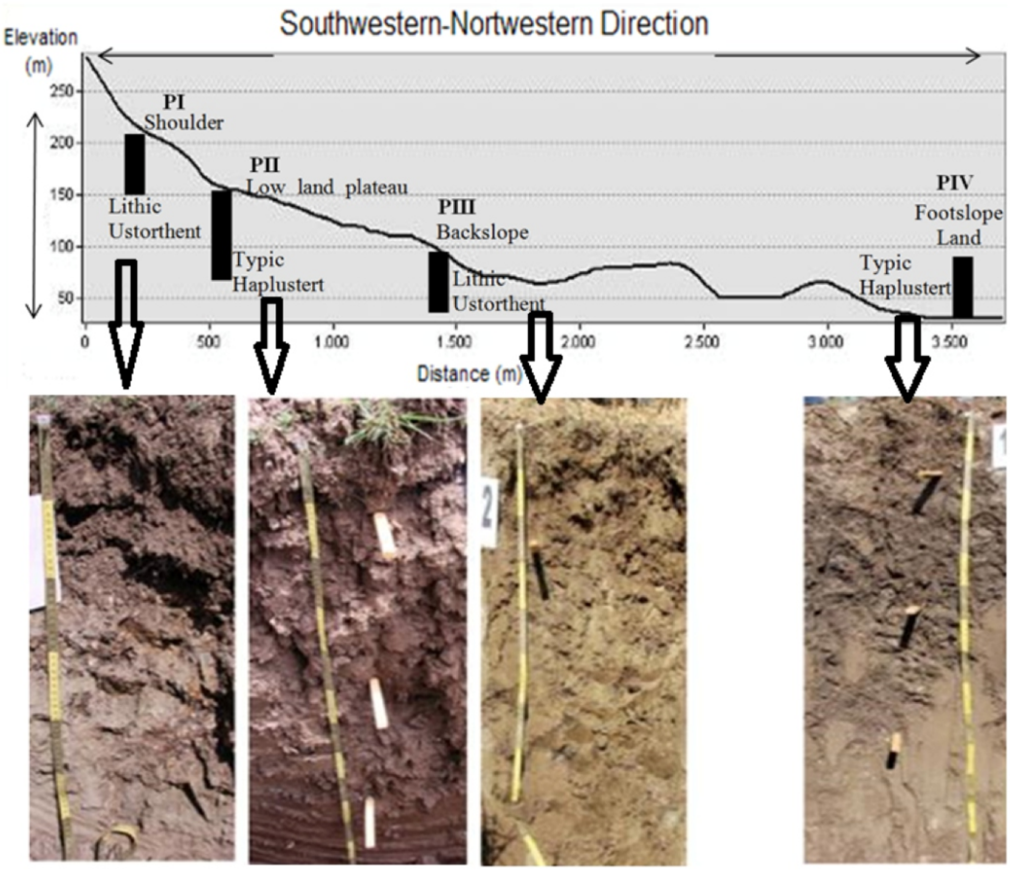

Figure 2. Transect of the four different soil profiles on basalt parent material but different topographical positions

of clay content and organic matter on the surface whereas, this amount shows reducing with the soil depth due to decreasing of organic matter content. In addition, organic matter content is 1.65% on the surface on the other hand, it falls dramaticly to 0.14% after 65 cm depth. The soil reaction of profile PIV has slightly alkaline and pH values range between 7.50 and 8.25. The amount of lime ($CaCO_3$) content was found low level in all the profile and changes between 0.20% and 2.67% from surface to depth because of leaching process. The dominant exchangeable cations of profile PIV are Ca and Mg ions in soils. Also, there is no salinity and alkalinity problem for this profile.

Lithic Ustortent showen as PIII symbols located on back slope position and slightly steep slope (12-20%). This profile has shallow depth. Generally the around fields of this profile have been used as degradated forest land due to deforestation activity. This situation leads to the transport of the soil from upland to low land due to unsuitable tillage practices. Profile PIII has low pedogenic process so, this soil can be defined as young soil and has Ap/Cr horizon order. While the surface horizon includes clay loam texture, subsurface layer (Cr) which is the parent material and mostly affected under parent rock alteration has sandy loam. It can also be said that although the CEC is 42.9 cmol(c). kg^{-1} due to the amount of clay content and organic matter on the surface it falls to 15.4 cmol(c). kg^{-1} after 24 cm depth. This situation shows parallel with the amount of organic matter and it was found 2.35% on the surface but it falls to 0.55% in the subsurface layer. The amount of lime was detected too low in the profile. On the other hand, due to dominant basic cations resulted from alteration and weathering of basaltic rock, soil reaction is also slightly alkaline and pH values range between 7.87 and 8.04. The dominant exchangeable cations are Ca and Mg ions in soils. Moreover, there is also no salinity and alkalinity problem for this profile.

The profile number PII classified as Typic Hapustert formed on lowland platue and has slightly slope (2-6%). The soils in these fields, which usually contain pasture covers, are depth and this profile showed similarity with PIV has heavy texture in all depth. Clay content varies between 40.3% and 68.5% in the profile. As in the profil coded as PIV, this case directly influences also the saturation increasing with clay content in soil depth. The bulk density values were the lowest in the surface or close to the surface horizons, and they increased progressively with depth. Similar results were reported by Göl and Dengiz (2008). Lower bulk density values were related to organic matter and clay content, especially at the surface horizon. The CEC values varied and could be correlated to clay and organic matter content, with maximum values of 42.80 cmol(c). kg^{-1}, in the surface soils of all profiles, and minimum values of 11.09 cmol(c). kg^{-1} in the subsurface horizons (C or Cr).Organic matter content was detected 1.71% in the surface soil but it decersed to 0.59% after 48 cm depth. The soil reaction slightly alkaline and pH values range between 7.05 and 7.96. The amount of lime is too low in the profile. Besides, while the lime content is 0.79% in the surface layer, this ratio became 1.37% with increasing depth due to leaching and calcification processes. As the other all profiles, the dominant exchangeable cations are Ca and Mg ions in for PII. It can be also said that there is no salinity and alkalinity problem in the soils.

Profile located on the highest posion (at 185 m from sea level) of southwest-northeast section, was coded as PI. In this profile the soils have steep slope and the surface covered by very weak intensity vegetation so, soil has been excessively exposed to erosion process caused very shallow depth. Sommer et al. (2008) reported that in general, some parts of the landscape will erode faster than others depending on the local geomorphic situation and spatially varying soil erodibility. Other parts, which are not affected by soil erosion/sedimentation, e.g., flat plateaus, are characterized by further progressive soil development. Therefore, slope has been regarded as one of the most important factor that controls the pedogenic process on PI, and PIII. Depth of the PI and PIII' soils decreases with increasing slope degree. The clay content (34.4%) was higher in the A horizon whereas, sand content was found about 75% in subsurface layer in this profile. Ovalles and Collins (1986) reported that physical soil properties such as the distribution of clay content with depth, sand content and pH were highly correlated to landscape position. This profile has lower pH values, being located on the upper slope positions that promote basic cation leaching, whereas other profiles were neutral to basic soil reaction pH values. In addition, $CaCO_3$ contents ranged from 0.20% to 2.67% even the development of all these profiles on basaltic parent material which doesn't produce carbonate. It can be said that this case resulted from carbonate contamination. Similar to our findings, Aksoy (1991) found a lime content of 2% to 26% in soils on the Kayacik plains in Gaziantep, although the primary material in the area of their study was basalt.

The profile PIII and PI have shallow soil depth that can not have enough pedogenetic process. Because, these soils are located on high slope position and they are not covered with enough vegetation. It is well known that Slope brings greater runoff, as well as to greater translocation of surface materials down-slope through surface erosion and soil movement. Therefore, they have been exposed to erosion due to unsuitable tillage practices. These soils do not usually have endopedon except for an ochric epipedone on the surface. There is no horizon except for lithic contact in the depth of 50 cm subsurface. The horizon orders of the PI and PIII profiles were defined as A-Cr horizons. The soils are classified in the orthent sub ordo due to their location on the slope land and also these soils are classified under the ustorthent and Lithic Ustorthent sub ordo due to the humidity regime. According to the FAO/WRB (2014) classification system, these profiles were classified as Eutric Regosol.

As for PIV and PII profiles have very large amounts of swelling clays (50% and more along with the profile), as indicated by surface cracks ranging from 1 to 5 cm in width, as well as intersecting slickensides and shiny pressure faces in the subsurface horizon (Bss) This also reflects a shrinking and swelling of the soil. Accordingly, profiles PII and PIV were classified as Typic Haplustert. These profiles were also classified as Haplic Vertisol by taking the FAO/WRB (2014) classification system into consideration.

Phosphatase Enzyme Activity of Soils

Surface and subsurface soil samples were taken from four profiles to determine the phosphatase enzyme activity of the soils. For this purpose, the phosphatase enzyme activity has been carried out 3 repeatedly and the results of this analysis are given in Table 3.

Most of the chemical events that take place in the soil are the result of activities of microorganisms living in the soil. Microorganisms decompose high polymer compounds such as cellulose, lignin, phosphate esters, protein, carbohydrate,

Table 1. Some soil chemical analysis results of profiles classified according to Soil Taxonomy (1999) and FAO-WRB (2014)

Horizon	Depth (cm)	pH	EC ($dS.m^{-1}$)	$CaCO_3$ (%)	O.M (%)	Exchangeable Cations ($cmol.kg^{-1}$)			CEC ($cmol.kg^{-1}$)
						Na^+	K^+	$Ca^{++}+Mg^{++}$	
PIV / Typic Haplustert- Haplic Vertisol / Foot slope / Dry Farming / 25 m									
Ap	0-23	7.50	0.17	0.20	1.65	0.22	1.67	40.91	42.8
Bss1	23-65	7.30	0.44	0.98	1.26	0.25	1.47	39.64	41.4
Bss2	65-106	8.25	0.17	1.10	1.09	1.33	1.41	37.59	40.3
C	106 +	8.14	0.11	2.67	0.14	1.35	1.40	36.04	39.9
PIII/ Lithic Ustorthent- Eutric Regosol / Back slope / Degradated Forest / 42 m									
Ap	0-24	7.87	0.55	0.49	2.35	0.41	0.28	42.24	42.9
Cr	24+	8.04	0.10	0.29	0.55	1.03	0.15	14.20	15.4
PII / Typic Haplustert- Haplic Vertisol / Lowland platue / Pasture /132 m									
A	0-12	7,05	0.16	0.79	1.71	0.35	0.24	40.17	40.8
Bss1	12-48	7.72	0.19	0.29	1.69	0.74	0.31	48.07	49.1
Bss2	48-89	7.79	0.34	1.37	0.59	1.31	0.41	47.25	48.9
C	89+	7.96	0.30	1.18	0.17	1.26	0.24	32.84	34.4
PI / Lithic Ustorthent- Eutric Regosol / Shoulder / Pasture / 185 m									
A	0-16	7.03	0.19	0.50	2.25	0.28	1.02	33.16	34.5
Cr	16+	6.93	0.25	0.20	0.42	0.45	1.24	9.39	11.1

pH: Soil Reaction EC: Electrical Conductivity, OM: Organic matter, C: Clay, Si: Silt, S: Sand

Table 2. Some soil physical analysis results of profiles classified according to Soil Taxonomy (1999)

Horizon	Depth (cm)	Texture (%)				BD ($g\ cm^{-3}$)	Saturation (%)
		Clay	Silt	Sand	Class		
PIV / Typic Haplustert- Haplic Vertisol / Foot slope / Dry Farming / 25 m							
Ap	0-23	56.2	23.1	20.7	C	1.45	74.1
Bss1	23-65	62.6	12.8	24.5	C	1.57	82.3
Bss2	65-106	68.4	15.8	15.8	C	1.45	85.0
C	106 +	78.4	2.8	18.8	C	-	93.6
PIII/ Lithic Ustorthent- Eutric Regosol / Back slope / Degradated Forest / 42 m							
Ap	0-24	32.1	27.9	40.1	CL	1.41	48.8
Cr	24+	17.2	17.1	65.7	SL	-	25.4
PII / Typic Haplustert- Haplic Vertisol / Lowland platue / Pasture /132 m							
A	0-12	41.5	24.2	34.3	C	1.48	82.5
Bss1	12-48	68.5	18.3	13.2	C	1.50	106.1
Bss2	48-89	49.8	26.4	23.9	C	1.53	89.3
C	89+	40.3	34.2	25.5	C	-	79.0
PI / Lithic Ustorthent- Eutric Regosol / Shoulder / Pasture / 185 m							
A	0-16	34.4	25.5	40.1	CL	1.53	50.4
Cr	16+	17.1	8.4	74.5	SL	-	28.1

Table 3. Concentrations of the phosphatase enzyme activity in surface and subsurface horizons of profile

Horizon	Depth (cm)	Phosphatase Activity ((p-NF) g^{-1})
PIV / Typic Haplustert- Haplic Vertisol / Foot slope / Dry Farming / 25 m		
Ap	0-23	144.6
Bss1	23-65	177.3
PIII/ Lithic Ustorthent- Eutric Regosol / Back slope / Degradated Forest / 42 m		
Ap	0-24	67.7
Cr	24-74	81
PII / Typic Haplustert- Haplic Vertisol / Lowland platue / Pasture /132 m		
A	0-12	154.9
Bss1	12-48	134.4
PI / Lithic Ustorthent- Eutric Regosol / Shoulder / Pasture / 185 m		
A	0-16	145.2
Cr	16+	5.2

starch in organic wastes by releasing ecto-enzymes at the end of the series of biochemical reactions. In addition to microorganisms, higher plants also benefit from nutrient ions that come from high polymer compounds due to the effects of enzymatic reactions in the soil. In addition, microbial population and its activity have not only a essential role on bio-geo-chemical cycles of element in a soil profile but also have a significant task for the weathering processes or soil aggregation by providing organic ligands and acids, and by supplying increased CO_2 concentrations in the soil (Drever and Vance 1994). In this study, it has been determined that the phosphatase enzyme activity of the soil samples taken from the profiles found on (SW-NE) transect was changed between 8.1-177.3 µg p-nitrophenol. When the results of the analysis were evaluated, the activity of phosphatase enzyme in soil samples was determined generally higher level in the surface soils than subsurface soils (except for Bss of PIV). Dengiz et al (2013) reported that one of the most effective factors is organic carbon on microbial population and their activities to get their energy and nutrient elements. This case was also supported by Nyamadzawo et al. (2009) and Christensen and Sorensen (1985). They indicated that various soil textural fractions influence microbial growth and substrate utilization in soils. In this case, particularly clay types and their specific surface area' size have a fundamental role because sand fractions have smaller surface area, thus they can only support a smaller microbial population. Clay fractions have a larger surface area and are among the most important constituents influencing microbial population and their activities. In this study, when compared Typic Haplustert and Lithic Ustorthent, it can be detected that Lithic Ustorthent has lower phosphatase enzyme activity than Lithic Ustorthent due to its low organic matter, insufficient nutrient element concentration, low clay and high sand content.

Relationship of Phosphatase Enzyme Activity with Land Use Types and Elevation of Soils

The results of phosphatase enzyme activity were evaluated statistically in three different ways which are i-) relationship between the profiles and phosphatase enzyme activity, ii-) relationship between the land use and phosphatase enzyme activity and iii-) relationship between the elevation and position of profile and phosphatase enzyme activity.

In first case (relation between phosphatase enzyme activity and profiles), the statistical results for the changes in phosphatase enzyme activities of soils on the southwest-northeast section are presented in Table 4. According to the results of ANOVA test, it was found that different profiles along the Southwest-Northeast line are important at 1% level of the effect on phosphatase enzyme activity (P=0.000<0.01). According to the DUNCAN test, it was determined that the highest phosphatase enzyme activity along the Southwest-Northeast line was in the PIV, PI and PII profiles, respectively. Also, the lowest phosphatase enzyme activity was found in the PIII profile.

Statistical results for the relationship between land use types and phosphatase enzyme activity in the Southwest-Northeast section are also given in Table 4. It was found the different values of phosphatase enzyme activity in soils under various land use types after analysis. On the other hand, it was deceted that there was statistically insignificant difference between the land use pattern and the phosphatase enzyme activity in the soil.

As for relation the phosphatase enzyme activit and elevation and land position of profiles, according statistical results for changes in between phosphatase enzyme activity and different altitude of profiles were found to be important at 1% level of the effect on the phosphatase enzyme activity in the soil (P=0.000<0.01). It was determined that the maximum phosphatase enzyme activity was 25 m, 185 m and 132 m altitude, and the lowest phosphatase enzyme activity was found at 42 m altitude and back slope position. Accordingly, it can be said that the enzyme activity decreases as the height increases. In this case, it can be said that phosphatase enzyme activity is decreasing with increasing altitude but this case is not lineer relation between them.

Conclusion

In this current study the properties of various developed four soils profiles formed on topographically different positions of SE-NE direction were investigated. The investigation considered the phosphatase enzyme activity in Typic Haplustert and Lthic Ustorthent soils represented by four profiles formed on basaltic parent material in order to understand its relationship with these soils, landscape, land use, land position and elevation

As a result of this research, some physical and chemical properties and phosphatase enzyme activity of the soils formed on the basaltic parent material in semi humid temperate climatic conditions were determined in the Engiz Basin in Bafra district of Samsun province. In addition to that, the relationships between different altitude-slope positions and different land use types with phosphatase enzyme activity were investigated.

Table 4. Relationship between phosphatase enzyme activity and profiles, land use types and elevation-land positions

Profiles	**Mean + Standard Error**
PIV / Typic Haplustert- Haplic Vertisol	160.9±8.8a
PIII/ Lithic Ustorthent- Eutric Regosol	37.9±13.3b
PII / Typic Haplustert- Haplic Vertisol	144.6±5.4a
PI / Lithic Ustorthent- Eutric Regosol	145.2±2.8a
Land Use Types	**Mean + Standard Error**
Acricultural land	144.8+3.6
Pasture	99.4±20.1
Degradated Forest	110.0±15.8
Elevation (m) and Land Positions	**Mean + Standard Error**
25 m and Foot slope	160.9±8.8a
42 m and Back slope	37.9±13.3b
132 m and Lowland platue	144.6.6±5.4a
185 m and Shoulder	145.2±2.8a

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