INDICATOR EFFECT OF SOIL ENZYMES
IN TERMS OF PLANT DISTRIBUTION

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SUMMARY

To find dissimilarities in different geographical regions, key parameters underlying any possible separation are needed. Generally, soil factors affect plant growth and plant type. The question of which soil predictive parameters affect the vegetation pattern in each ecological unit should be answered. For this reason, a study was designed to explain variations in the composition of vegetation by soil variation and to understand most effective soil characteristics on the structure and composition of the vegetation. Therefore, this study was conducted to determine whether plant distribution could be monitored through the most effective soil parameters. For this aim, plants with diverse growth pattern and life-span (herbaceous, shrub and tree) were collected from two unlike geographical regions of Turkey. Soil samples were also collected from the rhizosphere of each plant sampled and then they were analyzed for soil physical and chemical properties and soil biological properties (soil enzyme activities). The enzymes (β-glucosidase, urease, phosphomonoesterases, and arylsulphatase) that are responsible for C, N, P and S cycles were chosen. Almost all enzyme activities (except urease) are significantly correlated with each other (P<0.01 or P<0.05).

Principal component analysis of soil properties and soil enzyme activities indicated that there were differences in the plant distribution parameters for different geographical regions. However, soil enzyme activities illustrated a better display for reflecting ecological variation. The results suggest that plant distribution in both geographical zones is not a random case; plant distribution is strongly related to soil factors and that especially soil enzyme activities provide a better explanation. Hence, plant distribution and soil enzyme activity were affected by abiotic environment and soil enzyme activity could be a good indicator for reflecting plant distribution in dissimilar ecologies.

KEYWORDS:
soil enzyme activities, PCA, plant distribution, plant ecology.

INTRODUCTION

Soil quality necessitates the following functions: crop production, filtration and degradation [1]. The most vital function is degradation that “defines the ability of a soil to mineralize soil organic matter and degrade exogenous plant material and anthropogenic inputs such as organic wastes, pesticides, hydrocarbon etc.”[2]. Degradation function largely depends on soil biochemical properties [3].

Plants need nutrients to survive and require nutrient cycling in soil which involves physical, chemical and biochemical reactions [4]. In fact, soil is a complex system that requires chemical, physical and biochemical factors held in dynamic equilibrium [5]. All biochemical reactions are catalyzed by enzymes and are mediated by microorganisms, plant roots and soil animals [4]. For that reason, the chemical properties of soils show variations in different regions.

General and specific biochemical parameters of soils can be used as sensitive indicators to reflect disturbance of the environment [1]. General biochemical parameters are related to the number and activity of soil microorganisms while specific biochemical parameters include the activities of extracellular hydrolytic enzymes [1]. Hydrolytic extracellular soil enzymes have a significant impact on nutrients since enzymes convert nutrients from unavailable to readily available forms for plants and microorganisms [6]. To determine natural and anthropogenic disturbances and to monitor changes in soil quality, soil enzyme activities can be used as an indicator due to their relationship to soil biology, ease of measurement, and rapid response to changes in soil management [4, 7, 8].

There are many studies focusing on the effects of changing farming practices (e.g. tillage), field management, pollution, afforestation, cropping systems on soil quality [9-17]. The sum of these studies especially use soil enzymes as a biological indicator. However, there is still more research needed to identify enzyme activities to use them as indicators of changes in plant pattern over different ecological regions.
Greig-Smith [18] indicated that “ecology and plant geography are largely concerned with the causes of patterns of distributions, patterns of all scales from those of individuals within a small area to those of vegetation types or taxa over the surface of the world. Patterns of distribution differ not only in scale, but also intensity, the degree of difference between different parts of the area under consideration.” We hypothesized that enzyme activities of soils reflect discrimination of plant distribution in different ecosystems.

Our objectives were: (1) to determine how plants affect soil enzyme activities (soil specific biochemical parameter) and soil properties in different ecological regions and (2) to relate soil-specific biochemical parameter and soil properties to site and vegetation pattern. Different techniques are necessary to distinguish the ecological regions from each other.

MATERIAL AND METHODS

Study area

Two different regions, Tokat (north-eastern Turkey) and Kocaeli (north-western Turkey), were chosen as experimental areas for the determination of the effects of soil enzymes on plant distribution. Samples were taken at two sites located in Tokat (40°19’N; 36°43’E and 530 m altitude) and Kocaeli-Kartepe (40°46’N; 29°55’E and 500 m altitude). The locations (Tokat and Kocaeli) have a long term precipitation average of 451.12 and 826.4 mm year⁻¹ and a mean annual temperature of 12.3 and 14.8 °C, respectively (Fig.1). Tokat’s climate represents a transition between the Central Black Sea and the Inner Anatolia climates. Similarly, the climate of Kocaeli reflects a transition between the Mediterranean Sea and the Black Sea climates. Tokat has a semi-arid climate whereas Kocaeli has a temperate climate.

The soils in Tokat and Kocaeli were different on the basis of some physical, chemical and microbiological soil properties. Tokat soils were superior for the levels of CaCO₃, clay, silt, pH and available phosphorus whereas Kocaeli soils had higher levels of organic matter, EC, sand, total nitrogen, organic carbon, C:N ratio and all studied enzyme activities (Table 1).

Soil sampling and soil analyses

Plants having different growth pattern and plant type (tree, shrub and herbaceous) were collected and identified. Their common English names and scientific names are given in Table 2. Soil samples were taken from plant rhizosphere in 0-20 cm soil depth.

Soil samples for enzyme analysis were placed into plastic bags, transported to the laboratory in a cooler with cold packs, and then stored at 5 °C until analysis. Soil samples used for physical and chemical analysis were air dried, ground to 2 mm, placed in plastic bags and securely stored.

Enzyme activity analyses were replicated three times and average values were used. β-glucosidase activity (EC 3.2.1.2.) was determined as described by Naseby and Lynch [19]. To determine β-glucosidase activity, 1.5 g soil sample was extracted with acetate buffer solution (sodium acetate
buffer, 0.5 M), the solution shaken for one hour in carou-
sel rotor were centrifuged for 15 minutes in 4000 rev min⁻¹. Then, p-nitrophenyl β-D-glucopyranoside was added to ex-
traction solution as a substrate and β-glucosidase activity was determined colorimetrically (at 400 nm). Alkaline and acid phosphomonoesterases activities (EC.3.1.3.2.) were
determined as described by Naseby and Lynch [19]. The method was similar to β-glucosidase; however, substrate was p-nitrophenyl phosphate, and soil samples were extract-
ed with alkaline buffer solution (sodium orthophosphate buffer, 0.2M) for alkaline phosphomonoesterase activity and with acid tampon solution (sodium acetate buffer, 0.5 M) for acid phosphomonoesterase activity. Arylsulphatase activity (EC.3.1.6.1) was also determined as described for
β-glucosidase activity, except that the substrate was p-nitrophenyl sulphate, and soil samples was extracted with alkal-
ine buffer solution (sodium orthophosphate buffer, 0.2M) as described by Naseby and Lynch [19]. Arylsulphatase, β-glucosidase, alkaline and acid phosphatase activities are expressed in mg p-nitrophenyl phosphate g⁻¹ h⁻¹.

Urease activity was determined with urea as substrate incubating at pH 9.0 (THAM buffer, 0.05 M) for 2 h at
37°C and determining released NH₄⁺ by steam distillation as described by Tabatabai and Bremner [20]. Urease activity is expressed in mg NH₄⁺ kg⁻¹ 2h⁻¹.

Soil organic matter [21], CaCO₃ % [22], texture [23], total N [24], available P [25], pH and EC [26] were also measured in soil samples.

### Statistical analysis

Principal component analysis (PCA) was used to ana-
yze the soil enzymes using the SPSS statistical program
[27]. To determine the best descriptive soil indicators in
variation of plants in different regions, two separate and independent PCA analyses (soil enzyme activities and soil properties in both sites) were run.

### RESULTS

#### Enzymatic activities

**Effect of Plant Type**

Arylsulphatase activities in soils with different plant
types in Tokat and Kocaeli are shown in Figure 2A. The
highest arylsulphatase activities were in soils with shrub fol-
lowed by woody and herbaceous plants at all studied sites.

Mean alkaline phosphatase activities in soils are speci-
fied for two different regions and different forms of plants. Alkaline phosphatase activities were the highest in soils with herbaceous plants and the lowest with woody plants in
Tokat region. The order of alkaline phosphatase activities
were shrub>woody>hebaceous plants in Kocaeli (Fig. 2 B).

The values of acid phosphatase activity in soils her-
baceous plants were two to three times lower than the values of alkaline phosphatase activity at both sites. The values of acid phosphatase activity in soils with shrub plants
FIGURE 2 - Enzyme activities of different forms of plants in studied sites.
(A) Arylsulphatase, (B) Alkaline phosphatase, (C) Acid phosphatase, (D) \(\beta\)-Glucosidase, (E) Urease activities
(AS, ALP, ACP, BG are expressed in mg p-nitrophenyl phosphate g\(^{-1}\) h\(^{-1}\) and UR is expressed mg NH\(_4\)\(^+\) kg\(^{-1}\) 2h\(^{-1}\).)

were lower than the alkaline phosphatase activities in both sites. In soils with woody plants, the values of acid phosphatase activity were two times lower than alkaline phosphatase activities in all regions (Fig. 2C). The highest acid phosphatase activities were in soil with shrub followed by herbaceous and woody plants in all studied sites.

Soil \(\beta\)-glucosidase activities showed a different order in the ecological regions. The order of soil \(\beta\)-glucosidase activities in Tokat was shrub > woody > herbaceous plants whereas the order of soil \(\beta\)-glucosidase activities in Kocaeli was herbaceous > shrub > woody plants (Fig. 2D).

As can be seen in Figure 2E, urease activities were the highest in soils with herbaceous and shrub plants in Tokat and Kocaeli, respectively. The lowest urease activities were determined in soils with woody and herbaceous plants in Tokat and Kocaeli, respectively.

Site effects

The two experimental sites are located in different parts of Turkey. One is in the north-eastern (Tokat) and the other is in the north-western part (Kocaeli) of Turkey. This geological discrimination also includes climate, soil,
pedology and vegetation (Figure 1 and Table 1). In other words, these two regions are completely dissimilar in terms of their ecology. Soil enzyme activities in these different ecologies were shown in the Figure 3. From the figure, it can be seen that these regions have their own enzyme activity pattern. Kocaeli with temperate climate has higher enzyme activity levels than the semi-arid Tokat and this difference was observed for all plant types from herbaceous to tree. However, in Kocaeli (temperate climate), alkaline and acid phosphatase activities were in the premier levels compared to the other enzymes.

![Figure 3](image)

**FIGURE 3** - Enzyme activities of studied sites in different forms of plants. (A) herbaceous (B) shrub (C) tree (AS, ALP, ACP, BG are expressed in mg p-nitrophenyl phosphate g⁻¹ h⁻¹ and UR is expressed mg NH₄⁺ kg⁻¹ 2h⁻¹).

### Correlations between soil enzyme activities

Correlations among different soil enzymes were sought by jointly considering the data from Tokat and Kocaeli regions (Table 3). Almost all activities (except urease) reported in this paper significantly correlated with each other (P<0.01 or P<0.05). Arylsulfatase activity was strongly correlated with alkaline phosphatase (0.81, P=0.01), acid phosphatase (0.85, P<0.01), and β-glucosidase (0.63, P<0.01) activity. Alkaline phosphatase activity was significantly correlated with arylsulphatase (0.81, P<0.01), acid phosphatase (0.88, P<0.01), and β-glucosidase (0.44, P<0.05) activity. Acid phosphatase activity was strongly correlated with arylsulphatase (0.85, P<0.01), alkaline phosphatase (0.88, P<0.01), and β-glucosidase (0.52, P<0.05) activity. β-glucosidase activity was significantly correlated with arylsulphatase (0.63, P<0.01), alkaline phosphatase (0.44, P<0.05), and acid phosphatase (0.52, P<0.01) activity. However, there was no significant relationship observed between urease and the other measured enzyme activities.

### Principal Component Analysis

Principle component analysis (PCA) was done to interpret differences between the both regions for soil enzyme activities. PCA indicated that these two different ecological sites were separated from each other based on either soil enzyme activities or soil properties. PCA is a multivariate statistical method designed to decrease a great amount of components for the idea of representing complex relations among the original variables in a two-three-dimensional space [28].

### Soil Enzyme Activities

In terms of soil enzyme activities, PCA presented that the first three components accounted for 62.86 %, 19.58 % and 12.58 % of variance correspondingly. The cumulative variance of the first three components was 95.03 % (Table 4). The first component was connected with arylsulphatase, acid and alkaline phosphatase activities with positive eigenvectors. Also, there was no negative eigenvector in the first component. The second component was linked with mainly urease and partially β-glucosidase activities with positive eigenvectors. The second component’s negative eigenvectors consisted of primarily acid phosphatase and additionally arylsulphatase and alkaline phosphatase activities. Figure 4A shows the first two components score sampling area where plants are sampled. Tokat and Kocaeli (sampling regions) were located in two separated groups in scatter diagrams obtained from the first two component scores of soil enzyme activities. Based on soil enzyme activities, plants were distributed by sampling region either Tokat or Kocaeli. A highly distinct separation for samples from Tokat can be seen, contrary to samples from Kocaeli. On the diagram, it can be seen that samples from Tokat were located in below zero levels of PC2 score; in contrast, samples taking from Kocaeli were clustered above zero levels of PC2 score. In addition, samples from Kocaeli were divided into two groups. This separation could be explained by samples collecting from different altitudes.
and variability between plants for growth preference. Some samples (KH3, KH4, KS1, and KH2) were taken from higher altitudes and some of them (KT2, KT1, KS2 and KH1) were taken from lower altitudes. Even though KS1 and KH2 were collected from higher altitudes they clustered with samples from lower altitude. Therefore, formation of two sub-groups in Kocaeli samples might also be explained by plants’ growth preference particularly based on soil factors.

### TABLE 3 - Pearson coefficients of pairwise correlation among enzymatic activities and soil properties (the analysis pools results from both studied sites).

<table>
<thead>
<tr>
<th></th>
<th>AS</th>
<th>ALP</th>
<th>ACP</th>
<th>BG</th>
<th>UR</th>
<th>AP</th>
<th>TN</th>
<th>OC</th>
<th>CN</th>
<th>PH</th>
<th>CAC</th>
<th>CL</th>
<th>SL</th>
<th>SD</th>
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</thead>
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<td>AS</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.86**</td>
<td></td>
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<td>ALP</td>
<td>0.85**</td>
<td>0.88**</td>
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<td>0.86**</td>
<td>0.86**</td>
<td>0.49**</td>
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<td>ACP</td>
<td></td>
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<td>0.85**</td>
<td>0.88**</td>
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<td>0.86**</td>
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<td>BG</td>
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<td>0.63**</td>
<td>0.44*</td>
<td>0.52**</td>
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<tr>
<td>AP</td>
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<td>0.48**</td>
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<tr>
<td>TN</td>
<td>0.82**</td>
<td>0.87**</td>
<td>0.83**</td>
<td>0.48**</td>
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<td>0.76**</td>
<td>0.90**</td>
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<tr>
<td>OC</td>
<td>0.82**</td>
<td>0.86**</td>
<td>0.86**</td>
<td>0.49**</td>
<td>0.93**</td>
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<td>CN</td>
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<td></td>
<td>0.73**</td>
<td>0.70**</td>
<td>0.42**</td>
<td>0.74**</td>
<td>0.90**</td>
<td>0.73**</td>
<td>0.67**</td>
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<td>PH</td>
<td>0.78**</td>
<td>0.83**</td>
<td>0.82**</td>
<td>0.44**</td>
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<td>0.47**</td>
<td>0.77**</td>
<td>0.83**</td>
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<td>CAC</td>
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<td>0.76**</td>
<td>0.77**</td>
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<tr>
<td>CL</td>
<td>0.51**</td>
<td>0.69**</td>
<td>0.71**</td>
<td>0.55**</td>
<td>0.84**</td>
<td>0.75**</td>
<td>0.74**</td>
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<tr>
<td>SL</td>
<td>0.63**</td>
<td>0.83**</td>
<td>0.78**</td>
<td>0.84**</td>
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<tr>
<td>SD</td>
<td>0.63**</td>
<td>0.74**</td>
<td>0.64**</td>
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<tr>
<td>EC</td>
<td>0.63**</td>
<td>0.74**</td>
<td>0.64**</td>
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</tbody>
</table>

**AS** (arylsulphatase), **ALP** (alkaline phosphatase), **ACP** (acid phosphatase), **BG** (β-glucosidase), **UR** (urease), **AP** (available **P**), **TN** (total **N**), **OC** (organic **C**), **CN** (C/N rate), **PH** (pH), **CAC** (CaCO3), **CL** (clay), **SL** (silt), **SD** (sand), **EC** (EC)

### FIGURE 4 - Score plots for PC1 and PC2 resulted from PCA analysis of (A) soil enzymes (AS, ALP, ACP, BG and UR) and (B) soil properties (AP, TN, OM, OC, CN, PH, CAC, CL, SL, SD and EC)

### TABLE 4 - Soil enzyme activities scored and eigenvectors of the first three principal components for 26 plants in two sites.

<table>
<thead>
<tr>
<th>Character</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>SD</th>
<th>Principal Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arylsulphatase</td>
<td>0.127</td>
<td>3.19</td>
<td>1.06</td>
<td>0.99</td>
<td>0.943 -0.083 0.04</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>0.451</td>
<td>19.93</td>
<td>5.31</td>
<td>5.67</td>
<td>0.909 -0.032 -0.326</td>
</tr>
<tr>
<td>Acid phosphatase</td>
<td>0.225</td>
<td>11.28</td>
<td>3.24</td>
<td>3.99</td>
<td>0.933 -0.160 -0.195</td>
</tr>
<tr>
<td>β-glucosidase</td>
<td>0.150</td>
<td>3.29</td>
<td>1.25</td>
<td>0.83</td>
<td>0.712 0.058 0.691</td>
</tr>
<tr>
<td>Urease</td>
<td>28.35</td>
<td>475.25</td>
<td>223.10</td>
<td>130.93</td>
<td>0.222 0.971 -0.084</td>
</tr>
<tr>
<td>Eigen value</td>
<td>3.143</td>
<td>0.979</td>
<td>0.629</td>
<td></td>
<td>62.86 19.58 12.58</td>
</tr>
<tr>
<td>% variation</td>
<td>62.86</td>
<td>82.45</td>
<td>95.03</td>
<td></td>
<td>62.86 19.58 12.58</td>
</tr>
</tbody>
</table>
Soil Properties

PCA indicated that the first three components accounted for 66.19 %, 9.45 % and 8.25 % of variance, respectively, based on soil properties. For the first three components, the cumulative variance was 83.9 % (Table 5). The first component was related to organic matter, total nitrogen and sand content with positive eigenvectors. The first component’s negative eigenvectors included pH levels, CaCO₃ and clay content. The second component linked with silt, CaCO₃, organic matter and total nitrogen content with positive eigenvectors. The negative eigenvectors of the second components were mainly sand content and additionally pH levels. In Figure 4B, it can be seen that the first two components score where plants are divided into two ecological groups as observed in enzyme activity PCA result (Tokat and Kocaeli). However, big variation occurred in both regions.

**DISCUSSION AND CONCLUSIONS**

Enzymes in this study were chosen because of their role in the nutrient cycle. Urease (EC 3.5.1.5) is an important enzyme involved in N cycle as it catalyses the breakdown of urea to ammonia, which can be assimilated by microbes and plants. Urease acts in the hydrolysis of organic to inorganic nitrogen, the farmer using urea-type substrates. Phosphatases enzymes (EC 3.1.3.2) catalyze the hydrolysis of a variety of organic phosphomonoesters and are therefore important in soil organic P mineralization and plant nutrition. β-glucosidase (EC 3.2.1.21) was selected because it catalyzes the hydrolysis of cellobiose, and thus, plays a major role in the initial phases of the decomposition of organic C compounds. Arylsulphatase (EC 3.1.6.1) is believed to be partly responsible for S cycling in soils as it participates in the processes whereby organic sulfate esters are mineralized and made available for plants. We assumed that C, N, P and S cycles and their enzymes would be good determinants for different regions.

β-glucosidase and urease enzymes linked with C and N cycles, correspondingly [29]. In our study, β-glucosidase activity increased with increasing organic carbon (OC) level and C/N ratio (correlated positively with OC and TN, P< 0.01). Urease activity rise with increasing total nitrogen (TN), and C/N ratio (correlated positively with TN and C/N ratio P<0.01). However, Aon and Colaneri [29] found a dissimilar relationship between urease activity and C/N ratio (negatively correlated with OC and positively correlated with TN). Some researchers found that urease activity was not significantly related with soil organic carbon [5, 11, 30]. Our results were also in agreement with these reports. Phosphatases are involved in the mineralization of organic phosphorus to inorganic forms [31]. Acid and alkaline phosphatase activities were negatively correlated with available phosphorus levels (r =-0.5, P<0.01, r =-0.39, P< 0.05, respectively) in this present study. In addition, all enzyme activities were correlated with soil properties (P< 0.05 or P<0.01). Enzyme activities (except urease) were negatively correlated with pH and the highest correlation belonged to acid phosphatase activity (r =-0.92, P<0.01). Arylsulphatase and acid and alkaline phosphatase activity were negatively correlated with soil CaCO₃ levels (P< 0.01).

Vegetation is influenced by several factors such as climate and soil factors. Thus, different parameters are needed and understood for the purpose of monitoring variability of vegetation. In this study, the most effective soil parameters on plant distribution were investigated to distinguish regional variations. In order to find the most effective soil factor on the distribution of vegetation types, principal component analysis was used. We hypothesized that soil enzyme activities would be better determinants than soil properties for reflecting regional variations.

Rhizosphere is a special place in which microorganisms accumulate because of root exudates. In general, plants release 10-20% of their photosynthates as root exudates [32]. Root exudates can be used as substrates for microbial activity and this excretion enhances quantity of microorganisms in the rhizosphere [34]. Populating microorganisms in rhizosphere depend on plant type and age and soil type [34]. Every plant type has its own rhizosphere structure [35] and in that unique soil enzyme activities due to root and micro-

**TABLE 5 - Soil properties scored and eigenvectors of the first three principal components for 26 plants in two sites.**

<table>
<thead>
<tr>
<th>Character</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>SD</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
</tr>
</thead>
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<tr>
<td>CaCO₃ (%)</td>
<td>1.28</td>
<td>48.8</td>
<td>14.12</td>
<td>11.01</td>
<td>-0.822</td>
<td>0.390</td>
<td>-0.209</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>0.43</td>
<td>11.04</td>
<td>3.84</td>
<td>3.25</td>
<td>0.939</td>
<td>0.311</td>
<td>0.065</td>
</tr>
<tr>
<td>pH</td>
<td>5.85</td>
<td>8.07</td>
<td>7.40</td>
<td>0.74</td>
<td>-0.885</td>
<td>-0.051</td>
<td>0.178</td>
</tr>
<tr>
<td>EC (µS cm⁻¹)</td>
<td>118</td>
<td>501</td>
<td>208.46</td>
<td>81.79</td>
<td>0.713</td>
<td>0.171</td>
<td>-0.055</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>5.2</td>
<td>48</td>
<td>27.22</td>
<td>13.33</td>
<td>-0.793</td>
<td>0.241</td>
<td>-0.010</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>15</td>
<td>66</td>
<td>36.82</td>
<td>14.10</td>
<td>-0.685</td>
<td>0.476</td>
<td>0.087</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>0.72</td>
<td>74.8</td>
<td>35.95</td>
<td>22.76</td>
<td>0.889</td>
<td>-0.436</td>
<td>0.060</td>
</tr>
<tr>
<td>Available P (µg g⁻¹)</td>
<td>11.42</td>
<td>83.54</td>
<td>28.28</td>
<td>14.44</td>
<td>-0.414</td>
<td>0.086</td>
<td>0.081</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.08</td>
<td>0.45</td>
<td>0.22</td>
<td>0.11</td>
<td>0.887</td>
<td>0.249</td>
<td>0.072</td>
</tr>
<tr>
<td>Organic C (%)</td>
<td>0.24</td>
<td>6.4</td>
<td>2.22</td>
<td>1.88</td>
<td>0.939</td>
<td>0.312</td>
<td>0.065</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>3</td>
<td>15.6</td>
<td>8.73</td>
<td>3.38</td>
<td>0.840</td>
<td>0.342</td>
<td>0.103</td>
</tr>
<tr>
<td>Eigen value</td>
<td>7.28</td>
<td>1.04</td>
<td>1.04</td>
<td>0.908</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>% variation</td>
<td>66.19</td>
<td>9.45</td>
<td>8.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative variation</td>
<td>66.19</td>
<td>75.65</td>
<td>83.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
bial activities [36]. Garcia et al. [34] found that enzyme activities were affected by the rhizosphere of six different plant species and enzyme activity levels were varied by studied shrub species. They also found that not all plant types influenced enzyme activities in the same way. In this study, there was not a clear relationship between plants having different growth pattern and life-span (herbaceous, shrub and tree) and enzyme activities. Different kinds of plants (herbaceous, shrub and tree) showed different order of enzyme activities, based on studied enzyme types and selected regions. However, there was a distinct relationship between regions and enzyme activities.

Our results also indicated that the soil enzyme activities would be a good predictor for finding plant distribution in nature instead of using soil properties. Many studies covering separation of the vegetation types focused on the relationships between soil properties and plant types. Jafari et al. [37] reported that soil properties, especially, soil salinity and texture were the two major features that cause separation of the type of plants. Many works carried out by different researchers found that distribution of plants was a function of soil salinity [38-44]. However, there is still more research required to assess whether plant distribution could be operated through specific biochemical parameters (i.e. hydrolytic enzymes) on ecologically separated-regions.

Principle component analysis of soil enzymes and soil properties indicated that there were differences both in soil enzymes and soil properties among the samples and that the samples tended to group based on sample locations which were Tokat and Kocaeli (Fig. 4 and 5). The data presented in this paper indicated that soil enzyme activity (specific biochemical properties) can be useful tool as indicator of plant distributions and is indicator of ecosystem functioning. PCA showed that two ecologies were separated from each other in terms of both their soil enzyme activities and soil properties. On the other hand, soil enzyme activities showed a better demonstration for reflecting ecological variation.

These results suggest that plant distribution in nature is not a random case; plant distribution is robustly connected with soil factors (soil enzyme activities and soil properties). Hence, plant distribution was influenced by abiotic environment and soil enzyme activity may possibly be a good indicator for reflecting plant distribution, vegetation pattern and abundance of populations due to discrimination of ecologies.

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REFERENCES


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