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Certain soil characteristics and light conditions of enzyme activities and variance conditional to plant type

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Abstract Soil is one of the most important factors in plant cultivation, and its content affects plant growth significantly. However, soil composition and characteristics vary depending on the environmental conditions in the area where the soil is located. In this study, urease and catalase enzyme activities in plant soils grown under different shade conditions were examined. The *Prunus cerasifera*, *Tilia tomentosa*, *Gleditsia triacanthos*, *Euonymus japonica*, and *Betula pendula* species were grown in five different light conditions during one vegetation period, and the urease and catalase enzyme activities and Ph, EC (mS.cm^{-1}), $CaCO_3$ (%), OM (%), P (ppm), and K (ppm) changes were examined within the scope of the study. As a result, it was found that characteristics other than Ph, which was the subject of the study, changed to a great extent depending on the plant species and light conditions; however, in the areas where different plant species were grown, the soil characters changed at different levels depending on the light. As a result of the study, the highest values in many characteristics were obtained under 45% and 65% light conditions.

Keywords *Betula pendula* · Environmental conditions · *Euonymus japonica* · *Gleditsia triacanthos* · *Prunus cerasifera* · Soil composition · Shade conditions · *Tilia tomentosa*

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Introduction

Plants are the most important group of living species in the world; they are vital for many other living species and are considered the source of life. In fact, all life on earth is largely dependent on plants, either directly or indirectly (Nowak et al. 2005; Kaya 2009; Cetin 2013; Cetin 2015a,b,c,d; Kaya et al. 2009; Cetin and Sevik 2016; Cetin 2016a,b; Cetin 2017; Yigit et al. 2018; Bozdogan Sert et al. 2019; Cetin et al. 2019; Kaya et al. 2019). The importance of plants stems from their photosynthesis ability, that is, to convert sunlight into food. Therefore, life on earth depends on photosynthesis Kacar et al. 2002; Yigit et al. 2018; Cetin et al. 2019; Cetin 2019; Kaya et al. 2019).

Roughly speaking, photosynthesis is the conversion of light energy into nutrients with the help of chlorophyll. Photosynthesis occurs under the influence of environmental factors and allows the plant to grow. Essentially, the interaction of edaphic, climatic, and biotic environments, which are necessary for the development of the plant, is the factor determining the growth rate of the plant (Nowak et al. 2005; Kaya 2009; Cetin 2015a,b,c,d; Cetin 2017; Cetin et al. 2018a, b; Sevik et al. 2019a; Bozdogan Sert et al. 2019; Cetin et al. 2019; Cetin 2019; Kaya et al. 2019; Adiguzel et al. 2020; Sevik et al. 2020a,b).

Among these factors, the edaphic factors, i.e., the soil and its components, are of particular importance. Soils contain a wide range of microbial fauna and many inorganic components that are the building blocks of plants. The microbial fauna plays a vital role in the nutrient cycle in nature (Arcak et al. 1994).

Enzymes released as a result of the activity of microbial fauna are protein molecules that catalyze biochemical reactions in cells. Since the early 1950s, studies of enzyme activity, which is the main research topic in the field of soil microbiology and biochemistry, have attracted great interest (Skujins 1978).

The measurement of soil enzymatic activities is widely used to evaluate soil fertility in terms of the ease of applicability and reliability when compared to other microbiological techniques (Kravkaz Kuscu 2014; Kravkaz Kuscu et al. 2018a, b; Kravkaz Kuscu 2019). The majority of studies on soil enzymes accept that the biological properties of the soil can be isolated by determining the activities of certain enzymes occurring at high levels in the soil. In this study, the determination of how the enzyme activities and some soil characteristics change under different shade conditions in different plants was attempted.

Material and method

The aim of this study was to determine the enzymatic activities of the soil and the change of some nutrients depending on the different shade conditions and plant species. For this purpose, in order to create different shade conditions, first, a greenhouse skeleton was constructed, and then, parcels were created in this area. The following parcels and the following conditions were created:

a) Open area (100% light)
b) 35% canopy (shady spot) (65% light)
c) 55% canopy (shady spot) (45% light)
d) 75% canopy (shady spot) (25% light)
e) 95% shade covered (5% light)

The plants were placed in the parcels so that the light filtering through the shade could reach the plants in the parcels from sunrise to sunset. Thus, all the plants were exposed to the same amount of shade during the day.

In this study, the plants were used in a tubed form, each experiment was carried out with five replications, and 25 plants from each species were placed in each parcel. *Prunus cerasifera*, *Tilia tomentosa*, *Gleditsia triacanthos*, *Euonymus japonica*, and *Betula pendula* were used in the study.

Soil Analysis was that the soil reaction was determined with a pH metered glass electrode (Jackson, 1967) and electrical conductivity (EC) in a 1/2.5 soil water mixture with an EC-meter (Jackson, 1962) and calcium carbonate (CaCO3) as described by Kacar (1995). The organic matter was determined according to the Walkley-Black incineration method with Scheibler calcimetry as reported by Jackson (1958).

Plant useful phosphorus (P) as reported by Olsen et al. (1954) was extracted into the solution with 0.5 N NaHCO3 (pH, 8.5) in the ICP-OES (inductively coupled plasma-optical emission) of Perkin Elmer. (K) as reported by Pratt (1965) soil samples were extracted with 1.0 N neutral (pH, 7.0) ammonium acetate (CH3COONH4), and the potassium in the filtrate (K) Perkin Elmer Optima 2100 DV model was measured by ICP-OES (inductively coupled plasma-optical emission).

Enzyme Activities in the Soils are the urease enzyme activity–urease enzyme used as a substrate urea hydrolyses of ammonia and carbon dioxide over a period of time to separate and, thus, formed and dissolved in the soil solution based on the principle of spectrophotometric reading as reported by Hoffmann and Teicher (1961)– was determined according to Beck (1971), which is based on a gasometrical measurement of the amount of oxygen resulting from the separation of hydrogen peroxide.

Results

Within the scope of the study, the *F* value, error rate, mean values, and the groupings formed by the Duncan test obtained as a result of variance analysis carried out for the purpose of the determination of the plant species on the soil characteristics are given in Table 1.

As a result of the study, it was determined that the pH, which is one of the soil characteristics of the study, did not change statistically at a confidence level of at least 95% depending on plant type, and all the other soil characteristics were statistically different at a 99.9% confidence level. When Table 1 is examined, it is noteworthy that *Tilia tomentosa* is in the first homogeneous groups in terms of urease, catalase, EC, OM, and P, whereas *Prunus cerasifera* is in the last homogeneous groups in terms of the catalase, urease, EC, CaCO3, and OM. Within the scope of the study, the *F* value, error rate, mean values, and groupings formed by the Duncan test obtained as a result of a variance analysis carried out

Table 1 Variation of soil characteristics by plant species

Type	Catalase	Urease	pH	EC (mS.cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
Prunus cerasifera	11.54 b	0.069 b	7.37	0.955 cd	11.66 d	6.16 d	38.41 b	115.55 b
Tilia tomentosa	3.79 a	0.043 a	7.67	0.598 a	10.39 c	2.05 a	18.15 a	177.24c
Gleditsia triacanthos	12.55 b	0.060 b	7.41	0.870 c	4.11 a	2.63 b	12.98 a	234.95 e
Euonymus japonica	22.50 c	0.061 b	7.01	0.997 d	4.58 a	3.75 c	143.51 d	211.83 d
Betula pendula	13.19 b	0.070 b	7.12	0.751 b	8.11 b	2.96 b	66.93 c	93.38 a
F value	21.302	9.678	1.018	18.995	101.12	86.640	163.048	66.881
Significant	0.000	0.000	0.404	0.000	0.000	0.000	0.000	0.000

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

for the purpose of determining the effect of the light amount on soil characteristics are given in Table 2.

As can be seen in Table 2, the amount of light caused a statistically significant change at a 95% confidence level only on the urease among the subject characteristics. However, the response of plants to the amount of light may vary by the species. Therefore, the soil characteristics of each species were evaluated separately depending on the amount of light in the soil, and the changes in the soil characteristics of *Prunus cerasifera* depending on the amount of light and variance and values obtained as a result of Duncan analysis are given in Table 3.

In *Prunus cerasifera*, the amount of light had a statistically significant effect on all the characteristics except in the pH, EC, and CaCO3 with a confidence level of at least 95%. When the values were examined, it was seen that all the characteristics changed with the amount of light; when this change was evaluated as a percentage, the highest change was in the amount of catalase which was 2.11 in the open area, which increased to approximately eight times that of the open area in 45% and 65% light conditions. Table 4 shows the variance and the values obtained from the Duncan analysis with the change of the soil characteristics depending on the amount of light in *Tilia tomentosa*.

In *Tilia tomentosa*, it was determined that the pH and K concentrations did not differ significantly from the soil characteristics at least at a 95% confidence level depending on the amount of light. When the average values and the groupings formed by the Duncan test were examined, it was seen that the urease amount increased significantly with the amount of light. Among the other characteristics, the catalase, EC, OM, and *P* values under 65% light conditions were in the last homogeneous groups according to the Duncan test results. Table 5 shows the values obtained as a result of the variance and Duncan analysis by changing the soil characters in *Gleditsia triacanthos* depending on the amount of light.

In *Gleditsia triacanthos*, it was determined that the amount of light was not only effective on the pH, but

Table 2 Variation of soil characters depending on the amount of light

Light (%)	Catalase	Urease	pH	EC (mS·cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	12.58	0.054 a	7.35	0.831	7.96	3.21	53.64	155.94
25	12.31	0.066 b	7.37	0.834	8.14	3.38	49.81	179.26
45	17.41	0.053 a	7.31	0.860	7.73	3.81	59.45	168.46
65	12.17	0.062 ab	7.31	0.857	7.49	3.76	51.66	172.55
100	9.34	0.068 b	7.37	0.803	7.67	3.45	66.40	159.69
F val.	2.039	3.198	.014	0.186	0.084	0.372	0.256	0.340
Sig.	.098	0.018	1.000	0.945	0.987	0.828	0.905	0.850

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Table 3 Variation of soil characters depending on the amount of light on *Prunus cerasifera*

Light (%)	Catalase	Urease	pH	EC (mS·cm̄ 1)	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	14.09 c	0.057 a	7.42	0.993	11.77	5.73 a	36.97 ab	117.09 b
25	7.94 b	0.090 c	7.42	0.940	12.07	5.83 a	37.66 ab	141.71 c
45	16.74 d	0.055 a	7.33	0.972	11.19	6.84 b	41.44 bc	114.61 b
65	16.81 e	0.069 b	7.37	0.912	12.51	5.77 a	33.46 a	106.04 ab
100	2.11 a	0.076 b	7.30	0.959	10.75	6.61 b	42.52 c	98.30a
F	162.697	19.978	0.035	0.688	2.375	4.829	5.908	13.092
Sig	0.000	0.000	0.997	0.611	0.099	0.011	0.005	0.000

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

statistically significant at at least a 95% confidence level. When the mean values and the Duncan test groupings were examined, it was noteworthy that the values obtained under 45% light conditions, except OM, are in the first or last homogeneous groups. While the highest urease activity was obtained in the open field and the lowest urease activity was obtained under 45% light conditions, the opposite activity in the catalase enzyme activity was obtained in the open field and the highest activity under 45% light conditions. Table 6 shows the values obtained as a result of the variance and Duncan analysis by changing the soil characteristics depending on the amount of light in *Euonymus japonica*.

In *Euonymus japonica*, it was determined that the pH and K concentrations did not differ significantly from the soil characteristics at at least a 95% confidence level depending on the amount of light. When the average values and groupings formed by the Duncan test were examined, it was noteworthy that the values obtained in the characteristics other than $CaCO_3$ were in the last homogeneous groups. Table 7 shows the values obtained as a result of the variance and the Duncan analyses by changing the soil characteristics depending on the amount of light in *Betula pendula*.

In *Betula pendula*, the pH, EC, and $CaCO_3$ concentrations did not differ significantly from the soil characteristics at at least a 95% confidence level depending on the amount of light. When the average values and the groupings formed as a result of the Duncan test were examined, it was seen that the highest urease activity was obtained at 65%, and the highest catalase activity was obtained under open field conditions. It can be said that catalase activity generally increases depending on the amount of light. Correlation analysis was applied to the data in order to determine the relationship levels of the soil characteristics to each other, and the results are given in Table 8.

When Table 8 was examined, it could be seen that the relationship between the amount of light and any other characteristic was not statistically significant. This can be explained by the fact that the variation of light and soil characters on the basis of species is different. When the other characters were examined, it was seen that catalase was statistically significant with all the characteristics except light and pH and has a positive

Table 4 Variation of soil characters depending on the amount of light in *Tilia tomentosa*

Light (%)	Catalase	Urease	pH	EC (mS·cm̄ 1)	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	4.01 b	0.034 a	7.72	0.549 a	10.98 b	1.44 a	15.74 a	181.16
25	4.09 b	0.039 ab	7.71	0.520 a	10.83 b	1.94 b	16.96 ab	174.56
45	1.85 a	0.040 ab	7.72	0.630 b	11.13 b	2.10 b	19.66 c	181.90
65	7.24 c	0.044 b	7.45	0.763 c	8.34 a	2.62 c	18.99 bc	182.64
100	1.77 a	0.056 c	7.74	0.528 a	10.69 b	2.17 b	19.39 c	165.93
F	178.281	18.502	171	18.635	8.140	27.638	5.849	1.057
Sig	0.000	0.000	0.950	0.000	0.001	0.000	0.005	0.411

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Table 5 Variation of soil characteristics depending on light amount in *Gleditsia triacanthos*

Light (%)	Catalase	Urease	pH	EC (mS·cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	14.99 c	0.055 b	7.35	0.859 b	4.38 b	2.21 a	13.58 bc	204.62 a
25	17.50 d	0.069 c	7.38	0.916 b	4.38 b	2.34 a	13.44 b	260.98 b
45	19.39 e	0.044 a	7.31	1.062 c	3.50 a	2.67 b	15.07 c	243.22 b
65	8.71 b	0.055 b	7.37	0.872 b	3.94 ab	3.52 c	12.09 ab	264.43 b
100	2.16 a	0.075 c	7.63	0.639 a	4.38 b	2.41 ab	10.73 a	201.53 a
F	167.073	17.104	0.195	19.021	5.839	25.668	10.407	10.785
Sig	0.000	0.000	0.937	0.000	0.005	0.000	0.000	0.000

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

relationship with the characteristics other than $CaCO_3$. Urease has a statistically significant and positive relationship with the pH, catalase, EC, and OM. While most of the other characteristics were found to have significant relationships with each other, the strongest relationship was found between the catalase and P (0.666).

Discussions

At the end of the study, changes in the catalase, urease, pH, EC, lime, OM, P, and K were determined according to the plant species and shading. The results of the study show that the characteristics other than the pH of the study subject generally varied due to the shading on the basis of plant species, but the variation in each plant species was different. For example, the highest catalase activity was determined in the open field in *Betula pendula*, while the lowest catalase activity was found in the open field in *Gleditsia triacanthos*. Similar results were obtained in other studies (Kravkaz Kuscu 2014; Kravkaz Kuscu et al. 2018a, b; Kravkaz Kuscu 2019).

The growth performance of plants, i.e., phenotypic properties, is the result of the interaction between genetic structure and environmental conditions (Yigit et al. 2016; Hrivnák et al. 2017), and since the genetic structure of each plant species or even individual is different, it is known that different plants can react differently to the same environmental conditions (Yucedag et al. 2019; Yigit et al. 2018). For example, the different clones of the same species were found to have different resistances to water and frost stress (Topacoglu et al. 2016; Sevik and Karaca 2016). Therefore, the components of these factors can affect the plant's growth performance, i.e., phenotypic properties.

The reactions of plants to environmental conditions are closely related to plant metabolism (Guney et al. 2016; Sevik et al. 2019b; Sevik et al. 2020a,b). Therefore, the stress level of the plant that significantly affects plant metabolism (Sevik and Cetin 2015; Turkyilmaz et al. 2019) is likely to affect the reaction level of the

Table 6 Variation of soil characteristics depending on the amount of light in *Euonymus japonica*

Light (%)	Catalase	Urease	pH	EC (mS·cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	1.800 b	0.065 b	7.02	0.979 ab	3.94 a	3.51	133.83	187.85 a
25	2.252 c	0.056 a	7.01	0.992 bc	5.40 c	4.08	140.59	216.38 b
45	3.362 d	0.057 a	7.07	0.869 a	4.38 ab	3.92	138.97	215.59 b
65	1.414 a	0.056 a	6.99	1.036 bc	4.67 b	3.51	153.58	210.08 ab
100	2.423 c	0.069 b	7.01	1.111 c	4.52 b	3.72	150.60	229.23 b
F	64.997	4.926	.012	5.275	8.768	2.939	2.195	3.358
Sig	0.000	0.010	1.000	0.007	0.001	0.056	0.119	0.038

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

Table 7 Variation of soil characters depending on the amount of light in *Betula pendula*

Light (%)	Catalase	Urease	pH	EC (mS·cm⁻¹)	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
5	11.55 b	0.065 a	7.11	0.762	8.61	3.10 c	67.14 b	86.22 ab
25	9.25 a	0.066 a	7.22	0.782	7.88	2.67 b	39.55 a	99.47 c
45	15.14 cd	0.066 a	7.00	0.758	8.32	3.44 c	81.07 c	83.98 a
65	13.74 c	0.085 b	7.22	0.682	7.88	3.32 c	39.28 a	96.54 b
100	16.28 d	0.069 a	7.03	0.772	7.88	2.29 a	107.59 d	100.66 c
F	29.175	8.900	0.138	1.811	1.132	16.719	107.950	4,.518
Sig	0.000	0.001	0.966	0.179	0.379	0.000	0.000	0.014

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

plants towards environmental conditions such as the plant origin (Sevik and Topacoglu 2015), chlorophyll amount (Sevik et al. 2012), and genetic structure (Hrivnák et al. 2017).

The different levels of development of the plant depending on environmental conditions also differentiate the potential of the plant to be affected by the surrounding conditions. For example, a fast-growing plant draws more minerals and water from the soil, and since it sweats more, it can change the surrounding humidity rate (Kacar et al. 2002). Changes in these conditions affect the soil moisture, and the moisture and shade conditions directly affect soil temperature, soil temperature microorganism activities, and the decomposition of organic matter and thus directly affect the soil characteristics. The light and soil temperature, which play an important role in the nutrient cycle, also affect the enzymatic activities in the environment, and enzymatic activities, in particular, are shaped depending on the light and soil temperature (Talgre et al. 2012). Therefore, it is expected that the soil characteristics will be at different levels under similar shade conditions in which different plants are grown. As a matter of fact, similar results were obtained in different plants grown under different shade conditions, and soil characteristics (Kravkaz Kuscu 2019), plant growth performance, and morphological characteristics (Aydemir Özcan 2017; Yılmaz 2018), and micromorphological characteristics (Kapucu, 2016) have been shown to have a significant impact.

There are many studies on the effect of plant species and shadow conditions on soil characteristics. Liu et al. (2002), in a study carried out in Taiwan, showed how a corn rice rotation system was applied in different ecosystems in the soil enzyme activity and observed changes in some soil quality parameters. Ghee et al. (2013) stated that the soil respiration and organic matter mineralization were temperature sensitive and had a positive relationship with the increase in the soil temperature (Ghee et al. 2013).

As a result of this study, it is seen that the highest values in many soil characteristics, especially enzyme

Table 8 Showing correlation analysis results

	Catalase	Urease	pH	EC (mS·cm⁻¹)	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
LIGHT	−0.139	0.228*	−0.002	−0.035	−0.049	0.062	0.085	−0.010
KATALAZ	1	0.236*	0.020	0.626**	−0.394**	0.258*	0.666**	0.272*
UREAZ	0.236*	1	0.414**	0.494**	0.147	0.499**	0.211	−0.083
PH	0.020	0.414**	1	0.389**	0.416**	0.221	−0.063	0.369**
EC	0.626**	0.494**	0.389**	1	−0.121	0.638**	0.474**	0.362**
KIREC	−0.394**	0.147	0.416**	−0.121	1	0.417**	−0.309**	−0.490**
OM	0.258*	0.499**	0.221	0.638**	0.417**	1	0.193	−0.225
Pppm	0.666**	0.211	−0.063	0.474**	−0.309**	0.193	1	0.102

*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level activities, are obtained under 45% and 65% light conditions. This can be interpreted as the result of the mutual relationship between the light and moisture because the stated light conditions create enough shade to reduce the loss of moisture in the soil, and light conditions allow the sun's rays to increase the temperature of the soil. The research on plants shows that the light and water parameters are the most important parameters affecting plant growth (Kacar et al. 2002; Kapucu 2016; Yılmaz 2018).

Conclusions

As a result of the study, it was determined that the soil characteristics were shaped significantly according to the shade conditions but that this change was different in each plant species. In this case, it was seen that the soil characteristics change significantly both in different shade conditions where the same plant is grown and in different plants grown under the same shade conditions. According to these results, the soil characteristics and especially the enzyme activities, which are an indicator of soil fertility, can be used to determine the most suitable plant species to be grown under each shade condition.

Soil characteristics are shaped by the interaction of many factors and directly and indirectly affect plant growth performance. Therefore, this mechanism must be fully resolved in order to use soils effectively. For this reason, to increase and diversify the studies focused on the subject is recommended.

Compliance with ethical standards

Informed consent Informed consent was obtained from all the individual participants in the study.

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