Environ Monit Assess (2019) 191: 178
https://doi.org/10.1007/s10661-019-7304-8

Changing of soil properties and urease–catalase enzyme activity depending on plant type and shading

Inci Sevinc Kravkaz Kuscu

Received: 15 November 2018 / Accepted: 7 February 2019 / Published online: 22 February 2019

Abstract Changes in urease and catalase enzyme activities were investigated in the soils of plants grown under different shade conditions to reveal how the shade conditions and sapling species affect the urease and catalase enzyme activities in the soil. In this study, four different plant species were grown under five different shade conditions during one vegetation period, and soil analyses were performed to investigate the change in urease and catalase enzyme activities. As a result, it was determined that, of the soil characteristics considered, urease, EC, lime, OM, P, and K differed significantly according to the plant species, while catalase, urease, EC, and OM differed significantly according to the amount of light. In addition, it was found that soil characteristics showed different levels of variation depending on the light in the areas where different plant species were grown. The amount of light was linearly correlated with EC and with OM, while catalase and urease were in a linear relationship with each other. EC was statistically significantly correlated with all the characteristics except urease; this relationship was negative with light, P, and K. The strongest relationship was between lime (CaOH) and OM.

Keywords Soil properties · Urease · Catalase · Shade conditions

I. S. K. Kuscu (✉)
Faculty of Forestry, Department of Forest Engineering, Kastamonu University, Kuzeykent, 37150 Kastamonu, Turkey
e-mail: ikravkaz@kastamonu.edu.tr

Introduction

Soils contain a large number of microbial flora that decompose organic matter with a wide range of characteristics. Many different types of microorganisms are sequentially involved in the decomposition of the various substrates contained in organic matter. These release different types of extracellular enzymes, which vary depending on the substrate type, in order to achieve the biochemical decomposition function. Thus, they play a vital role in the nutrient cycle in nature (Arcak et al. 1994). Enzymes are molecules in the protein structure that catalyze biochemical reactions in cells. Those that have very important metabolic functions in cells have entered into daily and economic life and are used for various purposes (Wiseman 1987). Studies on enzyme activity have been of great interest for many years, and in the early 1950s, a major development took place in soil microbiology and biochemistry fields (Skujins 1978).

Enzymes play a vital role in the cycle of carbon, nitrogen, sulfur, and other nutrients in the soil ecosystem (Tabatabai and Dick 2002; Caldwell 2005). The cycle of the organic matter in soil is controlled by the activity and size of the microbial mass, and biological and biochemical parameters play an important role in the ecological formation of soil (Roldan et al. 2003). Soil temperature significantly influences the nutrient cycle, the soil-water balance, the thermophysical properties of the soil, and the vegetation time of plants (Wang et al. 2006; Guntinas et al. 2012; Krzysztof et al. 2014; Schütt et al. 2014; Guo et al. 2014). Soil temperature also affects microorganism activities, the decomposition of organic matter, and the growth and yield of plants. Light and soil temperature, which play important roles in the nutrient cycle, also affect the enzyme activities in the soil in the environment where the plant is grown, and enzymatic activities are themselves influenced by the light and soil temperature (Talgre et al. 2012).

Soil microorganisms are an important component of soil quality (Hackl et al. 2004) and play a vital role in fertility through decomposition and the nutrient cycle (Kızılkaya and Hepşen 2004). It is important to consider biological issues when evaluating functions related to fertility and soil conservation in complex soil systems.

The measurement of soil enzymatic activities has been widely used in order to obtain more reliable results in the evaluation of soil fertility and is more easily applicable than other microbiological techniques (Ünal 1967). Most studies on soil enzymes accept that the biological properties of the soil can also be determined by examining the activity of certain enzymes found in high amounts in soil. The present study attempted to determine how enzyme activities in and some characteristics of the soils where different plants were grown varied under different shade conditions.

Material and methods

The study aimed to identify enzymatic activities and nutrient levels under different shade conditions and in the soils of different plants. Accordingly, a greenhouse framework containing three different parcels was created, and these parcels were covered with:

a) 0% shade, i.e., 100% light
b) 35% shade, i.e., 65% light
c) 55% shade, i.e., 45% light
d) 75% shade, i.e., 25% light
e) 95% shade, i.e., 5% light

The plants were placed in tubular planters, and positioned so that the light passing through the shades reached them from sunrise to sunset. Thus, plants were exposed to consistent amounts of shade throughout the day.

Four different plant species—*Hibiscus syriacus*, *Cornus mas*, *Fraxinus excelsior*, and *Prunus armeniaca*—were used. Each experiment was set up with five repetitions, meaning that a total of 25 pieces of each plant were used.

Soil analyses

The soil reaction (pH) was determined using a pH meter with a glass electrode in a soil-pure water suspension with a ratio of 1/2.5, as suggested by Jackson (1967). The electrical conductivity (EC) was determined with an EC meter in a soil-water mixture with a 1/2.5 ratio, as outlined in Jackson (1962). The calcium carbonate ($CaCO_3$) level was determined as described by Kacar (1995), and the organic matter was determined according to the Walkley-Black method with a Scheibler calcimeter, as reported by Jackson (1958).

Plant-available phosphorus (P) was determined using the technique reported by Olsen et al. (1954). The amount of P passing to the solution by extraction with 0.5 N $NaHCO_3$ (pH = 8.5) was determined in a Perkin Elmer Optima 2100 DV model inductively coupled plasma-optical emission (ICP-OES) device. Exchangeable potassium (K) was determined as reported by Pratt (1965), and the soil samples were extracted with 1.0 N neutral (pH = 7.0) ammonium acetate (CH_3COONH_4). The amount of K in the filtrate was determined using the Perkin Elmer Optima 2100 DV model ICP-OES device.

Results

The F value, error rate, and mean values obtained as a result of the variance analysis performed to determine the effect of the plant species on soil characteristics, as well as the groupings formed as a result of Duncan's test, are presented in Table 1.

Of the soil characteristics subject to the study, catalase and pH did not differ significantly. This finding can be reported with a confidence level of at least 95%, depending on the plant species. A statistically significant difference was found in urease (at a 99% confidence level) and in EC, lime, OM, P, and K (at a 99.9% confidence level). Table 1 shows that the lowest amounts of urease, lime, and OM were obtained from *Cornus mas*, while the highest values K and C were obtained from *Prunus armeniaca*, the highest lime values from *Fraxinus excelsior*, and the highest OM values from *Hibiscus syriacus*. The F value, error rate, and mean values obtained as a result of the variance analysis performed to determine the effect of the amount of light on soil characteristics, as well as the groupings formed as a result of Duncan's test, are presented in Table 2.

Table 1 Change in soil characteristics by plant species

Plant species	Catalase	Urease	pH	EC (mS cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
Hibiscus syriacus	7.68	0.042b	7.60	0.571b	10.18c	3.20c	13.77a	70.00a
Cornus mas	7.44	0.034a	7.35	0.552b	2.32a	2.18a	27.08b	108.70b
Fraxinus excelsior	8.19	0.049b	7.58	0.586b	11.33d	2.84b	11.74a	114.65b
Prunus armeniaca	7.43	0.045b	7.38	0.484a	5.38b	2.80b	77.10c	167.41c
F value	1.212	6.459	1.263	9.928	333.758	25.324	89.182	133.044
Significant	0.311	0.001	0.293	0.000	0.000	0.000	0.000	0.000

The letters a, b, c, etc. indicate groupings according to Duncan's test results. These are statistically different from the values contained in different groups. The lowest numerical values are assigned to group a, and the highest to group d

As shown in Table 2, the amount of light caused a significant change only in catalase, urease, EC, and OM. This change can be determined with at least a 95% confidence level. However, the response of plants to the amount of light may vary by species. Therefore, soil characteristics in areas receiving different amounts of light were evaluated separately. The values obtained from the variance and Duncan's analyses, along with the change in soil characteristics depending on the amount of light in *Hibiscus syriacus*, are presented in Table 2.

In the case of *Hibiscus syriacus*, the amount of light had a statistically significant effect (at a 99.9% confidence level) on all characteristics except pH. When the values were examined, it was observed that the amounts of catalase, lime, P, and K increase with the amount of light. The highest values of urease were obtained in 5% and 100% light areas, while the highest values of EC were obtained in 45% and 65% light areas.

The values obtained from the variance and Duncan's analyses, as well as the changes in soil characteristics depending on the amount of light in *Cornus mas*, are presented in Table 2. Of the soil characteristics considered, it was determined that urease and EC, catalase, OM, and K all differed significantly according to the amount of light received by *Cornus mas*. The difference can be established at a 95% confidence level for urease and EC, and at a 99.9% confidence level for catalase, OM, and K. It is noteworthy that the amounts of lime and organic matter increased in direct proportion to the amount of light, while the highest values of urease and catalase were obtained under intense shade conditions.

The values obtained from the variance and Duncan's analyses, as well as the change in soil characteristics depending on the amount of light received by *Fraxinus excelsior*, are presented in Table 2. In this case, the amount of light was determined having an effect only on catalase, urease, EC, P, and K. The change in these characteristics according to the amount of light is statistically significant in P, at a 99% confidence level, and in urease, at a 99.9% confidence level. In general, it can be said that the amount of catalase and urease increased in proportion to the amount of light.

The values obtained from the variance and Duncan's analyses, as well as the change in soil characteristics depending on the amount of light received by *Prunus armeniaca*, are presented in Table 2. In the soils in which *Prunus armeniaca* was grown, the amount of light affected all characteristics, except for pH and EC, with at least 95% confidence level. It was observed that the amounts of catalase, urease, P, and K generally differed in inverse proportion to the amount of light. Correlation analysis was applied to the data in order to determine the relationship levels between the soil characteristics investigated in this study, and the results are presented in Table 3.

When Table 3 is examined, we can see that the amount of light was inversely proportional to EC and directly proportional to OM in a weak correlation, and that catalase and urease were directly proportional to each other in a moderate correlation. The amount of EC had a statistically significant correlation with all characteristics except for urease, and this correlation was inversely proportional to light, P, and K. The strongest correlation was between lime and OM.

Conclusion

The amount of light on the catalase, urease, EC, and OM was confirmed to be statistically significant, at a confidence level of at least 95%. However, the response of plants to the amount of light may vary by species.

Table 2 Change in soil characteristics by the amount of light and species

Species	Light (%)	Catalase	Urease	pH	EC (mS cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
Hibiscus syriacus	5	7.03ab	0.055b	7.58	0.529b	7.50a	2.51a	11.27a	54.64a
	25	6.78a	0.034a	7.58	0.559b	10.75b	3.28b	13.31b	70.94bc
	45	7.15ab	0.034a	7.60	0.629c	9.71b	2.88a	13.04b	64.17b
	65	7.90 b	0.034a	7.50	0.684c	12.07c	3.82c	17.77c	76.83cd
	100	9.52c	0.055b	7.75	0.453a	10.89bc	3.51bc	13.44b	83.42d
	F val.	13.633	19.607	0.095	16.066	18.267	16.842	19.609	16.439
	Sig.	0.000	0.000	0.983	0.000	0.000	0.000	0.000	0.000
Cornus mas	5	8.02c	0.042b	7.40	0.572	2.06a	2.06b	28.19	104.24b
	25	10.14d	0.032a	7.34	0.572	2.35bc	1.66a	25.08	124.04d
	45	4.78a	0.034a	7.26	0.569	2.50c	2.42c	27.37	89.62a
	65	7.38bc	0.033a	7.37	0.553	2.20ab	2.72d	28.73	107.25bc
	100	6.87b	0.030a	7.35	0.496	2.50c	2.06b	26.02	118.35cd
	F val.	42.467	4.488	0.033	2.359	4.499	21.979	2.059	9.876
	Sig.	0.000	0.014	0.998	0.100	0.014	0.000	0.137	0.000
Fraxinus excelsior	5	7.48a	0.034a	7.53	0.583ab	11.27	2.87	11.42a	107.25a
	25	9.07b	0.044b	7.47	0.643b	10.98	2.94	11.14a	128.54b
	45	7.92ab	0.057c	7.59	0.543a	11.42	2.71	11.14a	109.07a
	65	7.66a	0.043b	7.51	0.629b	12.00	2.96	14.12b	103.04a
	100	8.81bc	0.066d	7.77	0.533a	10.98	2.71	10.88a	125.33b
	F val.	4.900	25.409	0.159	4.332	0.915	1246	8.586	6.581
	Sig.	0.010	0.000	0.956	0.016	0.481	0.334	0.001	0.003
Prunus armeniaca	5	9.61c	0.066c	7.27	0.529	5.27ab	2.85b	123.55d	199.22b
	25	7.63b	0.039ab	7.37	0.472	6.29c	2.44a	70.25b	165.93a
	45	4.75a	0.043b	7.46	0.483	5.56b	3.01b	51.59a	156.76a
	65	7.35b	0.034a	7.37	0.453	4.83a	2.81b	90.14c	147.80a
	100	7.81b	0.042b	7.44	0.483	4.97ab	2.89b	49.96a	167.36a
	F val.	34.622	29.857	0.066	2.213	7.600	3.902	92.814	8.815
	Sig.	0.000	0.000	0.991	0.117	0.001	0.023	0.000	0.001
General	5	8.04b	0.049b	7.45	0.553b	6.53	2.57a	43.61	116.33
	25	8.40b	0.037a	7.44	0.561b	7.59	2.58a	29.94	122.37
	45	6.15a	0.042ab	7.48	0.556b	7.30	2.76ab	25.78	104.91
	65	7.57b	0.036a	7.44	0.580b	7.77	3.08b	37.69	108.73
	100	8.25b	0.048b	7.58	0.491a	7.34	2.79ab	25.08	123.61
	F val.	8.851	5.058	0.191	3.810	0.243	2.732	1.137	0.738
	Sig.	0.000	0.001	0.942	0.007	0.913	0.035	0.346	0.569

ns, at $P < 0.05$, the mean difference is not significant, based on Duncan's test; *F* val., *F* value obtained by analysis of variance; Sig., the error rate calculated as a result of the variance analysis (sig. + confidence level = 1)

*The mean difference is significant at the 0.05 level

**The mean difference is significant at the 0.01 level

***The mean difference is significant at the 0.001 level

*Significant at 0.05 level; **significant at 0.01 level; ***significant at 0.001 level. The letters a, b, c, etc. indicate groupings according to Duncan's test results. These are statistically different from the values contained in different groups. The lowest numerical values are assigned to group a, and the highest to group d

Table 3 Correlation analysis results

	Catalase	Urease	pH	EC (mS cm^{-1})	$CaCO_3$ (%)	OM (%)	P (ppm)	K (ppm)
Light	0.003	0.013	0.078	− 0.249*	0.059	0.228*	− 0.142	0.023
Catalase		0.445**	0.394**	0.253*	0.228*	0.093	0.085	0.254*
Urease			0.367**	− 0.044	0.316**	0.222*	0.17	0.281*
Ph				0.499**	0.326**	0.465**	− 0.086	0.074
EC (mS cm^{-1})					0.396**	0.327**	− 0.371**	− 0.279*
$CaCO_3$ (%)						0.691**	− 0.424**	− 0.306**
OM (%)							− 0.041	− 0.092
P (ppm)								0.794**

*Significant at 0.05 level; **significant at 0.01 level

In the case of *Hibiscus syriacus*, the amount of light had a statistically significant effect (at 99.9% confidence level) on all characteristics except pH. With *Cornus mas*, it was determined that the soil characteristics that differed to a significant degree as a result of light were urease at a 95% (confidence level) and EC, catalase, and OM (at a 99.9% confidence level). In *Fraxinus excelsior*, the amount of light only had effects on catalase, urease, EC, P, and K. In the soil surrounding *Prunus armeniaca*, the amount of light affected all characteristics except pH and EC (at a confidence level of least 95%).

The study determined that levels of urease, EC, lime, OM, P, and K enzymatic activity differed significantly according to the plant species. The amount of light was also found to cause significant changes in levels of catalase, urease, EC, and OM.

Discussion

The results of the study show that light conditions significantly affect urease and catalase enzyme activities. Shade conditions affect soil temperature, and soil temperature affects microorganism activities, organic matter decomposition, and therefore soil characteristics directly. Light and soil temperature, which play important roles in the nutrient cycle, also affect enzyme activities in the environment (Talgre et al. 2012).

There have been many studies on the effects of plant species and shade conditions on soil characteristics. In a study conducted in Taiwan, Liu et al. (2002) observed changes in enzyme activity and some soil quality parameters in soils in different ecosystems in which a corn-rice rotation system was applied. In their study, which was conducted by composting organic fertilizers and N, they examined the changes in eight enzyme activities, namely X-glucosidase, L-asparaginase, urease, amidase, acid phosphatase, phosphomonoesterase, arylsulfatase, and dehydrogenase enzymes, which are associated with C, N, P, and S cycles, and showed that the quality index of the agricultural soil was significantly correlated with the corn crop.

Ghee et al. (2013) stated that soil respiration and organic matter mineralization are sensitive to temperature and positively correlated with an increase in soil temperature. The microclimate on the soil surface is associated with temperature and moisture, and is an important factor for plant growth. This factor controls the biological (germination, plant growth, etc.) and hydrological (infiltration, runoff, erosion, etc.) processes in the areas close to the soil surface. The management of soil temperature and moisture content thus affects that microclimate, as does vegetation (Flerchinger and Pierson 1997). The change in shading on the soil surface affects the soil temperature and moisture, CO_2 concentration, and soil respiration, thereby limiting the thermal and hydrological properties of the soil (Tanaka and Hashimoto 2006).

Trasar-Cepeda et al. (2008) obtained results similar to the ones in this study, reporting that the plant species affected urease enzyme activity, and that the lowest urease enzyme activity was detected in vineyards and soils in which corn was grown. They found that it was high in eucalyptus forests, and higher in pine and oak forests, but the highest mean values were obtained in the pastures.

Kravkaz-Kuşcu (2014) investigated the effect of different land uses, aspect and soil depths on enzyme activities, analyzed soil (pH), electrical conductivity (EC), organic matter (OM), calcium carbonate ($CaCO_3$), total nitrogen (N), plant-available phosphorus (P), and exchangeable potassium (K) reactions; determined the relationships between urease and catalase enzyme activities and these parameters; and revealed the effect of the plant species on soil characteristics.

Kravkaz Kuscu et al. (2018a) conducted a study to determine the main tree species and soil characteristics in Taşköprü district of Kastamonu province. They investigated the texture, pH, bulk density, organic matter, electrical conductivity, and maximum water-holding capacity in soil samples of yellow pine (*Pinus sylvestris* L.), black pine (*Pinus nigra subsp. pallasiana* [Arnold]), and oak (*Quercus* ssp.). The results of their study showed that bulk density, especially in soils with a depth of 0–5 mm, differed significantly in yellow pine, black pine, and oak. The lowest value was obtained from yellow pine, and the highest value was obtained from oak. In soils with a depth of 0–5 mm, the highest water-holding capacity was found in yellow pine, and the lowest capacity was found in oak, in contrast to the bulk density. It was determined that the highest amount of organic matter was reached in 0–5 mm soils in yellow pine, in 10–15 mm soils in black pine, and in 20–25 mm soils in oak, while the amount of organic matter was higher than 50% in the areas of yellow pine and black pine at these depths.

Shade conditions are among the most important factors affecting not only the soil, but also the plant growth performance. Plant growth performance is influenced by climate parameters and soil characteristics, chiefly including light and temperature. At the same time, it affects soil characteristics. Therefore, light, plant growth rate, the morphological structures of plants, soil characteristics, enzyme activities in the soil, and many other systems are interconnected and interact with each other (Kravkaz Kuscu et al. 2018a, b; Turkyilmaz et al. 2018; Sevik et al. 2016; Sevik et al. 2018; Cetin et al. 2018a, b).

In many respects, plants are the source of life in the living world. They perform many ecological functions in their environments, and they shape the lives of other entities in those environments. The ability of plants to fulfill their functions primarily depends on the availability of appropriate climatic and edaphic conditions. Therefore, soil is one of the absolutely necessary conditions for plant existence, which, in turn, is essential to other forms of life. The soil is defined as the part of the solid earth that has been altered by the loosening of the earth, humus formation, and chemical decomposition, by the transport of humidification and chemical decomposition products. When it is examined in detail, the soil is revealed to be a very complex structure whose biological and biochemical processes provide the basis of the terrestrial ecosystem. For this reason, it is very important to examine structural changes in the soil and to determine their relationships with plants. Some studies have looked specifically at connections between soil structure and forest tree species, investigating enzymatic activity in forest environments (Cetin 2013a, b, 2015a, b; Cetin et al. 2018a, b, c, d).

Light is considered by many researchers to be the most important factor affecting growth, given that photosynthesis shapes plant growth, form, and structure (Zivcak et al. 2014). Research has shown that light is the most important factor affecting diameter growth (Mäkınen et al. 2003) and crown structure (Hein et al. 2007). Such findings have been supported by the work of Ersoy and Demirsoy (2012), who determined the seasonal variation of some nutrient elements in the camarosa strawberry variety under different shading applications. Their study found that the nutrients in the roots, stems, and leaves of plants grown in greenhouses were fewer and lower than those in plants grown in open fields, indirectly confirming the centrality of light to plant development. To increase the effectiveness of soil fertility improvement and effective land use initiatives, studies on these and related subjects should be increased and diversified.

Compliance with ethical standards

Conflict of interest The author declares that there is no conflict of interest.

References

Arcak, S., Haktanır, K., & Karaca, A. (1994). Relations between some ecological and chemical properties and enzyme activities in the soil water national park soils. *Turkish Journal of Agriculture and Forestry, 21*(1997), 35–40 Tubitak, Ankara.

Caldwell, B. A. (2005). Enzime activities as a component of soil biodiversity. A review. *Pedobiologia, 49*, 637–644.

Cetin, M. (2013a). Chapter 27: landscape engineering, protecting soil, and runoff storm water, InTech-Open Science-Open Minds, online July 1st, 2013. In *Book title: Advances in landscape architecture-environmental sciences, chapter page* (pp. 697–722).

Cetin M. (2013b). *Pavement design with porous asphalt*. PhD Thesis.

Cetin, M. (2015a). Chapter 55: using recycling materials for sustainable landscape planning. In *Book title: Environment* *and ecology at the beginning of 21st century* (pp. 783–788). Sofia: ST. Kliment Ohridski University Press.

Cetin, M. (2015b). Consideration of permeable pavement in landscape architecture. *Journal of Environmental Protection and Ecology, 16*(1), 385–392.

Cetin, M., Sevik, H., & Yigit, N. (2018a). Climate type-related changes in the leaf micromorphological characters of certain landscape plants. *Environmental Monitoring and Assessment., 190*, 404.

Cetin, M., Sevik, H., Yigit, N., Ozel, H. B., Aricak, B., & Varol, T. (2018b). The variable of leaf micromorphogical characters on grown in distinct climate conditions in some landscape plants. *Fresenius Environmental Bulletin, 27*(5), 3206–3211.

Cetin, M., Onac, A. K., Sevik, H., Canturk, U., & Akpinar, H. (2018c). Chronicles and geoheritage of the ancient Roman city of Pompeiopolis: a landscape plan. *Arabian Journal of Geosciences., 11*, 798. https://doi.org/10.1007/s12517-018-4170-6.

Cetin, M., Onac, A. K., Sevik, H., & Sen, B. (2018d). Temporal and regional change of some air pollution parameters in Bursa. *Air Quality, Atmosphere & Health Air Qual Atmos Health*, (2018). https://doi.org/10.1007/s11869-018-00657-6.

Ersoy, B., & Demirsoy, H. (2012). A research on the effects of different shading practices on seasonal variation of some elements in camarosa strawberry. *Journal of Agricultural Sciences of Anatolia, 21*(1), 82–88.

Flerchinger, G. N., & Pierson, F. B. (1997). Modelling plant canopy effects on variability of soil temperature and water: model calibration and validation. *Journal of Arid Environments, 35*, 641–653.

Ghee, C., Neilson, R., Hallet, P. D., Robinson, D., & Paterson, E. (2013). Priming of soil organic matter mineralisation is intrinsically insensitive to temperature. *Soil Biology & Biochemistry, 66*, 20–28.

Guntinas, M. E., Leiros, M. C., Trasar-Cepeda, C., & Gil-Sotres, F. (2012). Effects of moisture and temperature on net soil nitrogen mineralization: a laboratory study. *European Journal of Soil Biology, 48*, 73–80.

Guo, J., Yang, Y., Chen, G., Xie, J., & Yang, Z. (2014). Carbon mineralization of Chinese fir (Cunninghamia lanceolata) soils under different temperature and humidity conditions. *Acta Ecologica Sinica, 34*, 66–71.

Hackl, E., Bachmann, G., & Zechmeister-Boltenstern, S. (2004). Microbial nitrogen turnover in soils under different types of natural forest. *Forest Ecology and Management, 188*, 101–112.

Hein, S., Mäkınen, H., Yue, C., & Kohnle, U. (2007). Modelling branch characteristics of Norway spruce from wide spacings in Germany. *Forest Ecology and Management, 242*(2), 155–164.

Jackson, M. L. (1958). *Soil chemical analysis* (pp. 1–498). Englewood Cliffs, New Jersey, USA: Prentice- Hall, Inc.

Jackson, M. C. (1962). *Soil chemical analysis*. USA: Prentice Hall. Ine. Eng. Cliff.

Jackson, M. L. (1967). *Soil chemical analysis*. New Delhi: Prentice Hall of India Private Limited.

Kacar, B. (1995). Bitki ve toprağın kimyasal analizleri. III. Toprak analizleri. *A.Ü.Z.F. vakfi yayınları.* No:3, Ankara.

Kızılkaya, R., & Hepşen, Ş. (2004). Effect of biosolid amendment on enzyme activities in earthworm (Lumbricus terrestris) casts. *Journal of Plant Nutrition and Soil Science, 167*(2), 202–208.

Kravkaz Kuscu, I. S., Cetin, M., Yigit, N., Savaci, G., & Sevik, H. (2018a). Relationship between enzyme activity (urease-catalase) and nutrient element in soil use. *Polish Journal of Environmental Studies, 5*(27), 2107–2112.

Kravkaz Kuscu, I. S., Sariyildiz, T., Cetin, M., Yigit, N., Sevik, H., & Savaci, G. (2018b). Evaluation of the soil properties and primary forest tree species in Taskopru (Kastamonu) district. *Fresenius Environmental Bulletin, 27*(3), 1613–1617.

Kravkaz-Kuşcu, İ. S. (2014). *Comparison of enzyme (catalase-urease) activities in agricultural-pasture-forest soils in Kastamonu region*. Istanbul University, Institute of Science. Ph.D. Thesis. Istanbul.

Krzysztof, M., Bronisław, W., Szymanski, W., & Muskala, P. (2014). Soil moisture and temperature variation under different types of tundra vegetation during the growing season: a case study from the Fuglebekken catchment, SW Spitsbergen. *Catena, 116*, 10–18.

Liu, K. L., Lai, C. M., & Helen, W. (2002). *Soil enzyme activities as indicators agricultural soil quality.* Symposium no. 32, p.1386, Thailand.

Mäkınen, H., Ojansuu, R., Saoranen, P., & Ylı-Kojola, H. (2003). Predicting branch characteristics of Norway spruce (*Picea abies* (L.) Karst.) from simple stand and tree measurements. *Forestry, 76*(5), 525.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, N. C. (1954). *Estimation of available phosphous in soil by extraction with sodium bicorbonate*. Washington. D.C: U. S. Dept of Agr. Cir. 939.

Pratt, P. F. (1965). *Methods of soil analysis. Part 2. Chemical and microbiological properties*. Ed. C. A. Black. Amer. Soc. of Agron. Inc. Puc. Agron. Series no. 9.

Roldan, A., Caravaca, F., Hernández, M. T., García, C., Sánchez-Brito, C., Velásquez, M., & Tiscareño, M. (2003). No-tillage, crop residue additions, and legume cover cropping effects on soil quality characteristics under maize in Patzcuaro watershed (Mexico). *Soil and Tillage Research, 72*(1), 65–73.

Schütt, M., Borken, W., Spot, O., Stange, C. F., & Matzner, E. (2014). Temperature sensitivity of C and N mineralization in temperate forest soils at low temperatures. *Soil Biology & Biochemistry, 69*, 320–327.

Sevik, H., Cetin, M., & Kapucu, O. (2016). Effect of light on young structures of Turkish fir (*Abies nordmanniana* subsp. *bornmulleriana*). *Oxidation Communications, 39*(1), 485–492.

Sevik, H., Ozel, H. B., Cetin, M., Ozel, H. U., & Erdem, T. (2018). Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. *Air Quality, Atmosphere & Health (Air Qual Atmos Health), 2018*, 1–7. https://doi.org/10.1007/s11869-018-0641-x.

Skujins, J. (1978). *History of Abiontic soil enzyme research in soil enzymes* (pp. 1–49). London: Academic Press.

Tabatabai, M. A., & Dick, W. (2002). Enzymes in soil: research and developments in measuring activities. In R. G. Burns & R. P. Dick (Eds.), *Enzymes in the environment* (pp. 567–570) USA.

Talgre, L., Lauringson, E., Roostalu, H., Astover, A., & Makke, A. (2012). Green manure as a nutrient source for succeeding crops. *Plant Soil and Environment, 58*, 275–281.

Tanaka, K., & Hashimoto, S. (2006). Plant canopy effects on soil thermal and hydrological properties and soil respiration. *Ecological Modelling, 196*, 32–44.

Trasar-Cepeda, C., Leiros, M. C., & Gil-Sotres, F. (2008). Hydrolytic enzyme activities in agricultural and forest soils. Some implications for their use as indicators of soil quality. *Soil Biology & Biochemistry, 40*, 2146–2155.

Turkyilmaz, A., Sevik, H., Cetin, M., & Saleh, E. A. A. (2018). Changing of heavy metal accumulation dependent on traffic density in some landscape plants. *Polish Journal of Environmental Studies., 27*(5), 2277–2284.

Ünal, H. (1967). *Enzyme activity of Rize tea soils and interest between important properties of these activities*. Ankara, Turkey: Ankara University Faculty of Agriculture, Publications 306 studies: 191.

Wang, C., Wan, S., Xing, X., Zhang, L., & Han, X. (2006). Temperature and soil moisture interactively affected soil net N mineralization in temperate grassland in northern China. *Soil Biology & Biochemistry, 38*, 1101–1110.

Wiseman, A. (1987). Chapter 3. The application of enzymes in industry. In *Handbook of enzymes biotechnology* (2nd ed., pp. 274–373).

Zivcak, M., Brestic, M., & Kalaji, H. M. (2014). Photosynthetic responses of sun-and shade-grown barley leaves to high light: is the lower Psıı connectivity in shade leaves associated with protection against excess of light? *Photosynthesis Research, 119*(3), 339–354.