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AFFORESTATION EFFECTS ON SOIL BIOCHEMICAL PROPERTIES

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Abstract

In this study afforestation effects on physical, chemical and biological soil properties were investigated in 10 and 23 years old black pine plantations used as grassland previously versus bear area. The results were also evaluated in terms of different landscape positions and soil depths.

Afforestation increased electrical conductivity and soil microbial respiration in 23 year old plantation; and decreased organic matter and β-Glucosidase activity in both of 23 and 10 years old plantations. There was no significant difference in phosphatase activity. Soil pH, total carbonates ($CaCO_3$), organic matter, β-Glucosidase and soil microbial respiration were affected by different landscape positions. It was founded that carbonates, pH, and microbial respiration were higher in the south-facing slopes than those of north-facing slopes; organic matter and β-Glucosidase activity were higher in the north-facing slopes. A decrease in organic matter and an increase in phosphatase activity were determined with soil depth.

Keywords: Afforestation, soil enzyme activity, microbial respiration.

INTRODUCTION

Land use change alters the below-ground ecosystem, often leading to loss of biodiversity and depletion of soil carbon (Doran and Zeiss, 2000). Some 1780 Mha of the world's soils are now known to be degraded in some way, with conversion of forests and grasslands to agriculture causing dramatic effects on physical and chemical properties (Bossio et al., 2005).

Soil microbial biomass carbon and soil respiration are often applied for understanding the environmental factors' effects on soil organisms, monitoring carbon, nitrogen, phosphorus cycles on soils exposed natural conditions or human activities and monitoring effects of human activities on soil ecosystems (Ocio et al. 1991).

Soil respiration is a major flux of CO_2 to the atmosphere, accounting for up to 25% of global CO_2 emissions (Schimel, 1995). The rate of soil respiration varies among different ecosystems and is generally the dominant component of ecosystem respiration (Raich and Schlesinger, 1992). Soil respiration in arid and semi-arid ecosystems has been less intensively investigated than in other ecosystems (Raich and Potter, 1995; Subke et al., 2006; Bond-Lamberty and Thomson, 2010).

Furthermore, arid and semi-arid ecosystems are prone to soil degradation, which may be aggravated by land use, especially grazing intensity and cropping history, and by climate change (Frank, 2002). Whether these ecosystems are sources or sinks of CO_2 is likely to depend on the extent to which the carbon stock in soils may change as a consequence of soil degradation (Rey et al., 2010).

Enzymes are the vital activators in life processes, likewise in the soil they are known to play a substantial role in maintaining soil health and its environment. The enzymatic activity in the soil is mainly of microbial origin, being derived from intracellular, cell-associated or free enzymes. A unique balance of chemical, physical, and biological (including microbial especially enzyme activities) components contribute to maintaining soil health. Evaluation of soil health therefore requires indicators of all these components. The enzyme levels in soil systems vary in amounts primarily due to the fact that each soil type has different amounts of organic matter content, composition, and activity of its living organisms and intensity of biological processes (Das and Varma, 2011). In practice, the biochemical reactions are brought about largely through the catalytic contribution of enzymes and variable substrates that serve as energy sources for microorganisms (Kiss et al. 1978). These enzymes may include amylase, arylsulphatases, β-Glucosidase, cellulose, chitinase, dehydrogenase, phosphatase, protease, and urease released from plants (Miwa et al. 1937), animals (Kanfer et al. 1974), organic compounds, and microorganisms (James et al. 1991; Richmond 1991; Shawale and Sadana 1981) and soils (Gupta et al. 1993; Ganeshamurthy et al. 1995).

Soil enzyme activities (1) are often closely related to soil organic matter, soil physical properties and microbial activity or biomass, (2) changes much sooner than other parameters, thus providing early indications of changes in soil health, and (3) involve simple procedures (Dick et al.1996).

Soil enzymes are important soil components that are closely associated with physicochemical and biological characteristics of soil. However, human activities, agricultural practices and environmental pollution severely influence their existence and activities in soil. Depending on their origin, soil enzymes are powerful tools applied in the assessment of short- or long-term changes in soil (Karaca et al., 2011).

Glucosidase is a common and predominant enzyme in soils (Eivazi and Tabatabai 1988; Tabatabai 1994a, b). Its final product is glucose, an important C energy source of life to microbes in the soil (Esen 1993). β-Glucosidase is characteristically useful as a soil quality indicator, and may give a reflection of past biological activity, the capacity of soil to stabilize the soil organic matter, and can be used to detect management effect on soils (Bandick and Dick 1999; Ndiaye et al. 2000). β-Glucosidase enzyme is very sensitive to changes in pH, and soil management practices (Acosta-Martı´nez and Tabatabai 2000; Madejo´n et al. 2001).

Soil urease originates mainly from plants (Polacco 1977) and microorganisms found as both intra- and extra-cellular enzymes (Burns 1986; Mobley and Hausinger 1989). On the other hand, urease extracted from plants or microorganisms is rapidly degraded in soil by proteolytic enzymes (Pettit et al. 1976; Zantua and Bremner 1977). This suggests that a significant fraction of ureolytic activity in the soil is carried out by extracellular urease, which is stabilized by immobilization on organic and mineral soil colloids. Urease activity in soils is influenced by many factors. These include cropping history, organic matter content of the soil, soil depth, soil amendments, heavy metals, and environmental factors such as temperatures (Tabatabai 1977; Yang et al. 2006). Generally, urease activity increases with increasing temperature.

Apart from being good indicators of soil fertility, phosphatase enzyme plays a key role in the soil system (Eivazi and Tabatabai 1977; Dick et al. 2000). For example, when there is a signal indicating P deficiency in the soil, acid phosphatase secretion from plant roots is increased to enhance the solubilization and remobilization of phosphate, thus influencing the ability of the plant to cope with P-stressed conditions (Karthikeyan et al. 2002; Mudge et al. 2002; Versaw and Harrison 2002).

Given the above described relationships, the research was undertaken to assess the afforestation effects on physical, chemical and biological soil properties were investigated in 10 and 23 years old black pine plantations used as grassland previously versus bear area.

MATERIAL AND METHODS

The study was conducted in black pine plantation in Kaymaz dam Basin, Eskişehir (39°49′N, 30°49′E). The site's average temperature is 11,2^{0}C and average annual rainfall is 400 mm. Cold, semi-arid climate conditions are dominant in the region (Güner et al. 2011). The altitude is between 1037 - 1164 m. (Figure 1).

Fig. 1. Study area in Eskişehir, Turkey (Kaymaz dam Basin)

The parent rock of the research area is micaschist, and the main soil type of the area is brown forest soil (Güner et al. 2011). The soil is sandy clay loam (the textural composition is 61.11% sand, 17.58% silt, 21.31% clay).

In this study, three sample plots were taken from adjacent bare area, 10 and 23 years old black pine plantations, respectively where used for grassland previously. The soil samples were collected from the north- and south-facing slopes in 2010, June. At each pilot, soil samples were taken from five subpoints at 0-10 cm and 10-20 cm depths and combined and mixed to represent each pilot. There were 60 soil samples in totally. They were passed through a 2-mm sieve and stored at 4°C until analysis. The samples were analyzed to determine a series of soil chemical (electrical conductivity, pH, total carbonates and organic matter content) physical (soil texture) and biological characteristics (β-Glucosidase and phosphatase enzyme activities, soil microbial respiration). Soil pH was determined in a 1:2.5 soil/water (v/v) ratio. Coarse, fine, and total sand, silt, and clay contents were determined by the Bouyoucos hydrometer method (Gülçur, 1974). Organic matter was measured by Walkley-Black (Jackson, 1962), and total carbonate content by using the Scheibler calcimeter method (Gülçur, 1974).

Samples were analysed for their β-Glucosidase activity (C cycle) and alkaline phosphotase activities (P cycle) by the methods of Naseby and Lynch (1997). Soil respiration was determined according to Isermeyer (1952), estimating the CO_2 evolved during soil incubation in a closed system. Urease activity was measured by the method of Hoffmann and Teicher (1961). A 7.5 ml citrate buffer (pH 6.7) and 10 ml of 10% urea substrate solution were added to 10 g soil, and subsequently the samples were incubated for 3 h at 37 °C. The volume was made up to 100 ml with distilled water at 37 °C. Following filtration through Whatman No. 42 filter papers, 1 ml of filtrate was diluted to 10 ml with distilled water, and 4 ml of sodium phenolate (12.5% (w/v) phenol + 5.4% (w/v) NaOH) and 3 ml of 0.9% sodium hypochloride were added. The released ammonium was determined spectrophotometrically at 578 nm.

All statistical analyses were conducted with SPSS for windows (SPSS 17.0). An One-Way ANOVA test was carried out to identify differences between bare and afforested plots. In the case of significant differences, a post-hoc Tukey HSD test was applied. Significant differences were considered at a $P<0.05$.

RESULTS

Afforestration increased electrical conductivity from 0.27 mS cm^{-1} to 0.39 mS cm^{-1} in the upper soil layers (0-10 cm); from 0.27 mS cm^{-1} to 0.49 mS cm^{-1} in the lower soil layers (10-20 cm), soil microbial respiration from 1.26 g C m^{-2} day^{-1} to 1.68 g C m^{-2} day^{-1} in the upper soil layers; from 1.15 g C m^{-2} day^{-1} to 1.68 g C m^{-2} day^{-1} in the lower soil layers in the both north- and south-facing slopes.

β-Glucosidase activity increased from 1.88 mg pNP h^{-1} g^{-1} soil to 2.01 mg pNP h^{-1} g^{-1} soil in the upper soil layers; from 1.36 mg pNP h^{-1} g^{-1} soil to 2.28 mg pNP h^{-1} g^{-1} soil in the lower soil layers and urease activity inreased from 0.14 μg N g^{-1} soil to 0.31 μg N g^{-1} soil in the upper soil layers; from 0.18 μg N g^{-1} soil to 0.25 μg N g^{-1} soil in the lower soil layers in the south-facing slopes with afforestation.

Organic matter decreased from 3.45% to 2.10% in the upper soil layers; from 2.06% to 1.65% in the lower soil layers in the south-facing slopes, β-Glucosidase activity decreased from 9.73 mg pNP h^{-1} g^{-1} soil to 1.88 mg pNP h^{-1} g^{-1} soil in the upper soil layers; from 10.00 mg pNP h^{-1} g^{-1} soil to 1.69 mg pNP h^{-1} g^{-1} soil in the lower soil layers and urease activity decreased from 0.22 μg N g^{-1} soil to 0.18 μg N g^{-1} soil in the upper soil layers; from 0.22 μg N g^{-1} soil to 0.20 μg N g^{-1} soil in the lower soil layers in the north-facing slopes with afforestation. There was no significant difference in phosphatase activity.

Afforestration increased urease activity (from 0.187 μg N g^{-1} soil to 0.236 μg N g^{-1} soil) in 23 year old plantations but decreased in 10 years old plantations (0.154 μg N g^{-1} soil) (Table1).

There was a significantly decrease with organic matter especially in the young plantations (from 2.622% to 1.826%) but in the old ages of plantation it is near to the bare area "2,321%" with afforestation. β-Glucosidase activity is also decreased (from 5.752 mg pNP h^{-1} g^{-1} soil to 1.964 mg pNP h^{-1} g^{-1} soil) (Table1).

Table 1. Afforestation effects on some soil parameters

Soil properties	**Bare area**	**10 years old plantation**	**23 years old plantation**
Sand %	60.80^a	60.91^a	61.64^a
Silt %	17.94^a	17.21^a	17.58^a
Clay %	21.27^a	21.88^a	20.78^a
pH	7.53^a	7.39^a	7.40^a
$CaCO_3$ %	13.99^a	3.71^b	8.05^{ab}
Organic Matter %	2.62^a	1.83^b	2.32^{ab}
EC (10^3 25^0C mS cm^{-1})	0.27^b	0.26^b	0.42^a
β-Glucosidase (mg pNP h^{-1} g^{-1} soil)	5.76^a	1.48^b	1.97^b
Phosphatase (mg pNP h^{-1} g^{-1} soil)	0.03^a	0.04^a	0.04^a
Urease (μg N g^{-1} soil)	0.19^{ab}	0.15^b	0.24^a
Soil microbial respiration (g C m^{-2}. day^{-1})	1.40^{ab}	1.31^b	1.57^a

Different letters on values show different groups based on a Tukey HSD test ($P<0.05$).

Soil pH (P<0.001), total carbonates (P<0.05), organic matter (P<0.05), β-Glucosidase (P<0.001) and soil microbial respiration (P<0.001) were affected by different landscape positions. It was founded that pH (N: 7.31, S: 7.56), total carbonate (N: 5.64%, S:11.53%), and soil microbial respiration (N: 1.26 g C m^{-2} day^{-1}, S: 1.59 g C m^{-2} day^{-1}) were higher in the south-facing slopes while organic matter (N: 2.45%, S: 2.06%) and β-glucosidase activity (N: 4.39 mg pNP h^{-1} g^{-1} soil, S: 1.74 mg pNP h^{-1} g^{-1} soil) were higher in the north-facing slopes of the area.

Organic matter content (from 2.69% to 1.82%) was found to be low (P<0.001) while phosphatase activity (from 0.027 mg pNP h^{-1} g^{-1} soil to 0.044 mg pNP h^{-1} g^{-1} soil) was high (P<0.01) depending on the soil depth.

There were significant possitive correlations between pH and total carbonates; pH and soil respiration; total carbonates and organic matter; total carbonates and soil microbial respiration, and there was a significant negative correlation between organic matter and phosphatase activity (Table 2).

Table 2. Pearson correlation coefficients (r) among measured variables in the study area. Asterisks refer to the level of significance; *, P < 0.05; **, P < 0.01.

	pH	$CaCO_3$	OM	EC	β-Glicosidase	Phosphatase	Urease	SMR
pH	1	0.510**	0.103	-0.058	0.000	0.086	0.175	0,305*
$CaCO_3$		1	0,301*	-0.082	-0.003	-0.075	0.153	0,266*
OM			1	0.081	0.125	-0.274*	-0.022	0.145
EC				1	-0.134	0.139	0.122	0.135
β-Glucosidase					1	-0.178	0.199	-0.248
Phosphatase						1	-0.025	0.076
Urease							1	0.132
SMR								1

OM: Organic matter, SMR: Soil microbial respiration

Discussion

Afforestation increased electrical conductivity. Rapid salinization of groundwater and soils in afforested plots was associated with increased evapotranspiration and groundwater consumption by trees (Jobbagy and Jackson, 2004) Salinization occurred rapidly where rainfall was insufficient to meet the water requirements of tree plantations and where groundwater use compensated for this deficit, driving salt accumulating in the ecosystem (Nosetto et al., 2008).

Afforestation increased urease activity in the southern slopes. In some studies it is founded that urease activity is decreased with afforestation (Szajdak and Baloniak, 2002). Zeng et al. (2009) reported that urease activity decreased in Magnolian pine plantation compared with grassland and savanna but they founded possitive significant correlation between Corg and urease activity. In contrast of our results Chodak and Niklinkska (2010) reported that urease activity was the highest under pine stand where total nitrogen content was the lowest and the organic carbon- to -total nitrogen ratios were the highest. In our study there was no significant but negative correlation between organic matter and urease activity. Changes in the quality and quantity of organic inputs with conversion of land use to the pine plantation from the grassland could cause differences in enzyme activities.

Afforestation increased soil microbial respiration. This result may be explained by the higher quantity and different quality of litter under the pine stands in comparison with bare areas. Zornoza *et al.* (2009), studying the impact of different land use, observed higher values of SR under forest than under abandoned and agricultural systems. Zeng et al. (2009) reported that negative correlation is founded between organic carbon and soil qCO_2 (calculated by dividing the mean values of basal respiration rate by the corresponding microbial biomass carbon). Although there was no significant correlation between soil microbial respiration and organic matter in our study, we observed a decrease in organic matter with afforestation while there was increase in soil microbial respiration.

Afforestation significantly decreased organic matter especially in young plantations but in old ages of plantation it is near to treeless area. β-Glucosidase activity is also decreased with afforestation. It was seen that β-Glucosidase enzyme activity changed at the same aspect with organic matter's.

Landscape position affected soil pH, total carbonates, organic matter, β-Glucosidase and soil microbial respiration. It was founded that carbonates, pH, and soil microbial respiration were higher in the south-facing slopes while organic matter and β-glucosidase activity were higher in the north-facing slopes of the area. β-Glucosidase enzyme is sensitive to changes in pH (Acosta-Martı´nez and Tabatabai 2000) so this enzyme activity higher levels may be related with lower levels of pH in the north-facing slopes. Dry soils generally had low organic matter because organic matter decomposition was faster than accumulation in these areas. Jia et al. (2005) reported that the slope position may affect the accumulation of soil organic matter and the soil in slope facing to south under pine-oak mixed forest had a higher temperature and lower water content.

Organic matter content was found to be less while phosphatase activity was high depending on the soil depth. Depending on the depth of soil there was a decrease at and an increase in phosphatase activity. Alkaline phosphatase activity increased with depth. It is considered that larger amounts of inorganic phosphorus at upper depths were inhibited the phosphatase activity. Inhibition of phosphatase is related to great amount of phosphate (PO_4) in the soil solution (Chunderova and Zubets, 1969).

In conclusion, our study demonstrates that land use change from grassland to plantation can significantly affect soil electrical conductivity, organic matter, β-Glucosidase and urease activities and soil microbial respiration. These results suggest that converting bare area which was used for grazing to a pine plantation on a semiarid soil will reduce soil organic C in young plantation and that may have negative consequences for soil fertility and long-term storage of soil organic C but this negative effect will be disappear in later ages of plantation. With age of plantation of forest, the trend changes in these soil parametres may be related to some factors, which probably included land-use history, slope position, light and changes in community plant species.

Vegetation type may have fundemental effects on soil properties. With this research, it seems that land use affects the interactions of soil components and change the some soil properties including β-Glucosidase and urease enzyme activities. Soil enzymes that substantially originated from soil microorganisms may therefore be more preferable compared to soil physical and chemical quality parameters. They enable researchers efficiently to monitor the impacts of a wide group of agricultural management practices and the differences between remediated and severely degraded soil conditions. Due to these advantages over soil physical and chemical quality attributes, soil enzyme activity is considered to be an integral index of soil health but it should be kept in mind that an accurate evaluation of soil health needs to be complemented by physical, chemical and other biological parameters (Karaca et al., 2011).

Enzyme activities and other microbial factors may widely vary under natural conditions typically. Therefore, soil enzyme activities investigations should be conducted with other chemical, physical and microbial measurements to evaluate soil health accurately and more comprehensive studies should be done.

Future research on the effects of land cover change on soil total and available nitrogen, phosphorus amounts in semiarid soils beside some fertility indexes (C_{mic}/C_{org}, qCO_2 etc.) and their relationship with changes in soil properties and processes would help us better understand the mechanisms for the changes we reported here.

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Yapılandırılmış Özet

Atmosfere salınan CO_2 'in %25 'inden toprak solunumu sorumludur (Schimel 1995). Toprak solunum oranı farklı ekosistemler arasında değişim gösterir ve ekosistem solunumunun temel bileşenidir (Raich ve Schlesinger 1992). Bununla beraber kurak ve yarı kurak ekosistemlerde diğer ekosistemlere göre daha az araştırılmıştır (Bond-Lamberty ve Thomson 2010).

Enzimler yaşam süreçlerinin çok önemli aktivatörleridir. Aynı şekilde toprak sağlığı ve çevresinin korunmasında da önemli rol üstlenirler. Topraklarda enzim aktivitesi büyük oranda mikroorganizmalardan kaynaklanır. Toprak enzimleri toprağın fizyokimyasal ve biyolojik özellikleriyle yakından bağlantılı önemli toprak unsurlarıdır. Bununla birlikte insan etkinlikleri, tarımsal uygulamalar ve çevresel kirlilik topraktaki varlıklarını ve aktivitelerini büyük oranda etkiler. Toprak enzimleri, bu etkilerin kısa ve uzun dönemli değerlendirmelerinde kullanılan güçlü araçlardır (Karaca vd. 2011).

Bu çalışmada Eskişehir'de Kaymaz Baraj Havzası daha önce otlatma yapılan ağaçlandırma sahalarında 10 ve 23 yaşlı ağaçlar altından iki derinlikten (0-10 cm ve 10-20 cm) toprak örnekleri alınmış ve ağaçlandırmanın toprağın biyokimyasal özellikleri üzerine etkisi incelenmiştir. Sonuçlar bakı ve derinlik etkilerine göre de değerlendirilmiştir.

Ağaçlandırma yapılan alanlarda elektiriksel iletkenliğin (0,264 mS cm^{-1} 'den 0,420 mS cm^{-1} 'e), üreaz aktivitesinin (0,187 µg N g^{-1} toprak 'tan 0,236 µg N g^{-1} toprak 'a) ve toprak mikrobiyal solunumunun (1,396 g C m^{-2} $gün^{-1}$ 'den 23 yaşlı ağaçlandırma sahalarında 1,574 g C m^{-2} $gün^{-1}$ 'e) arttığı, organik madde (2,622% 'den 1,826% 'e) ve β-Glukosidaz aktivitesinin (5,752 mg pNP h^{-1} g^{-1} toprak 'tan 1,964 mg pNP h^{-1} g^{-1} toprak 'a) azaldığı görülmüştür.

Eskişehir'de yıllık yağış mktarının düşük olduğu (400 mm) göz önüne alındığında Kaymaz Baraj Havzası ağaçlandırma sahalarında elektriksel iletkenlikteki artışın, ağaçların su açığını taban suyundan sağlamasına bağlı olduğu düşünülmektedir. Nitekim yağışın ağaçlar için yetersiz olduğu plantasyon sahalarındaki hızlı tuzlanmanın su açığını kapatmak için taban suyunun kullanıldığı durumlarda gerçekleştiği kaydedilmiştir (Nosetto vd. 2008).

β-Glukosidaz aktivitesi ile organik maddenin birbirine paralel olarak ağaçlandırmayla azaldığı görülmüştür. Mikrobiyal solunumdaki artışın ise organik madde özelliklerinin bitki örtüsüne bağlı olarak organik girdilerin niteliklerindeki değişikliğe bağlı olabileceği düşünülmektedir. Organik madde ve CO_2 çıkışı arasında negatif korelasyon tespit edilmiştir (Zeng vd. 2009). Bizim araştırma sonuçlarımıza göre de anlamlı olmamakla beraber negatif bir korelasyon tespit edilmiştir.

Toprak reaksiyonu, toplam kireç, organik madde, β-Glukosidaz ve toprak mikrobiyal solunumu farklı bakılardan etkilenmiştir. Güney bakılarda kireç, pH ve toprak mikribiyal solunumu yüksek iken, organik madde ve β-Glukosidaz aktivitesi kuzey bakılarda yüksek bulunmuştur.

Derinliğe bağlı olarak da organik madde miktarının azaldığı, fosfataz enzim aktivitesinin arttığı görülmüştür. Alt derinlikte fosfataz aktivitesindeki bu artışın, üst derinlikte yüksek inorganik fosfor miktarının fosfataz aktivitesini engellemesinden kaynaklandığı düşünülmektedir.

Sonuç olarak bu çalışmada daha önce olatma yapılan açık alanların ağaçlandırılmasının toprağın elektirksel iletkenliğini, organik maddesini, β-Glukosidaz ve üreaz enzimleri aktivitesini ve toprak mikrobiyal solunumunu-CO_2 çıkışını etkilediği görülmüştür. Elde edilen veriler değerlendirildiğinde, yarı kurak bölgemizde otlatmaya maruz açık alanın karaçam plantasyonuna dönüştürülmesi ile ağaçlandırmanın erken dönemlerinde toprak organik karbonundaki azalmanın toprak verimliliği ve uzun dönemli toprak organik karbon depolaması açısından olumsuz sonuçlar doğurduğu düşünülebilir fakat bu negatif etki ağaçlandırmanın ilerleyen yaşlarında kaybolmaktadır.

Enzim aktiviteleri doğal koşullar altında geniş ölçüde değişkenlik gösterir. Bundan dolayı toprak sağlığının doğru değerlendirilmesi için toprak enzim aktiviteleri diğer fiziksel, kimyasal ve mikrobiyal ölçümlerle birlikte yürütülmeli ve bu konuda daha kapsamlı çalışmalar yapılmalıdır. Toprak toplam ve yarayışlı azot, fosfor miktarları yanında bazı verimlilik indeksleri (C_{mic}/C_{org}, qCO_2 vs.) nin tespiti ve toprak özellikleriyle ve süreçleriyle ilişkilerinin ortaya koyulduğu çalışmalarn yapılmasının bu araştırmada sunduğumuz değişimlerin işleyişlerini anlamamız açısından faydalı olacağı düşünülmektedir.

Anahtar kelimeler: Ağaçlandırma, toprak enzim aktivitesi, mikrobiyal solunum

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