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Original Article

Seasonal Changes of Microbial Biomass Carbon, Nitrogen, and Phosphorus in Soil Under an Oriental Beech Stand

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ABSTRACT

Microbial biomass, which is both a pool and a nutrient source for plants, is commonly accepted as an index indicating the health and fertility of the soil. Soil microbial biomass at higher levels can be obtained through the presence of more favorable environments, availability of nutrients and organic carbon, soil moisture content and temperature, and residues from plants. This study investigated the seasonal variation of some physical-chemical properties and the carbon, nitrogen, and phosphorus in the microbial biomass of the soil under an oriental beech stand in the Arıt-Bartın region of Turkey. A chloroform fumigation-extraction procedure was applied to the fresh soil samples to determine the C, N, and P in their microbial biomass. The results showed that the highest mean contents of microbial biomass of carbon (C_{mic}), nitrogen (N_{mic}), and phosphorous (P_{mic}) of soil were measured in autumn (C_{mic} = 650.51; N_{mic} = 128.39; and P_{mic} = 30.77 µg g^{-1}) and the lowest in spring (C_{mic} = 516.75; N_{mic} = 83.33; and P_{mic} = 21.40 µg g^{-1}). This can be explained by the lower levels of organic carbon (C_{org}), total nitrogen (N_{total}), and available phosphorus (P) in the soil during spring. In addition, a positive correlation was found between microbial biomass and the moisture and temperature of the soil, C_{org}, N_{total}, and available P. These findings indicated that the soil temperature and soil moisture, along with the above-mentioned variables, affect the level of C_{mic}, N_{mic}, and P_{mic} of soil. Except for the soil reaction (pH), the C_{org}:N_{total} ratio, and soil C_{mic}, a notable seasonal change was found in some physical-chemical properties of the soil and in the P and N in the microbial biomass under the oriental beech stand.

Keywords: Fagus orientalis Lipsky, forest soil, organic matter, phosphorus, soil characteristics, soil microbial biomass

Introduction

Microbial decomposition of organic residues in soil plays a vital role in the cycles of the nutrients essential to plants, for example, nitrogen (N), oxygen (O), sulfur (S), and trace elements. During the process of mineralization, considerable amounts of carbon (C), N, and phosphorous (P), as cellular constituent parts of the decomposing residues, are inhibited, but are later liberated upon the death of the microbial biomass (Chen et al., 2018; Pankhurst et al., 1997). The microbial biomass in the soil, in addition to being a nutritional source and nutrient sink, is a vital element in forest ecosystems. The soil microbial biomass is the chief component in the decomposer sub-system, which regulates nutrient cycling, the energy flow, and ultimately, the productivity of plants and the ecosystem. Every change in the microbial biomass may affect the turnover of the organic matter in the soil. Thus, the microbial biomass in the soil directly impacts ecosystem fertility and stability (Bolat, 2014; Yang et al., 2010). The soil microbial biomass can respond rapidly to the temperature, moisture, and nutritional status of the soil organic matter as well as to its amount and type. The soil microbial biomass can be used in the ecological study of the soil and sustainable environmental management as an indicator of soil fertility and health (Bargali et al., 2018; Rawat et al., 2021; Yadav, 2012). At the same time, seasonal changes in microbial biomass can have considerable consequences for the nutrient cycle and the functioning of the ecosystem (Lipson et al., 2002). It has been reported by many researchers (Haron et al., 1998; Mlambo et al., 2007) that in an ecosystem, the soil microbial biomass size at any given time is determined by the fresh carbon and nutrient input from litter and by the past input of soil organic matter.

Like other soil microorganisms, soil microbial biomass also requires C and nutrients for metabolism and growth; therefore, their deficit will restrict the soil microbial biomass activity (Holub et al., 2005). Numerous studies have shown that microbial biomass in the soil under a forest ecosystem is directly affected by seasonal changes, especially changes in the temperature and moisture content of both the air and soil (Aponte et al., 2010; Bolat et al.,

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2015; Wang et al., 2020). Seasonal variations have caused changes in the moisture content and temperature of the soil, the root activity, and the organic matter returned to the soil via litterfall and rhizodeposition (Chen et al., 2003). Information on soil C_{mic} and N_{mic} in various forest ecosystems has been reported by a number of studies (Bargali et al., 2018; Bolat, 2014; Bolat & Şensoy, 2019; Bolat et al., 2015). However, information is limited on seasonal changes in the C_{mic}, N_{mic}, and P_{mic} in oriental beech forest ecosystems in Turkey as compared to other countries. Hence, the present study aimed to investigate seasonal fluctuations in some physical-chemical characteristics and in the C_{mic}, N_{mic}, and P_{mic} contents of the soil under an oriental beech stand in Arıt-Bartın.

Material and Methods

Study Area

The sampling area of the study is located within the 41°39' northern latitude and within the 32°36' eastern longitude. The study area is covered by a temperate mixed forest dominated by oriental beech (*Fagus orientalis* Lipsky), which is indicated by the number 130e in the management plan. The oriental beech stand covers about 13.4 ha. The average altitude of this stand is approximately 775 m ASL (range 710–840 m). Its average slope is 47% (25°) and the dominant aspect includes both the north and the northwest (Figure 1). The stand canopy closure averages 85% (70–100%), with the number of trees in the stand at 337 trees per hectare. Additionally, the stand is fairly homogeneous in terms of basal area, age, productivity (mainly phytomass), and growth. The average diameter at breast height is 26 cm and the average tree height is 27 m (Turkish General Directorate of Forestry [TGDF], 2001).

The average annual values for precipitation and temperature are 1,431.4 mm and 8.8 °C, respectively for the study area, which is located 35 km from the Bartın city meteorological station (Turkish State Meteorological Service [TSMS], 2009). The region, designated as having a mesothermal climate, is quite humid and features warm summers. There are four distinct seasons: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). Based on the meteorological station data for the study area gathered over the past 31 years, there is no dry season. The mean annual temperatures reach a maximum (18.2°C) in July and a minimum (0.3°C) in January (Figure 2). A moder humus form (2–4 cm) is found under the oriental beech stand. In the study area, limestone (calcareous, stony, and fine-textured) comprises the main bedrock. Hence, the soil is characterized by a clay texture (sand 24.1% and clay 48.8%) and its bulk density is 1.19 g cm^{-3}, with pore space of 54.7%.

Soil Sampling and Laboratory Methods

Soil Sampling

Topsoil (0–5 cm) samples for both physical-chemical and biochemical analyses were obtained methodically from 15 different sites under an oriental beech stand in the spring, summer, autumn, and winter seasons. For each season, 30 soil samples from each site (120 in total) were collected under the oriental beech stand. For physical-chemical analyses, soil samples were collected at 0–5 cm depth from the topsoil as 9.1-diameter soil cores. These were then ground and passed through a 2-mm sieve after air drying. For biochemical analyses, after removing the plant, root, and stone debris from the soil samples, they were passed through a 2-mm sieve and then stored at 4 °C until the measurements for C_{mic}, N_{mic}, and P_{mic} were carried out.

Physical and Chemical Soil Analyses

The soil moisture content was determined gravimetrically by drying the samples at 105°C. At the same time as the soil samples were collected for each season, the soil temperature was recorded in the field using temperature sensors inserted in the soil at a depth of 0–5 cm. The hydrometer technique described by Bouyoucos (1962) was used to determine the distribution of particle size. The soil pH was measured using a pH meter with a glass electrode (soil–water suspension 1:2.5, w/v). For determination of soil C_{org}, the chromic acid digestion method was used (Walkley & Black, 1934) and for N_{total} concentration,

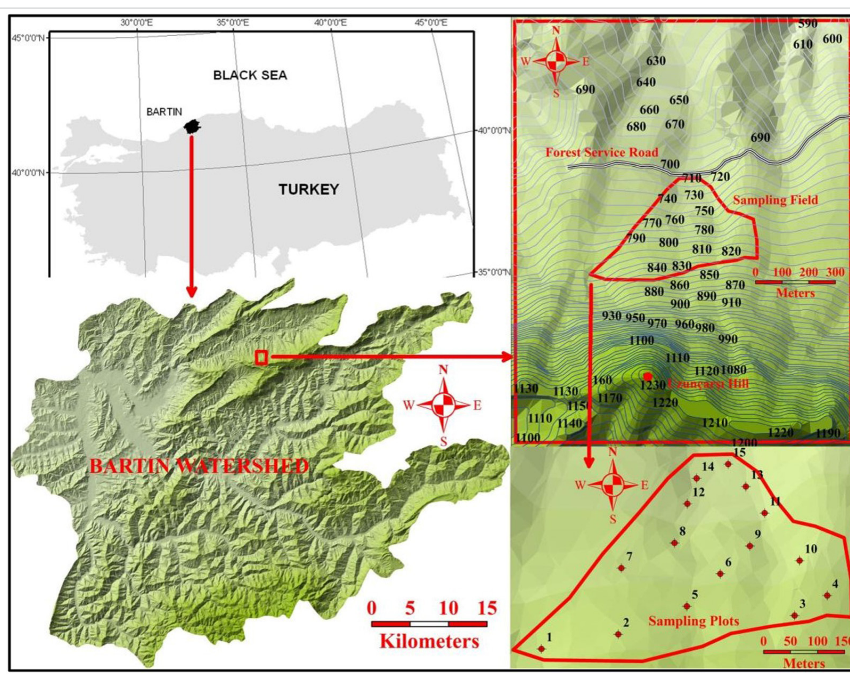

Figure 1.
Location of the Sampling Plots and Field Within the Bartin River Watershed (Basin) at the Western Black Sea Region of Turkey.

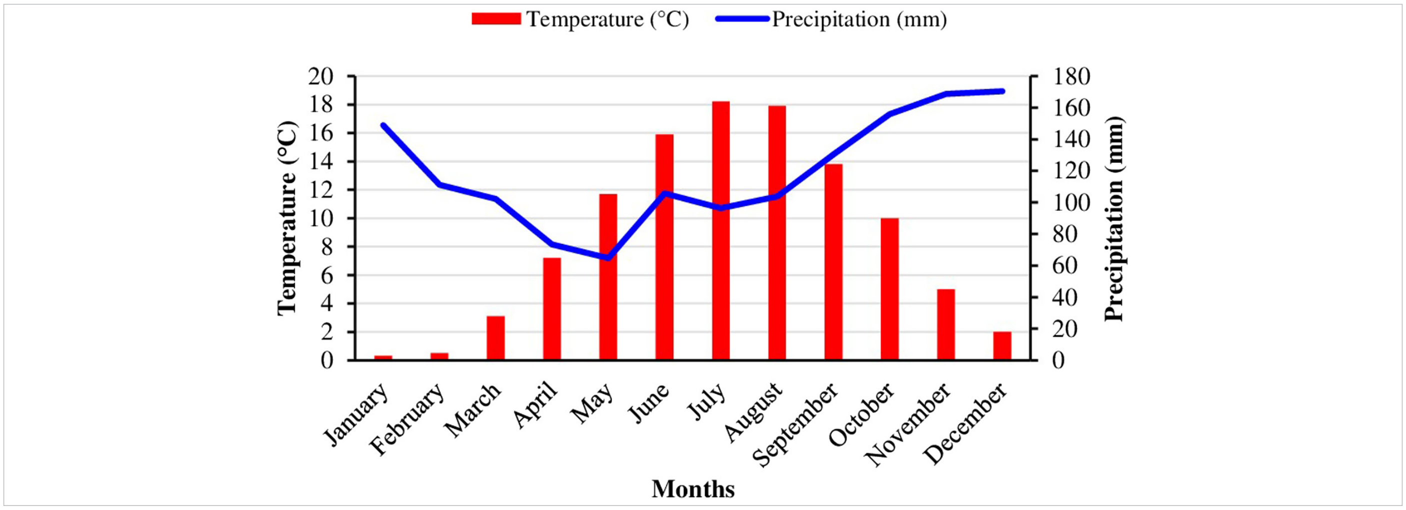

Figure 2.
Average Monthly Precipitation and Temperature in the Study Area Based on Bartin City Meteorological Station (1979–2009).

the micro-Kjeldahl digestion method was applied (Rowell, 1994). Available P was extracted by modifying ammonium molybdate-ascorbic acid and then determined at a wavelength of 880 nm using a UV–Vis spectrophotometer (UV-2450 Shimadzu) to measure blue light absorption (Anderson & Ingram, 1996; Rowell, 1994).

Biochemical Soil Analyses

A chloroform fumigation extraction procedure was applied to the fresh soil samples in order to determine the C, N, and P in their microbial biomass (Anderson & Ingram, 1996; Brookes et al., 1982; Olsen et al., 1954). Eqn.1–2 were used in the calculation of soil C_{mic} (Vance et al., 1987):

$$E_C = \left(\text{biomass } C_{\text{fumigated}} - \text{biomass } C_{\text{unfumigated}}\right) \quad (1)$$

$$C_{\text{mic}} = E_C * 2.64 \quad (2)$$

where 2.64 represents the proportionality factor of the biomass C discharged by fumigation extraction.

Equations 3–4 were used to calculate soil N_{mic} (Brookes et al., 1985).

$$F_N = \left(\text{biomass } N_{\text{fumigated}} - \text{biomass } N_{\text{unfumigated}}\right) \quad (3)$$

$$N_{\text{mic}} = \frac{F_N}{0.54} \quad (4)$$

where .54 represents the fraction of the N_{mic} resulting from fumigation extraction.

Equations 5–6 were used to calculate soil P_{mic} (Brookes et al., 1982).

$$E_P = \left(\text{biomass } P_{\text{fumigated}} - \text{biomass } P_{\text{unfumigated}}\right) \quad (5)$$

$$P_{\text{mic}} = \frac{E_P}{0.40} \quad (6)$$

where .40 is the fraction of P_{mic} resulting from fumigation extraction.

Statistical Analyses

One-way variance analysis (ANOVA) was carried out to reveal the seasonal differences in the soil properties (physical, biological, and chemical). The mean values of the physical-chemical soil properties and the soil microbial N, C, and P, depending on the season, were compared using Tukey's HSD and Tamhane's T2 tests, with the differences among soil samples indicated at a 95% confidence interval ($p < .05$).

Results and Discussion

Physical and Chemical Soil Properties

According to the seasons, soil moisture content was at a minimum during the summer and at a maximum during the winter, whereas soil temperature was at a minimum during the winter and at a maximum during the summer. In addition, soil moisture content and temperature both differed significantly ($p < .05$) depending on the season. Soil temperature and moisture content are the most important environmental factors influencing microbial activity and growth in soils (Pietikäinen et al., 2005). It is generally accepted that there is an approximate doubling of microbial activity in soil for each 10°C rise in temperature, up to around 30–35°C (Bardgett, 2005). Soil reaction (pH) was greater during the spring, decreased sharply during the autumn, and again increased during the winter through the rainy seasons. Nevertheless, no statistically significant ($p > .05$) seasonal differences were found (Table 1). The fact that the soil reaction was around 5 (pH 5) in all four seasons may have been due to the high amount of total rainfall during the year (approximately 1430 mm) and the subsequent heavy leaching. As a result, moderately acidic soils had developed in the study area. Bacteria and fungi are the most important groups of soil microorganisms. Most bacterial species have been found to grow at a pH of 4–9, whereas optimal growth of soil fungi usually falls in the pH range of 4–6 (Paul & Clark, 1996). The lower soil pH in the autumn season could have been the result of the potential loss of plant nutrients through leaching (Sarıyıldız, 2008). The soil C_{org} content varied significantly depending on the season. It was significantly ($p < .05$) higher in the summer and winter seasons than in the spring and autumn. These seasonal differences in the content of soil C_{org} depended strongly on the organic matter amount, soil temperature, and soil moisture content, that is, the climate. This rise in the amount of soil C_{org} during the summer and winter was the result of an increase in organic matter, presumably nutrient-rich leaf litter and other plant materials added to the soil and also of the recycling of these nutrients, as reported by Singh and Ghoshal (2011). Moreover, the rising of soil temperatures during summer seasons has definitely been shown to enhance mineralization of soil organic matter/decomposition of plant residues (Paul, 2007).

Similarly, the highest soil N_{total} concentration found during the summer season may have resulted from the regular supplementation of plant litter containing above- and below-ground parts of plants and the acceleration of mineralization by soil microorganisms under suitable soil temperature and moisture conditions. The slight increase in soil N_{total} concentration during the winter compared to autumn was mostly a result of lower soil temperature and higher soil moisture content depending on high precipitation, which reduce microbial activity and rates of decomposition (Bardgett, 2005). The lowered concentrations of N_{total} during the spring, autumn, and winter seasons (e.g., rainy season) indicate that this element is excessively leachable, which was suggested by Maithani et al. (1998) and Barbhuiya et al. (2004). In addition, the decrease in soil N_{total} during these seasons, as well as in the spring, might mostly be attributed to the greater demand for this element by oriental beech, which continues its growth during these periods. This is in agreement with Maithani et al. (1998), who reported that the reduction in ammonium and nitrate-N during the rainy season may mainly result from the increased need of higher plants for these nutrients, as this is their most vigorous growth period. The decomposition rate (e.g., C_{org}:N_{total} ratio) varied seasonally, with the maximum value seen in spring and the minimum in autumn. However, no significant seasonal difference was found in the C_{org}:N_{total} ratio.

Soil available P values were lowest in the spring, rose to reach maximum values during the summer, saw a sudden decline in the autumn, and finally showed an increase in the winter. Significant ($p < .05$) seasonal differences were also found in the soil available P. Throughout most of the world, after N, P is considered to be the most important soil nutrient. The amount of P that comes into solution and is taken up by crops during their life cycle is known as available P. Soil available P is specific to the time and the crop and is therefore a quantitative/extensive parameter. Crop uptake/sorption leads to a rapid decline in available P, whereas the application of fertilizer will cause a rapid rise. The characteristics of the soil affect the rates of decline or increase of available P. These rates differ greatly among soils and depend on the soil characteristics that are essential in its quantification (Holford, 1997). It was reported by Chen et al. (2012) that the major impact factors on available P content in soil were total P content, organic matter content, and soil pH value. The available P content increases in parallel with the organic matter content (positive linear correlation) and with the decrease of the soil pH value (negative linear correlation). Therefore, in this study, the available P content change according to the seasons might be associated with the change in soil C_{org} content as there was no significant change in soil pH values (Table 1).

Biochemical Properties of Soil

Soil Microbial Biomass C (C_{mic})

The soil samples showed seasonal variations in the maximum–minimum contents of C_{mic}, which were found as 516.75–650.51 µg g^{-1}. The highest content of soil C_{mic} was observed in autumn and the lowest in spring. However, the one-way ANOVA revealed that there were no significant ($p > .05$) seasonal differences in the soil (Figure 3). In other words, the soil content of C_{mic} was not significantly affected by the season.

The content of soil C_{mic} is known to be higher in the autumn because soil conditions may be more suitable then, in terms of temperature and moisture content of the soil, C_{org}, and the presence of plant residues that produce considerable energy for the growth of the microbial biomass (He et al., 1997). During this season, soil temperature and moisture (i.e., water availability) would no longer restrict the growth of the microbial biomass (Figure 1; Table 1). In the current study, the correlation was positive ($r = .178$), although, not significant ($p > .05$) between the soil C_{mic} and soil temperature. At the same time, the correlations between soil moisture and the soil C_{org} and soil C_{mic} were positive ($r = .193$ and .233, respectively) and significant ($p < .05$). It is reported in the literature that the amount, availability, and quality of C_{org} and other nutrients available from organic amendments, root exudates, and plant residues directly affect microbial biomass size and activity (Bolat, 2019; Bolat & Öztürk, 2016; Habekost et al., 2008; Rawat et al., 2021). On the other hand, in the oriental beech ecosystem studied, a higher C_{mic} content was not observed with the higher C_{org} content in the summer. Accordingly, other factors, such as interactions with soil fauna, were presumably responsible for the increase in the autumn season. Otherwise, declines in C_{mic} during the spring and winter are most likely ensured by low soil temperatures and high soil moisture, especially in the winter. The uptrend in C_{mic} in the winter compared to that in the spring could have originated because a greater amount of the fungi were affected by humidity, as reported by Diaz-Ravina et al. (1995), since soil moisture content was the highest in the winter (Table 1). Additionally, literature studies have shown that the proportion of bacterial biomass compared to fungal biomass is lowest in the winter and increases in the

Table 1.
Changes in Some Physical and Chemical Properties of Soil Among the Seasons

	Seasons			
Some Physical and Chemical Properties of Soil	Spring	Summer	Autumn	Winter
Moisture at the time of sampling (%)	40.11^a	25.88^b	38.94^a	53.77^c
Temperature at the time of sampling (°C)	9.70^a	18.07^b	13.34^c	6.64^d
pH (H_2O)	5.19^a	5.48^a	5.00^a	5.33^a
Organic C (%)	3.26^a	4.15^b	3.44^a	3.75^b
Total N (%)	0.20^a	0.26^b	0.23^a	0.24^b
C_{org}:N_{total} ratio	15.71^a	15.52^a	14.92^a	15.05^a
Available P (µg g^{-1})	6.01^a	8.56^b	7.45^b	8.51^b

Note: The values shown by different lower-case letters among the seasons are significantly different ($p < .05$).

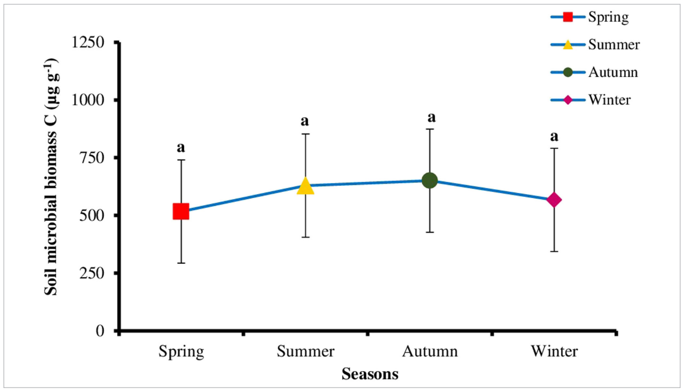

Figure 3.
Seasonal Changes in Microbial Biomass C Content of Soil Samples. Values Shown by Similar Lower-Case Letters Among the Seasons Are Not Significantly Different (p > .05).

summer because fungal biomass is more adapted to cold temperatures and benefits from the complex substrates, cellulose, and vanillic acid, whereas bacterial biomass utilizes the simple amino acids and glycine. Hence, these differences in substrate utilization could represent the different substrates available seasonally, that is, in the summer, fresh plant material, live roots, and their exudates, and in the winter, dead plant material (Lipson et al., 2002).

Soil Microbial Biomass N (N_{mic})

The current study found 30.04 and 315.21 µg g^{-1} N in the soil microbial biomass in the spring and autumn seasons, respectively. Significantly ($p < .05$) higher average amounts of soil microbial biomass N (N_{mic}) were recorded in the autumn, followed by the summer season (Figure 4).

This study found that the reason these amounts were higher in the autumn and summer than in the other seasons may be attributed to temperate and humid periods (Figure 1), high soil C_{org} content, rapid decomposition rates (relatively low C_{org}:N_{total} ratio; Table 1), and consequently, high microorganism activity. Unlike in the spring and winter, during the summer and autumn, an increase in N_{mic} was to be expected because of rising soil temperatures and sufficient soil moisture. Similarly, the literature indicates that the effects of seasonality on microbial populations appear to result from changes in soil temperature and moisture and the quality of the organic matter, all of which regulate microbial processes like immobilization and mineralization (Aponte et al., 2010). Moreover, in the literature, it is reported that close relationships exist between the microbial biomass and the moisture content in the soil (Devi & Yadava, 2006; Tan et al., 2008), soil temperature (Bell et al., 2009), C_{org} (Bolat, 2019; Tan et al., 2008), and the organic matter from litterfall returned to the soil (Chen et al., 2003). In this study, a positive relationship was found between the N content of the microbial biomass and soil temperature ($r = .265$; $p < .01$) as well as N_{total} ($r = .510$; $p < .01$). Although not significant ($p > .05$), a positive, correlation ($r = .167$) was found between soil moisture content and N_{mic}. The soil N_{mic} contents varied from 83.33 to 128.39 µg g^{-1} (mean: 105.89 µg g^{-1}), which were lower than concentrations reported in broad-leaved deciduous forest soils (36–347 µg g^{-1}; mean 126.9 µg g^{-1}) (Joergensen et al., 1995a) and in mixed deciduous forest soils (61.1–229.8 µg g^{-1}; mean 129.9 µg g^{-1}) (Kara & Bolat, 2008); however, they were comparable to those in a mixed-oak forest ecosystem (18.5–115.7 µg g^{-1}) (Devi & Yadava, 2006), and in temperate forest soils (84.1–92.6 µg g^{-1}) (Kara et al., 2008). Contents of soil N_{mic} might have been affected by the vegetation type because several authors (Malchair & Carnol, 2009; Yue et al., 2017) have reported that soil organic matter quantity and dynamics, along with microsite conditions, were potentially influenced by changes in tree species and composition. This finding suggests that the moderate soil temperatures and moisture during the summer and autumn seasons provide more favorable conditions for soil microbial biomass. However, the lower temperature and higher moisture content of the soil may be an obstacle to the growth of the microbial biomass in the ecosystem and may explain why microbial biomass declined during the spring and winter seasons.

Soil Microbial Biomass P (P_{mic})

Soil microbial biomass P (P_{mic}) values ranged from 3.66 µg g^{-1} (in spring) to 66.16 µg g^{-1} (in autumn), that is, in the soil samples, the lowest P_{mic} value was found in the spring, whereas the highest was seen in the autumn. Similarly, average values of P_{mic} were at a minimum in the spring and a maximum in the autumn. According to the one-way ANOVA, the results indicated that the average P_{mic} content varied significantly ($p < .05$) depending on the season (Figure 5).

Soil P_{mic} is an important potential source of soil available P since the microbial biomass in the soil frequently includes up to 20–30% of the pool of total soil organic P (Bardgett, 2005). Soil P_{mic} increases consistently from the spring to autumn seasons and decreases thereafter (Figure 5). This might be attributed to the increments in both the available P amount

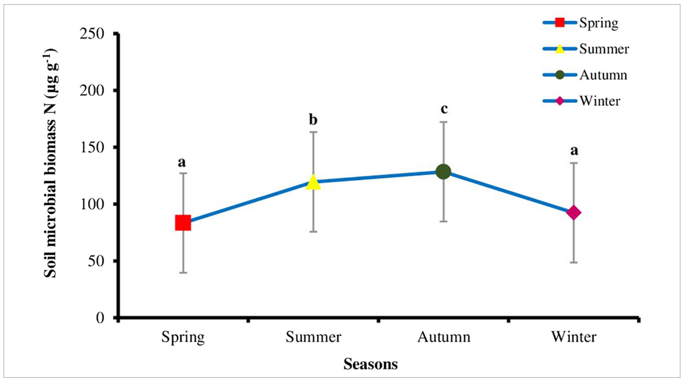

Figure 4.
Seasonal Changes in Microbial Biomass N Content of Soil Samples. Values Shown by Different Lower-Case Letters Among the Seasons Are Significantly Different (p < .05).

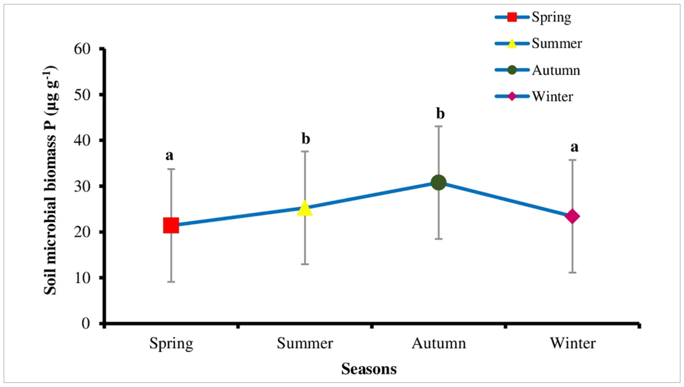

Figure 5.
Seasonal Changes in Microbial Biomass P Content of Soil Samples. Values Shown by Different Lower-Case Letters Among the Seasons Are Significantly Different (p < .05).

and the soil microbial biomass size. Notably, Hedley et al. (1982) stated that more P is generally assimilated by microorganisms that grow in a high P-content medium than by those that grow in a low P-content medium. According to some authors, the seasonal variation seen in soil microbial biomass reflects the level of mineralization-immobilization of the nutrients in the soil. A rise in the amount of soil microbial biomass may result in immobilization of nutrients, whereas its reduction can lead to nutrient mineralization (Bargali et al., 2018; Bolat et al., 2016; Yang et al., 2010). Additionally, there was a significantly positive correlation of the P_{mic} in the soil with the available P, as previously reported by Tan et al. (2008). Therefore, the high soil P_{mic} in the summer and autumn seasons in this study might be explained by the greater microbial immobilization of nutrients in the decomposing litter. In the study, significant ($p < .01$) positive correlations ($r = .258$, .404, and .286) were found between the moisture content of the soil, C_{org}, and available P, respectively, with the soil P_{mic}. Although not significant ($p > .05$), a positive correlation ($r = .075$) was found between P_{mic} in the soil and the soil temperature. The mean monthly temperature for the spring in our study area is 9.7°C and for the winter 6.6°C. Therefore, the lower P_{mic} in the spring and winter may well be related the low soil temperature in these seasons. In addition, low values of soil P_{mic} in the spring and autumn might be explained by the lower soil microorganism activity and slower decomposition rates as a result of the low soil temperature, as previously reported by Bargali et al. (2018) and Rawat et al. (2021). Contents of P_{mic} in the soil were well within the specified ranges for soils of deciduous woodland, meadows, and arable land (5–67 μg g^{-1}) (Brookes et al., 1984), for tropical wet-evergreen forests (16.74–36.85 μg g^{-1}) (Barbhuiya et al., 2004), and for mixed pine forests (13.6–42.9 μg g^{-1}) (Chen et al., 2003). Moreover, the soil P_{mic} obtained in the study is consistent with the 9.23–74.81 μg g^{-1} range for subtropical humid forests (Arunachalam & Arunachalam, 2000), the 0.20–68.25 μg g^{-1} range for a temperate forest ecosystem (Rawat et al., 2021), and the 17.7–174.3 μg g^{-1}: mean 60.6 μg g^{-1} for *Fagus slyvatica* forests (Joergensen et al., 1995b).

Conclusion

Except for soil reaction (pH), C_{org}:N_{total} ratio, and soil C_{mic}, seasonal changes were found in the physical, chemical, and biological (e.g., N_{mic} and P_{mic}) properties of the soil at the sites in the study area. Moreover, in the present study, the changes in soil C_{mic}, N, and P were relatively high during the summer and autumn seasons, whereas they were low during the spring and winter. In other words, soil C_{mic}, N_{mic}, and P_{mic} were high during the summer and autumn when soil moisture content and temperature conditions were suitable for microbial activity. Hence, current knowledge indicates a close relationship of the soil microbial biomass with the soil temperature and moisture content, C_{org}, and N_{total}. Thus, the microbial biomass is quite sensitive to the changes in environmental conditions. High soil microbial biomass during the summer and autumn seasons may be considered as a kind of nutrient preservation strategy that prevents the loss of plant nutrients from the ecosystem as a result of leaching during the decomposition process. Consequently, any soil microbial biomass will be a net sink or source for C, N, and P, presumably dependent upon interaction between the dynamics of microbial population and environmental factors (e.g., soil moisture, temperature, and substrate availability) during seasonal transitions. Similarly, new research to be carried out in the study area will clearly reveal the changes (positive or negative) in the ecosystem, both seasonally and temporally. In addition, the basal respiration and metabolic coefficient are other indicators of soil health and productivity. Therefore, more accurate results can be obtained in terms of the ecosystems if studies involving these factors are carried out.

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