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Fine Root Biomass in Acer monspessulanum Trees and Its Relation to Ecological Factors in Zagros Mountain Forests

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ABSTRACT

Aims Roots of diverse diameters and various physiological behaviours and physical roles compose the root systems of forest trees and its distribution influence the quantities and distributions of plant obtainable water and nutrient.

Materials & Methods Fine roots of Acer trees (n=40) were sampled randomly at soil depths of 0-15 and 15-30 cm in north and south positions under canopy of trees. The fine roots were washed (d≤ 2 mm) and dried at 70°C and weighed. Furthermore, diameter at breast height (cm), total height (m), crown (m) for target trees and slope, altitude, and exposition of each sample point were measured in research site.

Findings The results showed that soil depth has been influenced on fine root biomass; so, the highest amount was observed in depth of 15-30 cm rather than 0-15cm. The difference between elevations was not significant with regard to fine root biomass. The value of biomass in west aspect was greater than east one. The slope had no effect on the fine root biomass of trees in the site, as well Pearson correlation coefficient indicated that with increasing crown of trees, fine root biomass was increased. There was a positive correlation ($p<0.05$) between the biomass of fine roots and BD (gr.cm-3), sand (%) and a negative, but statistically insignificant correlation with P ($p<0.05$)

Conclusion We found that depth of soil profile, exposition, crown of trees, as well as bulk density and sand (%) appeared to be a contributing factors for fine root biomass values in Acer trees.

Keywords Montpellier Maple; Soil; Tree Root

CITATION LINKS

[1] Are beech (Fagus sylvatica) roots ... [2] Patterns of root respiration rates ... [3] Fine root dynamics in relation to nutrients in ... [4] Methods for estimating root biomass and production ... [5] Fine root interactions in subtropical mixed ... [6] Fine root distributions of shelterbelt trees ... [7] Fine root biomass and dynamics in beech ... [8] stands depending on the climatic ... [9] Fine-root dynamics change during stand ... [10] Modelling fine root biomass of boreal tree ... [11] Effect of stand age on fine-root biomass and ... [12] Soil microarthropods alter the growth and ... [13] Fine root dynamics of trees and ... [14] Root turnover and root necromass ... [15] Root biomass along subtropical to ... [16] Effects of tree species and topography on ... [17] Fine root vertical distribution and temporal ... [18] Autecology of Montpellier maple ... [19] Spatial pattern analysis of Montpellier ... [20] Floristic investigation of Noujian ... [21] Differences in fine root traits ... [22] Extremely low fine root biomass in Larix ... [23] The role of environmental filters and ... [24] Methods of soil ... [25] Annual and seasonal changes ... [26] Quercus ilex forests are influenced by ... [27] Fine root biomass, production ... [28] Soil reinforcement by the roots ... [29] Fine root biomass and root ... [30] Mean root depth estimation ... [31] Why fine tree roots are stronger than ... [32] Vertical distribution of fine roots ... [33] Carbon and nitrogen accumulation ... [34] Fine root production and turnover in ... [35] Fine root biomass dynamics and ... [36] The relationship between tree diameter ... [37] Modelling height to diameter ratio ...

Introduction

Trees must stake restricted resources, including water and nutrients within forest and, clearly, roots of trees show a vital role in this regard [1]. Roots of diverse diameters and various physiological behaviours and physical roles compose the root systems of forest trees [2].

In belowground net primary productivity, fine and coarse roots of trees are the main funders, and also show acute characters in the biogeochemical cycling of forest ecosystems [3, 4]. To maintain the plant growth and existence, fine roots (d≤2 mm) are liable for attaining nutrients and water from the soil [5, 6], and its distribution influences the quantities and distributions of the plant obtainable water and nutrient [6].

Tree fine roots show a significant role in forest ecosystems [7] and the type of the root system is a forest trees characteristics changed via environmental situations such as soil environment as well as climatic conditions [8]. Fine roots make about 2–5% to total forest biomass [9] and play a significant role in carbon and nutrient dynamics of forest ecosystems [10]. The growth of fine root is determined to a great extent by quantity of nutrient in the soil, but other ecological situations such as soil temperature and soil water conditions influenced it [11]. The growth level and morphological features of fine root systems are essential for nutrient uptake of trees in forest soil environment [12]. Through forest development stages, changes in composition and structure of plant species and also physico-chemical properties of soil might influence fine root features, including biomass, production, and turnover amounts [13]. Most studies investigated different fine root features of tress within forest ecosystems [14-16]. The findings of these studies reflect the role and function traits of fine roots in trees structure in forests. To calculate the role of fine roots in material cycling, it is essential to know about its distribution, tree biomass, and nutrient quantity [17].

Zagros forests in the west of Iran are one of the important forest ecosystems and *Acer monspessulanum* subsp.*cierascence* (Family *Aceraceae*) is known as a dominant tree species within this forest. This tree species, as woody and deciduous plant found at high elevations, plays an important ecological and diversity protection role in Zagros region. Several studies were conducted on interactions of various environmental factors and some features of this tree [18, 19], but research on fine root of this species is scarce.

The aim of the present research was to determine the fine root biomass (FRB) of *Acer monspessulanum* subsp.*cierascence* in mountain forests of western Iran, Lorestan. Our specific objectives were: (i) to identify the effect of exposition, elevation, slope, and soil depth on biomass of fine roots, (ii) to measure correlation between some features of trees as well as soil properties and FRB. So, we tested the hypotheses that (i) physiography and soil depth of site affect the biomass of fine roots, and (ii) correlation between some features of trees as well as soil properties and FRB is significant.

Materials and Methods

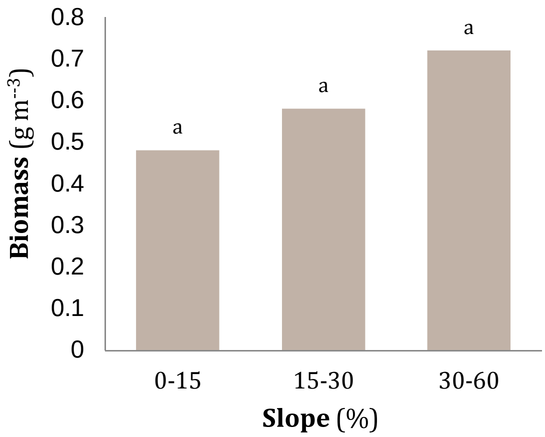
Study area: The fine root sampling of trees was carried out in the mountain forest of Zagros (33°15′ to 33°17′N, 48°25′ to 48°27′E), which is located approximately 35 km southwest of Khorramabad, Lorestan province, Iran. This mountainous region has an altitude ranging from 2050 to 2300 m a.s.l. The study site was situated on moderately steep slopes (4-30%). In order to investigate FRB of Acer trees, a 53 ha site was defined in October, 2016. The climate is cold-semi-humid and the minimum and maximum mean annual temperature are -7°C and 43.2°C, respectively. The annual precipitation is 400-500 mm. The major soil type is Entisols and Inceptisols [20].

Data collection: Trees root sampling in research site was conducted in October 2016. We used a soil corer with an inner diameter of 8 and a length of 30 cm. The healthy trees (n=40) were selected randomly within stand and the soil cores were collected at 1 m intervals from the stem of each tree in south-north direction [21] in depths of 0-15 and 15-30 cm [22]. Soil samples (n=80) were stored in plastic bags at 4°C [5, 7] until processed. In the laboratory, all samples were washed in water and cleaned from soil residues, using a sieve of 1 mm mesh size. Then, fine roots (d≤2 mm) were collected [5, 7] and root samples were dried at 70°C (48 h) and weighed [7, 22, 23]. In stand, diameter at breast height (cm), total height (m), crown (m) for target trees, slope, altitude, and exposition of each sample point were measured. In site, 3 classes of slope (0-15, 15-30, and 30- 60%), 2 expositions (east and west) and 2 altitudes (2000-2150 and 2150-2400 m a.s.l.) were identified. Mineral soils were sampled in south-north direction of target trees and at a distance of 1 m from the base of the stem of trees, where forest floors had been removed. Mineral soil sampling was confined to the upper 0-30 cm of soils. One composite sample (n=20) was prepared by taking sub-samples from 2 points in each plot. All soil parameters including organic carbon (%), N, P, K, pH, bulk density, and soil texture were measured based on Page [24].

Data analysis: All data were tested for a normal distribution, using Kolmogorov-Smirnov test and datasets indicated a normal distribution. Data were tested for the homogeneity of variances with Levene's test. Thus, for the comparison of soil depth, exposition and altitude, parametric statistics (independent T test) was used. A one-way analyses of variance (ANOVA) was performed for analysing the effect of slope position on FRB. S.N.K test was used for multiple comparisons of FRB in relation to slope positions following the results of one-way ANOVA. To calculate interaction between FRB and soil properties, physiographic factors with tree morphology and Pearson's correlation coefficient were used. All statistical analyses were performed with SPSS software and the statistical significance was done based on α=0.05.

Findings

Soil depth significantly differed in the FRB within the site as the second depth (15-30cm) significantly provided greater value (g m^{-3}) than depth of 0-15 cm (Table 1). The difference between elevations was not significant in regard to FRB (t=0.899; p=0.370; Diagram 1a). The exposition significantly affected FRB and the value of biomass in west aspect was greater than east one (Table 1). The result indicated that different slopes had no significant effect on FRB in forest stand (t=1.130; p=0.326; Diagram 1b). A positive significant correlation of FRB with crown (r=0.424, p=0.009) and slightly negative correlation with height (r=-0.034, p=0.842) of trees has been detected, but there was no significant correlation with diameter at breast height (DBH; r=0.226; p=0.171; Diagrams 2a, 2b, and 2c). According to Pearson correlation analyses (Table 2), FRB indicated a significant positive correlation with Bulk Density (BD; gr cm^{-3}), sand (%) and a negative, but statistically insignificant correlation with Phosphorus (P; ppm). Soil characteristics in different expositions were comparable (Table 3). In general, we did not observe very great differences between expositions in regard to soil variables. Although there was small difference in P and N contents between expositions. Descriptive characteristics of Acer trees are presented in Table 4 and Pearson's correlation coefficients indicate negative correlation between elevation and height, crown depth, and H/D ratio of trees in site (Table 5).



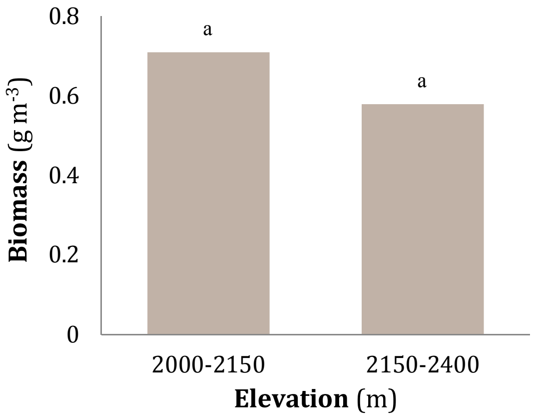


Diagram 1) Comparison fine root biomass (gr m^{-3}) values in different slope (a) and elevation (b); Similar letters indicate no significant difference.

Table 1) Independent T test for comparing fine root biomass (g m^{-3}) values in different soil depth (cm) and expositions (Mean± SE)

FRB			Soil depth (cm)		Exposition	
t	df	Sig.	0-15	15-30	West	East
-0.2.07	75	0.042*	0.53±0.12	0.83±0.12	-	-
-0.3.75	78	0.000**	-	-	0.91± 0.11	0.40± 0.07

*, ** significant at level= 0.05 and 0.01.

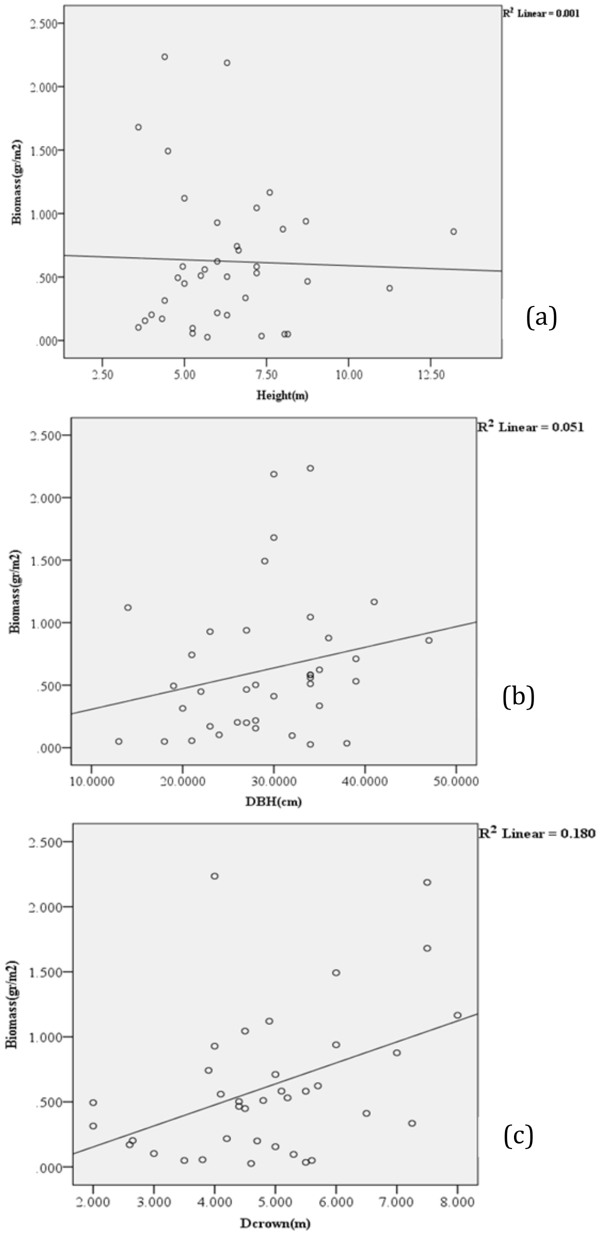


Diagram 2) Correlation between the fine root biomass and height (a), DBH (b), and crown diameter (c) of trees within stand

Table 2) The relationship between fine root biomass (g m^{-3}) and soil properties in forest stand

Properties	Correlation coefficient (r)	p-value
OC (%)	0.098	0.568
N (%)	0.097	0.572
P (ppm)	-0.391	0.018
K (ppm)	0.01	0.563
C/N	-0.241	0.134
C/P	0.036	0.834
N/P	0.082	0.616
pH	0.043	0.803
Bulk density (gr/cm³)	0.358	0.032
Sand (%)	0.365	0.029
Silt (%)	0.347	0.347
Clay (%)	-0.291	0.086

Table 3) Comparison of soil properties (mean± SEM) between expositions at depth of 0-30 cm

Soil variable	Exposition	
	West	East
pH	7.53 (0.01)	7.66 (0.03)
OC (%)	1.77 (0.24)	2.02 (0.24)
N (%)	0.17 (0.02)	0.19 (0.02)
P (ppm)	13.6 (1.05)	10.16 (1.53)
K (ppm)	437.5 (45.3)	470.22 (35.12)
DB (gr/cm³)	1.48 (0.05)	1.5 (0.04)
Sand (%)	38.45 (2.06)	38.95 (1.77)
Silt (%)	31.65 (1.32)	29.65 (0.69)
Clay (%)	29.9 (1.78)	31.4 (1.57)

SEM=standard error of the means

Table 4) Descriptive statistics for target trees (n=40) at study site

Variable	Minimum	Maximum	Mean± SE
Height (m)	3.60	13.20	6.27±0.31
DBH (cm)	13	45	28.92±1.18
Crown depth (m)	3.25	6.25	4.93±0.25

Table 5) Pearson's correlation coefficient between physiographic factors and Acer trees structure

Variable	Slope	Elevation
Height		
r	0.062	0.344*
p	0.702	0.043
DBH		
r	0.039	0.050
p	0.514	0.745
Crown depth		
r	-0.114	-0.386*
p	0.824	0.020
H/D		
r	0.059	0.321
p	0.719	0.045

*p<0.05

Discussion

In our research, the vertical distribution of FRB changed toward more biomass in the deeper soil layers; it can be attributed to climatic conditions in Zagros region. López *et al.* [25] showed that in Mediterranean climate, amount of water is low in the upper soil layers than the lower layers, and this factor can limit the growth of fine roots in the upper soil layers. The absorption of water by root through the dry period depends on shallower soil horizons and also on direct accessibility of root to the groundwater [26]. The changes in the vertical distribution of fine roots in Acer trees in the soil layer can be related to the genetic structure of the species.

Ostonen *et al.* [27] believed that the genetic potential of tree species exerts a strong influence on their vertical distribution fine root in the soil. One of the important factors in the development of root system could be soil properties such as moisture and soil fertility [28]. According to Rosado *et al*., vertical distribution of FRB with stand age in our work might be correlated to water and nutrient competition, and/or might be related to soil nutrients and texture [29]. This permits the effective absorption of water and nutrients from surface layers of soil [11]. The greater FRB and shallower distribution of fine roots, particularly at mountain forests, might increase absorption of nutrients [30].

The slope and altitude variables had no influence on FRB of Acer trees, which can be attributed to low slope and altitude changes in the region. The slope stability can be influenced by rooting systems of plant via the supported soil through network of root [31] and diminishing water erosion [32] as well as root biomass [28].

In the forest stand, we observed that the aspect affected the amount of FRB in trees in such a way that led to changes in the amount of biomass. Factors, especially aspect, can greatly change the amount of biomass of fine roots and carbon in soil [16].

Soil features in different expositions were comparable. In general, we did not observe very great differences between expositions with regard to soil variables, but these differences could also be attributed to the topographic position of forest stand. The results of this research reveal that fine roots have an effect on the accessibility of P and N to roots in soil and, thus, on the P and N nutrition of Acer trees. In this work, FBR was slightly correlated with total N in the soil, although other soil factors may have affected the fine root distribution.

Fine roots have a tendency to increase at a region with the great nitrogen concentration [33]. A negative relationship was observed between P concentration and FRB, indicating that the FRB might be affected by soil P. Soil features, such as soil bulk density and fertility, can fundamentally influence root system improvement [28]. Soil properties such as nutrient content, temperature, bulk density, water and clay, as well as microorganisms alter with depth of soil horizon might influence the biomass of fine root [29]. Kochsiek *et al*. [3] declared that trees on sandy loam texture attain absorptive area through quicker growth of fine root. The FRB differs a lot of depending frequently on tree species, soil condition, and forest stand age [34].

Changes in FRB and its relation to the characteristics of Acer trees (height, DBH, and crown) can be attributed to stand age and canopy closure according to Finér *et al*. [34]. High crown density shows that the crown layer could stock more nutrients for the growth of fine root [35]. As stand features such as tree diameter could be valued precisely and easily in site, the results of this research may be of great significance in predicating FBR at the tree level in Acer forests. In conclusion, the findings of this study indicate that soil depth and exposition play an important role in fine-root biomass of Acer trees in Zagros mountain ecosystem. The ecological and climatic conditions of this study site may have caused a disparity of site quality; thus, the interaction between elevation and height to diameter ratio (HD), DBH, and crown diameter of Acer trees may differ from a plot to another. Changing climatic situations play critical role in assessing the growth of tree height and diameter [36]. Generally, a better-developed root system in trees indicates a low value of the height to diameter ratio [37] and similar condition could be existed in our study site.

Conclusion

This study investigated the FBR of *Acer monspessulanum* trees in mountain forests of Zagros region. We found that depth of soil profile, exposition, crown diameter of trees, as well as bulk density and sand (%) appeared to be a contributing factors for FBR values in Acer trees. There was no significant difference between expositions (east and west) with regard to soil properties in site. The ecological and climatic conditions of our research site might have brought about a disparity of site quality. These above-mentioned results have important implications for forest management in Zagros region provided that soil conditions, trees features, and physiography are taken into consideration.

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