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Effects of Herbivory on Plant and Soil Characteristics; Allometric Relationships Change among Different Grazing Sites

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Abstract

In this study we developed and compared allometric relationships at the branch and at the whole plant levels of *Artemisia sieberi* in three grazing rate treatments in Miandasht Protected area, Iran. Three 100 m^2 plots in no-grazed, mildly-grazed and over-grazed sites were selected. In each plot four soil samples and five *A. sieberi* were randomly selected for laboratory analyses. For the soil samples, bulk density, soil water content, soil organic matter, pH, N and P were measured. For the plant samples, density (m^{-2}), BD, CA and aboveground biomass were determined. Coarse and fine roots biomasses were measured in different soil depths in six soil sample columns taken per plot. Vegetation coverage was significantly lower for the over-grazed site than the two other sites but the density of *A. sieberi* was highest for the mildly-grazed site. Correlations among plant characteristics were significant for all three sites. All of the relationships were significant among the three sites. Coarse and fine roots biomasses were highest and lowest for the mildly- and over-grazed sites, respectively. Aboveground biomass was highest for the mildly-grazed and then for the no-grazed and over-grazed sites, respectively. Vertical distribution pattern of fine root biomass was not significantly different between the no-grazed and mildly-grazed sites ($P > 0.05$) but it was significantly different for the over-grazed site. This study also revealed that a light grazing in some cases may increase vegetation biomass.

Keywords: Grazing intensity, *Artemisia sieberi*, Allometric equations, Miandasht Protected Area

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1. Introduction

In addition to providing habitat, plants are the most important food sources for other organisms (Kent and Coker, 1992). Consequently, estimation of produced plant biomass in ecosystems is one of the key aspects in their management. There are several methods for plant biomass assessment of which “direct harvesting” techniques are the most accurate (Moghaddam, 2012), but they are usually labor-intensive and time-consuming to apply in great scales (Ketterings *et al.*, 2001). Today, allometric equations are widely used to estimate aboveground parts at the whole plant levels on the basis of easily measured growth attributes (Bullock and Heath, 2006; Kershaw and Maguire, 1995; Monserud and Marshall, 1999; Navar *et al.,* 2002; Northup *et al.,* 2005; Porte *et al.,* 2002; Xiao and Ceulemans, 2004).

After interesting work of Li and Xiao (2007) in estimation of above- and belowground biomass of *Artemisia ordosica* communities in three contrasting habitats (fixed, semi-fixed and shifting dunes of the Mu Us desert) we decided to implement a similar study for *Artemisia sieberi* in three different grazed sites (no-grazed, mildly-grazed and overgrazed) in Northern Khorasan Province, Iran. More than 52% of Iran's total area is covered by rangelands that are mostly located in arid and semi-arid regions and are faced with overgrazing problems. Rangelands in this country are divided into three classes based on vegetation density: dense, semi-sparse and sparse (with 8.5, 25.3 and 66.2 percentages, respectively) (IFRWO, 2014). Therefore, estimations of produced plant biomass in these ecosystems are very important for rangeland managers who try to estimate stocking rate and to survey effective factors on rangelands condition. *Artemisia sieberi* is undoubtedly the dominant species in Iran-Turanian vegetation realm that covers about ¾ of Iran’s extent (Bashari *et al.,* 2004; Tregobov and Mobayen, 1970). Although this species is not always very palatable for livestock and has been increased due to overgrazing and the change in plant composition in Iran’s rangeland, but it is used as forage after fall raining and leaching of its essences (Azarnivand, 2003; Hassanzadeh Khayyata and Karimi, 2004; Mozaffarian, 1999).

The aim of this study was firstly to develop and compare allometric relationships at the branch and at the whole plant levels capable of predicting biomass of various parts of *A. sieberi* communities in three grazing rate treatments. In fact, this study aims to seek if disturbances (particularly grazing) can affect allometric relationships in plants. The results will have applications for data intensive research, land management and modeling. The second objective was to estimate and compare the biomass and its allocation, and the vertical distribution of the fine root biomass of *A. sieberi* communities in different habitats, and to examine a relationship of stand fine root biomass with stand crown area in the Miandasht Protected area, northeast of Iran.

2. Materials and methods
2.1. Study area
Miandasht protected area with an area of 84314 ha is located between 56˚25′39″E and 56˚57′50″E and between 36˚46′44″N and 37˚02′18″N in the Northern Khorasan Province, northeast of Iran. Mean annual precipitation in this area is about 280 mm. Its climate is arid and semi-arid with dry-cold winters (minimum temperature of -10 ˚C) and dry-warm summers (maximum temperature of +35 ˚C). Elevation of this area ranges from 950 to 1250 m asl with some mountains in its south with dry valleys and a wide plain that covers other parts of the area. This area contains a relatively high density of deer, cheetahs and wild sheep and has been registered as a protected area in 1973. Plant diversity in the area is also high and contains more than 110 species in 29 families and 94 genera that mostly are xerophyte or halophyte (Ahmadpour, 2014). The abundant animals in the area are sheep and goats and their numbers are estimated to be about 14000 AU. There is a sanctuary zone in this area that is completely protected where grazing is forbidden (the no-grazed site). Other parts of the area are grazed moderately (the mildly-grazed site) while heavy grazing near the villages and water sources is observable (the overgrazed site) (Figure 1).

Figure 1. Pictures of a) over-grazed b) Mildly-grazed and c) no-grazed sites in the study area

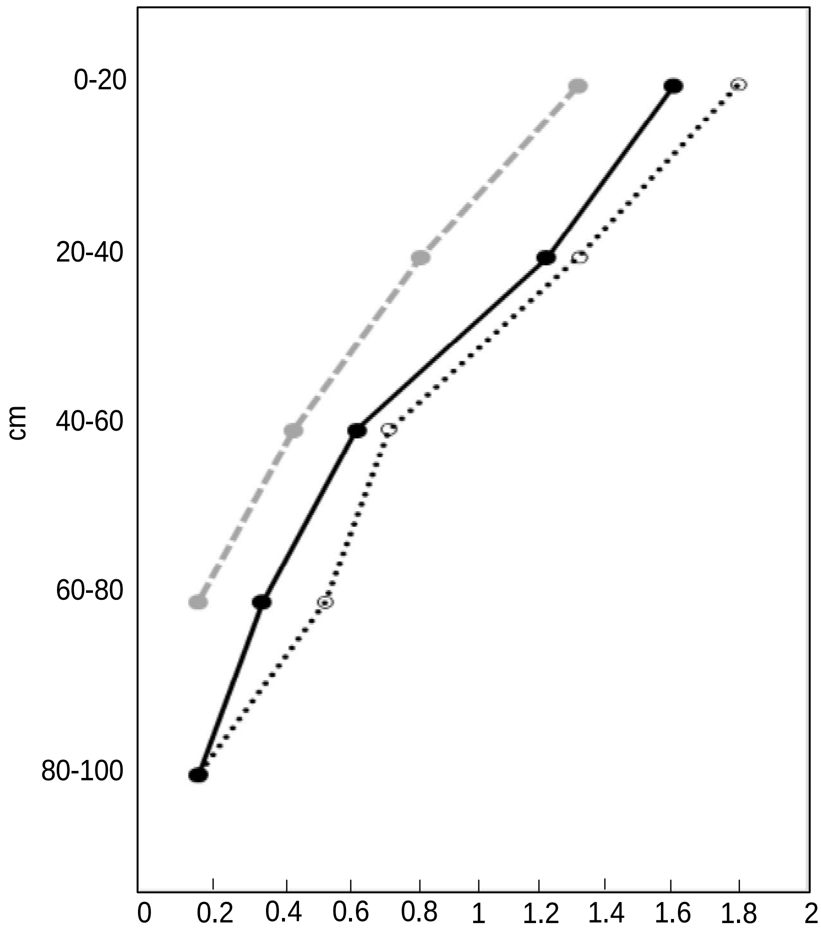

Figure 2. Vertical distribution of the fine root mass density (mg.cm^{-3}) of different root size classes of the *A. sieberi* communities in different sites

2.2. Soil and vegetation sampling

According to vegetation coverage of each site, in May 2013 three 100 m^2 plots on different no-grazed, mildly-grazed and over-grazed sites were selected (CCICCD, 1997). In each plot, the soil samples were collected from four random points (0-100 cm deep and 4 cm diameter), and then mixed into one sample for assessing soil characteristics of the three sites. Samples were air dried in the shade after the surface organic materials and fine roots were carefully removed, and then soil bulk density, soil water content (SWC), soil organic matter (SOM), soil pH, total nitrogen (N) and total phosphorous (P) were determined in the laboratory.

Soil bulk density in each habitat was measured using the cutting ring method (Lu, 1999). SWC was measured using soil-dry method and SOM was determined through dichromate oxidation method. Soil pH was measured by a glass electrode in a 1:5 soil–water suspension, soil total N by semi-micro Kjeldahl method, and total P by molybdenum blue colorimetric method as described by Bao (2000).

In each habitat and from each plot five individuals of *Artemisia sieberi* species were randomly selected and picked using harvest technique (Lodhiyal and Lodhiyal, 1997). Before the harvest, density (individuals per m^2) and crown dimensions (the crown length at its widest point, C_L; the perpendicular crown extent at the same height, C_W) and the diameter at branch base (BD) were measured with a tape ruler and a digital caliper for each branch of the sample plants (Northup *et al.*, 2005; Rosenschein *et al.*, 1999).

Stand fine root biomass was determined using core sampling to a depth of 100 cm. Six soil sample columns were taken per plot. A total of 60 sample columns were excavated using a soil corer (inner diameter of 8 cm) for soil columns. Samples from different depths (0–20, 20–40, 40–60, 60–80 and 80–100 cm) were labelled and stored in a refrigerator at 4˚C until processed. All roots were individually and manually removed, washed from the soil samples, and sorted into diameter classes (<1 mm, and 1–2 mm). Live and dead root fragments were subsequently separated by visual inspection as described by Persson (1980). Dry biomass was determined after oven-drying at 65˚C for two days.

2.3. Mathematical analyses

Crown area (CA, cm^2) was calculated as $CA = \pi \times C_L/2 \times C_W/2$ (Sah *et al.*, 2004). From each plant at least 3 branches were selected randomly; totally 60 branches were separated from the sampled plants in each habitat. BD was measured for each sampled branch and then each branch was subdivided into leaf, branch and fruit, and weighed after having been oven-dried at 65 °C for 3 days. Coarse roots (diameter > 42 mm) were carefully excavated up to 100 cm soil depth and their diameters were measured with a mini-shovel and a digital caliper for each plant. Live and dead coarse root fragments were subsequently separated, dried, and weighed.

A general nonlinear allometric equation ($Y = aX^b$, where Y is leaf, branch or fruit biomass in gram, and X is BD in centimeter) was used to predict leaf, branch or fruit biomass at the branch level. The equations were developed and compared in order to predict biomass of leaf, branch and fruit at the branch level. Leaf, branch, and fruit biomass were calculated for each sampled plant using the branch level equations. Furthermore, the non-linear equation ($Y' = aX'^b$, where Y' is leaf, branch, fruit or coarse root biomass in gram, and X' is CA in square centimeter) was developed and compared to predict leaf, branch, fruit and coarse root biomass at the whole plant level. Stand biomass of leaves, fruits, branches and coarse roots was calculated as the sum of the respective biomass of each individual plant in each plot estimated using the allometric relationships at the whole plant level. Also, a linear regression was used to determine the relationship between stand fine root biomass and stand CA (the sum of CA of each individual plant in each plot).

Significance was evaluated at the $P<0.05$ probability levels. A nonlinear least squares fitter was used to determine (1) allometric relationships between leaf, branch and fruit biomass and BD at the branch level, and (2) allometric relationships between leaf, branch, fruit and coarse root biomass and CA at the whole plant level. A linear fitter was used to determine the relationship between stand fine root biomass and stand CA. Through one-way analysis of covariance (ANCOVA) of the transformed data, these nonlinear regressions were tested for equality of slopes. The allometric level (*b* value) obtained from each equation was tested for significant difference with a t-test (Zar, 1999). One-way analysis of variance (ANOVA) was used to detect the habitat effects on plant height, soil characteristics, biomass of the different organs and fine root mass density in each soil layer. Tukey analysis was used to determine significant differences between means.

3. Results

3.1. Plant and soil characteristics

The basic information of each plot such as plant age and height, and soil physical and chemical characteristics is listed in Table 1. Significant differences were found in plant height, soil pH, bulk density, SWC, SOM, N and P contents, and C/N ratio ($P< 0.05$; Table 1) among the three sites. All of the factors decreased from the no-grazed site to the over-grazed site, with intermediate values for the mildly-grazed site. Vegetation coverage was almost equal for the no- and mildly-grazed sites but both were obviously higher than the over-grazed site. Density of *A. sieberi* was significantly different ($P < 0.05$; Table 1) among the three sites and it was the highest for the mildly-grazed site and then for the no- and over-grazed sites respectively.

Coarse roots biomass was not significantly different for the no- and over-grazed sites ($P>0.05$) and both were significantly lower than the mildly-grazed site. However, fine roots biomass for the no- and mildly-grazed sites did not show a significant difference, although they were significantly higher than the over-grazed site. Relative biomass proportions were similar between sites: branches and fine roots contained the largest and lowest proportions respectively. However, in the overgrazed site, the proportion of fine roots increased saliently. The below to aboveground biomass ratio was not significantly different ($P > 0.05$) among sites.

Table 1. Plots structure, plant age and height, and soil characteristics of *A. sieberi* communities in different sites

Variables	No-grazed	Mildly-grazed	Over-grazed
Location	4090098N-489216E	4087447N-484241E	4085816N-487095E
Altitude (m)	1050	1220	980
Vegetation coverage (%)	40	35	15
Density of *A. sieberi* (m^{-2})	1.6^{a}	2.9^{b}	0.4^{c}
Mean of Plant ages (y)	18.8	18.2	7.4
Plant height (cm)	52^{a}	41.5^{b}	22.5^{c}
Bulk density ($g.cm^{-3}$)	1.3^{a}	1.35^{a}	1.5^{b}
pH (H_2O)	7.5^{a}	7.6^{a}	7.9^{b}
SWC (%)	5.7^{a}	4.8^{b}	2.1^{c}
SOM ($g.kg^{-1}$)	9.8^{a}	6.6^{b}	2.4^{c}
N ($g.kg^{-1}$)	0.6^{a}	0.5^{a}	0.2^{b}
P ($g.kg^{-1}$)	0.3^{a}	0.3^{a}	0.1^{b}
C/N ratio	14.2^{a}	12.2^{b}	8.7^{c}

Values with the same superscript letters (a, b or c) indicate non-significant differences (Tukey test) among habitats ($P < 0.05$).

3.2. Allometric relationships

At the branch level, correlations relating leaf and branch biomass to BD were significant at the 0.05 level for the mildly- and over-grazed sites while they were highly significant at the 0.01 level for the no-grazed site. Also, leaf and branch biomass showed a highly significant correlation at the 0.01 level for all of the three sites (Table 2). Allometric equations were established to predict biomass of leaf and branch at the branch level using BD (Table 3).

At the whole plant level, correlations relating leaf, branch and root biomass to CA were significant at the 0.05 level for the mildly- and over-grazed sites while they were highly significant at the 0.01 level for the no-grazed site. Also, leaf, branch and root biomass showed a highly significant correlation at the 0.01 level for the three sites (Table 4). Separate allometric equations were established to predict biomass of these organs at the whole plant level using CA (Table 5).

The slope of the equation *b* differed significantly in all equations among the no-grazed, mildly-grazed and over-grazed sites (ANCOVA, $P<0.05$). In the established equations involving BD, the slope *b* was significantly higher for no- and over-grazed sites than mildly-grazed site ($P<0.05$). The slope *b* in most equations including CA was significantly higher for no- and over-grazed sites than mildly-grazed site ($P<0.05$).

Table 2. Correlations among characteristics of organs of *A. sieberi* at the branch level in different sites

Sites		Branch biomass	Leaf biomass
No-grazed	Brunch diameter	**	**
	Leaf biomass	**	
Mildly-grazed	Brunch diameter	*	*
	Leaf biomass	**	
Over-grazed	Brunch diameter	*	*
	Leaf biomass	**	

*Significant correlation at the 0.05 level
**Significant correlation at the 0.01 level

Table 3. Mathematical equations (Y=aXb) and their coefficients (a, b) to estimate biomass of different organs of *A.sieberi* at the branch level in different sites

Dependent variable	Independent variable	Site	a	b	R-sq.
Brunch	Brunch diameter	No-grazed	0.51 (0.02)	0.56 (0.07)	0.81
		Mildly-grazed	0.57 (0.10)	0.49 (0.29)	0.21
		Over-grazed	0.27 (0.06)	1.10 (0.47)	0.22
Leaf	Brunch diameter	No-grazed	0.11 (0.01)	0.87 (0.11)	0.8
		Mildly-grazed	0.14 (0.02)	0.48 (0.22)	0.22
		Over-grazed	0.11 (0.01)	0.65 (0.28)	0.22
Brunch	Leaf	No-grazed	1.92 (23)	0.57 (0.07)	0.8
		Mildly-grazed	5.36 (1.78)	1.12 (0.20)	0.72
		Over-grazed	7.74 (3.68)	1.46 (0.25)	0.66

R-sq. was multiple coefficient of determination; Values between brackets indicate standard errors.

Table 4. Correlation among characteristics of organs of *A. sieberi* at the whole plant level in different sites

Site		Branch biomass	Leaf biomass	Root biomass
No-grazed	Crown area	**	**	**
	Root biomass	**	**	
	Leaf biomass	**		
Mildly-grazed	Crown area	*	*	*
	Root biomass	**	**	
	Leaf biomass	**		
Over-grazed	Crown area	*	*	*
	Root biomass	**	**	
	Leaf biomass	**		

* Significant correlation at the 0.05 level
** Significant correlation at the 0.01 level

Table 5. Mathematical equations ($Y=aX^b$) and their coefficients (a, b) to estimate biomass of different organs of *A.sieberi* at the whole plant level in different sites

Dependent variable	Independent variable	Site	a	b	R-sq.
Brunch	Crown area	No-grazed	0.14 (0.04)	0.60 (0.05)	0.89
		Mildly-grazed	0.30 (0.33)	0.50 (0.22)	0.25
		Over-grazed	0.15 (0.03)	0.99 (0.40)	0.25
Leaf	Crown area	No-grazed	0.05 (0.02)	0.53 (0.08)	0.73
		Mildly-grazed	0.12 (0.10)	0.40 (0.16)	0.28
		Over-grazed	0.03 (0.04)	0.64 (0.30)	0.2
Root	Crown area	No-grazed	0.03 (0.01)	0.70 (0.06)	0.88
		Mildly-grazed	0.22 (0.23)	0.44 (0.20)	0.22
		Over-grazed	0.01 (0.01)	1.09 (0.50)	0.22
Brunch	Leaf	No-grazed	3.78 (0.11)	0.76 (0.16)	0.57
		Mildly-grazed	4.21 (0.14)	0.98 (0.26)	0.55
		Over-grazed	3.06 (0.28)	0.94 (0.27)	0.42
Root	Leaf	No-grazed	1.29 (0.02)	1.16 (0.11)	0.87
		Mildly-grazed	2.14 (0.07)	0.75 (0.25)	0.43
		Over-grazed	1.58 (0.15)	1.31 (0.31)	0.52
Root	Branch	No-grazed	0.29 (0.05)	1.08 (0.14)	0.78
		Mildly-grazed	0.79 (0.17)	0.69 (0.15)	0.6
		Over-grazed	0.53 (0.10)	0.84 (0.20)	0.47

R-sq. was multiple coefficient of determination; Values between brackets indicated standard errors

Table 6. Stand biomass ($g.m^{-2}$) and biomass allocation of *A. sieberi* communities.

	No-grazed	Mid-grazed	over-grazed
Total biomass	51.6	199.5	39.8
Leaf biomass	8.4 (16.3)^a	9.3 (4.7)^b	7.2 (18.1)^c
Branch biomass	33.1 (64.1)^a	39.3 (19.7)^b	22.4 (56.3)^c
Coarse root biomass	6.2 (12)^a	15.7 (7.9)^b	7.2 (18.1)^a
1-2 mm fine root biomass	3.8 (7.4)^a	3.1 (1.6)^a	2.4 (6)^b
< 1 mm fine root biomass	1.1 (2.1)^a	1.2 (0.6)^a	0.6 (1.5)^b
Below- to aboveground ratio	0.3^a	0.4^a	0.3^a

Values between brackets indicate proportions (%). Mean values with the same superscript letters (a, b or c) indicate non-significant differences (Tukey test) among habitats ($P < 0.05$).

3.3. Vrtical distribution of fine root biomass

Vertical distribution pattern of fine root biomass was not significantly different between the no- and mildly-grazed sites ($P>0.05$) but it was significantly different for the over-grazed site (Figure 1, $P<0.05$). The mass density of fine root was decreased by increase in soil depth. More than 50% of the fine roots were found in the 0-40 cm soil layer in the three sites, but, fine root mass density in each soil layer was significantly affected by habitat ($P<0.05$), and decreased from the no-grazed to the over-grazed sites and intermediate values for the mildly-grazed site. No root was found in the 80-100 cm soil layer in the over-grazed site.

3.4. Stand biomass

Estimated stand biomass of *A. sieberi* using allometric equations was 51.6, 199.5 and 15.9 $g.m^{-2}$ for no-grazed, mildly- and over-grazed sites respectively (Table 6). Stand biomass of leaves and branches showed significant differences for the three sites ($P<0.05$). They were highest for the mildly-grazed site and subsequently for the no- and over-grazed sites.

4. Discussion

In this study, allometric relationships relating leaf and branch biomass and branch diameter at branch level and to canopy characteristics at whole plant level were developed and compared for three different grazing sites. Branch characteristics such as BD have been used as the main variables to predict branch and foliage biomass in various tree species (Blazier *et al.,* 2002; Helmisaari *et al.,* 2002; Li and Xiao, 2007; Xiao and Ceulemans, 2004). In this study, allometric relationships based on BD were well adapted for the prediction of leaf and branch biomass at the branch level in *A. sieberi* plants in no-grazed, mildly-grazed and over-grazed sites of the Miandasht Protected area. We tried in this study to find if grazing affects allometric relationships in plants and if so, how intensity of grazing can influence these relationships.

Equations showed significant differences among the different sites, possibly due to the different environments and plant ages affecting branch morphology and growth of *A. sieberi* plants in different ways. Also, the developed relationships were significant at a higher level for the no-grazed site than the mildly- and over-grazed sites, presumably caused by more stable conditions. In fact, results showed that plants in no-pressure situations morphologically reflect the normal behaviors of growth but it can be affected by disruptive factors such as grazing.

In the majority of past studies dealing with different species at the whole plant level, allometric relationships have commonly been used to estimate biomass of aboveground compartments in combination with plant characteristics (e.g. Na ´ var *et al.,* 2002; Porte *et al.,* 2002; Xiao *et al.,* 2003). However, only a few studies reported allometric relationships involving belowground components such as stumps or coarse roots (Hakkila, 1975, 1979; Marklund, 1988; Van Lear and Kapeluck, 1995; Xiao *et al.,* 2003). In our study which follows the work of Li and Xiao (2007), allometric relationships between biomass and easily measurable plant characteristics accurately predicted the biomass of aboveground and coarse root compartments. Leaf, branch and coarse root biomasses were estimated precisely by CA, which is usually used as an independent variable in shrub biomass regressions (e.g. Halpern *et al.,* 1996; Ludwig *et al.,* 1975; Martin *et al.,* 1981; Ohmann *et al.,* 1981; Peek, 1970). Also in this study, significant correlations among leaf, branch and coarse root biomass allowed us to develop allometric equations.

Percentage of vegetation coverage for the no- and mildly-grazed sites was not very different but density of *A. sieberi* is obviously higher for the no-grazed site and some other species are abundant in this site. This phenomenon is probably related to palatability of species that is not very high for *A. sieberi* (Moghaddam, 2012). These species are called increasing species in grazing situations, as they are grazed in a lower proportion by animals than highly palatable species. Hence, they tend to increase in the vegetation composition (Davies *et al.,* 2014; Waler *et al.,* 1999; Wang *et al.,* 2011). However, over-grazing had an apparent effect on both vegetation coverage and density of *A. sieberi* due to the high frequency of defoliation (Hickman *et al.,* 2004; Trlica and Rittenhouse, 1993).

Although fine root has a very important role in plant life and ecosystems (Michael *et al.,* 1997; Vogt and Bloomfield, 1991), it has been rarely estimated because of difficulty in its determination in the field. However, a significant relationship linking stand fine root biomass with stand CA was observed in our study. The results showed that the relationship can be affected by habitats or plant age (Table 5) that was not in agreement with findings of Li and Xiao (2007). Grazing even in minimum intensity has an explicit effect on both above- and belowground organs of grazed plants so it can affect the relationship between them.

Biomass of desert plant species has been proposed to be used as indicator of desertification (Padro ´ n and Navarro, 2004). Plant growth depends not only on age, but also on the correlations between community structure and environment in the natural instances (Li *et al.,* 2001; Yang *et al.,* 2002). In our study, stand total biomasses were 51.9, 199.5 and 15.9 g.m-^{2} in no-, mildly- and over-grazed sites, respectively. The increase in plant growth in the mildly-grazed site resulted from light natural pruning and stimulation of growing buds and optimization of environment for growth (Belsky, 1986; McNaughton, 1979). The decrease in plant growth in the over-grazed site was mainly related to plant age, but another reason might be the decrease in SWC, SOM, and soil N and P contents in this site (Table 1).

SWC, SOM, and soil N and P contents reflect soil water and nutrient availability, and higher values of these variables could represent more favorable conditions for the plant in terms of more soil water and nutrients. Our results are in agreement with several comparable studies dealing with the impact of increased nutrient availability on plant growth (Azarnivand *et al.,* 2003; Burton *et al.,* 2000; King *et al.,* 2002; Kubiske *et al.,* 1998). The results of this study showed that a light grazing has not disruptive effect on soil and plants but it may increase vegetation biomass. Additionally, coarse roots and fine roots showed significantly different reactions to grazing. Over-grazing had greater and negative effects on fine roots while mild-grazing had positive effects on coarse roots.

In our study, the below to aboveground biomass ratio did not show significant differences among the no-grazed, mildly-grazed and over-grazed sites. These results are not in agreement with comparable experimental studies (Chartzoulakis *et al.,* 1993; Ferna ´ ndez *et al.,* 2002; Ostertag, 1998). In fact, soil condition and plant age are different for the three sites, but the biomass allocation remained fixed and it is in contrast with some previous studies (Mokany *et al.,* 2006; Schmid, 2002; Vogt *et al.,* 1983; Li and Xiao, 2007). It seems that the synchronic effects of age and grazing have a role in this case. Although the above-ground biomass was affected by over-grazing, the low age of plants effected the below-ground biomass.

The below to aboveground biomass ratio of desert and shrubland species is usually higher than 1 (e.g. Jackson *et al.*, 1996; Mokany *et al.*, 2006). However, in our study, the ratio was equal to 0.3 for the no- and over-grazed sites and 0.4 for mildly-razed site. The lower values of below to aboveground biomass ratio in the three sites are related to the growth properties of *A. sieberi*. Indeed, in this species, individual plant growth of aboveground organs is much faster than belowground growth (Azarnivand, 2003; Mozaffarian, 1999). Another reason for this phenomenon may be related to the higher precipitation (mean annual precipitation is 280 mm in the Miandasht area) and better soil conditions (Table 1) which are also beneficial to the natural growth of *A. sieberi* plants.

5. Conclusion

In conclusion, this study provided some useful allometric equations that allow researchers to accurately predict biomass of leaf and branch at the branch and the whole plant level for *A. sieberi* in different grazing systems of the Miandasht area, based on simple and easily measurable traits. Also, results showed that grazing has obvious effects on some characteristics in rangelands such as vegetation composition. Significant differences in stand biomass were observed among different grazing pressures. Vertical distribution of fine root biomass was not significantly different for the no- and mildly-grazed sites but it was significantly different for the over-grazed site. A significant and positive relationship between stand fine root biomass and stand crown area was also shown. These results will help to predict how the species will alter their ecological adaptive strategies through adjustments in morphology and biomass of different compartments under different grazing pressures.

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