Quantitative and qualitative characteristics of Persian oak along altitudinal gradation and gradient (Case study: Ilam province, Iran)

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ABSTRACT: Quantitative and qualitative characteristics of Persian oak (*Quercus persica*) were studied in relation to altitude and slope variations in Ilam province. A total area of 1,500 m^2 (30 × 50 m) was covered in five altitudinal classes ranging from 800 to 1,800 m a.s.l. Samples were taken based on a systematic random sampling method with 24 sample plots at each class. In total, 120 sample plots (in five classes) were collected covering four gradient categories ranging from < 20 to > 60%. An analysis of variance (ANOVA) was carried out to compare differences between group means in gradient categories and Duncan's post-hoc test was performed to reveal differences between the means of various quantitative characteristics (e.g. growing stock, basal area, diameter at breast height, tree height and regeneration) and the altitudinal classes. The Kruskal-Wallis test was used to examine the differences between the means of qualitative variables and different altitudes and slopes categories. The results indicated that variations with altitudes may have a higher impact than slopes on the quantitative characteristics of the oak stands in the region while the qualitative variables of the native species were influenced by both altitudes and slope variations.

Keywords: habitat; growing stock; DBH; tree height; tree quality; regeneration

The area of Iranian forests is about 12.4 million ha representing 7.5% of the total area of the country (Sagheb-talebi et al. 2003; Erfanifard et al. 2007; Hassanzad Navroodi 2009). The central Zagros Mountain is one of the most important habitats for *Quercus* forests in the west of Iran (Azizi et al. 2013). The forests of Zagros extend from the western Azerbaijan province to the southern province of Fars. The Zagros regions are classified as semi-arid (Sagheb-talebi et al. 2003) and roughly 3 million ha of forests are covered by different oak species, of which *Quercus persica*, *Quercus infectoria* and *Quercus libani* are dominant species in the north-west of Iran (Fatahi 1995; Erfanifard et al. 2007; Elahi, Rouzbehan 2008; Azizi et al. 2013). The Persian oak (*Quercus persica*) can form pure or mixed stands with other woody species. *Quercus* is the largest genus in the family Fagaceae, with more than four hundred species (Nixon 1993; Huang et al. 1999; Xing et al. 2013). It is found throughout temperate and subtropical montane regions of the northern hemisphere. It extends into the southern hemisphere in northern South America and Indonesia (Nixon 1993; Huang et al. 1999; Deng et al. 2008).

Oak (*Quercus* spp.) forests play an important role from economic and ecological points of view. Various benefits can be mentioned for oak including wood for fuel, charcoal for smelting ores, pulpwood for paper, and lumber and laminates for furniture, panelling and flooring and food for many birds and mammals (Johnson et al. 2001; Ohsawa et al. 2008). Most Zagros forests are now semi-degraded and coppiced because of intensive utilization and overgrazing by cattle and fire severities

(Jazirehi, Ebrahimi 2003; Pourreza et al. 2014). In the north-west of Iran where these three species are dominant, some small ruminants such as goats graze on the leaves and twigs of oak. The leaves are also harvested by people or fed by livestock (Singh et al. 1996; Elahi, Rouzbehan 2008; Abarghuei et al. 2011).

Quantitative evaluation of tree distribution in a forest stand is the first step towards understanding the forest community dynamics (Shimatani, Kubota 2004). Since the Zagros forest ecosystem is threatened by a variety of problems, determining the quantitative and qualitative characteristics of trees particularly in the Persian oak (a native and valuable tree species in Iran) can help forest managers and decision-makers to develop successful forest restoration/conservation and management programs. In the west of Iran, the Persian oak is commonly found at the altitudes between 1,000 and 2,300 m a.s.l. The species is native to Iraq, Turkey, Syria and Lebanon as well (Jazirehi, Ebrahimi 2003).

Up to now, several studies on the growth and ecological characteristics of oak species have been conducted worldwide. However, in Zagros region, one could hardly find enough information with regard to the condition of habitat for the Persian oak. Erfani-fard et al. (2009) developed a method to determine the spatial pattern of trees as a robust indicator to monitor changes from black and white (B&W) aerial photographs for Persian oak (*Q. brantii* var. *persica*) forests of Zagros, Iran. Bordbar et al. (2010) studied the effect of environmental factors on the natural distribution of Manna oak (*Q. brantii* Lindl.) to identify the optimal habitat conditions for the species in Fars Province (Iran). Hosseini et al. (2008) examined the effect of site elevation on natural regeneration and other characteristics of *Q. brantii* in the Zagros forests in order to determine the most suitable tree stands taking into account the tree density, diameter and quality. More recently, Salehi and Eriksson (2010) predicted (based on a diameter class model) the effects of different forest management practices on the growth and yield conditions of mixed coppice stands of Persian oak (*Q. persica*) in the semiarid forests in the southern Zagros. A study was conducted by Mirzaei et al. (2007) for demonstrating the frequency of naturally regenerated seedlings of *Q. brantii* trees and shrub species based on physiographic and edaphic conditions in Arghavan reservoir in Ilam, Iran. Shakeri et al. (2009) compared seedling and coppice regeneration in pruned and undisturbed oak forests in the northern Zagros to determine the most important factors including livestock grazing, fire, acorn collection by villagers,

summer drought, pests and diseases on acorns and seedlings which affect oak regeneration in this region. Sutherland et al. (2003) studied the characteristics of mixed oak forests in southern Ohio in terms of tree species composition, understorey vegetation, soil characteristics and tree regeneration. Ecological consequences of topographic gradients were studied in mixed oak forests in southern Ohio (Rubino 2001). Quantitative data on the structure and composition of vegetation were obtained for red oak-dominated stands at different sites in the Ridge and Valley and Blue Ridge physiographic provinces of western Virginia (Stephenson, Adams 1989). Based on this study, the most important association of red oak was red maple, black birch and white oak.

The objective of the present study was to evaluate some quantitative and qualitative characteristics of *Q. persica* in Zagros forests (west of Iran). More specifically, it was examined that whether altitudinal gradient changes can affect the habitat requirements of the target species based on some qualitative and quantitative variables or not. The outcomes of such study could get more insight into ecological conditions of Persian oak stands in Iranian western forests. Moreover, the obtained results could help forest managers and stakeholders to better restore/conserve the deteriorated oak stands in the region.

MATERIAL AND METHODS

Study area and site selection. This study was carried out in the southern part of Ilam province in Iran, between Darreshahr and Abdanan (Fig.1). The study area of about 700 ha is located between 47°41'44'' and 47°43'13'' longitudes and 33°3'18'' and 33°3'50'' latitudes. The altitude of the area is between 800 and 1,800 m a.s.l. and the geographical
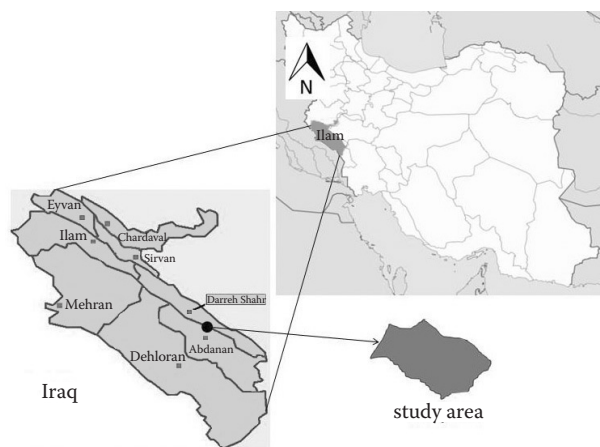
Fig. 1. The location of study area (●) in the southern part of Ilam Province, Darreshahr County, Iran

direction occurs in the north aspect. The climate of the study site has a Mediterranean regime according to Dumbarton's classification with average annual precipitation about 483 mm with a minimum of 447 mm and maximum of 759 mm. Annual air temperature in the region ranges from 8 to 38°C. The soil type of the Zagros Mountains is mainly calcareous (Jazirehi, Ebrahimi 2003).

Data collection and sampling designs. Based on a set of tree characteristics (qualitative and quantitative tree conditions), data were gathered in the Zagros forest located in Ilam Province, Darreshahr County (Iran) over a study period (2010–2011).

Initially, a geographical map (1:50,000) was created by means of GPS set. The area was classified into five altitude classes including 800–1,000, 1,000–1,200, 1,200–1,400, 1,400–1,600 and 1,600–1,800 m a.s.l. Besides, the gradient of the area was classified into four categories consisting of < 20%, 20–40%, 40–60% and > 60%. A systematic random sampling approach was used for forest inventory. Sampling was carried out with 24 sample plots covering an area of 1,500 m² (30 × 50 m) at each latitude class with an overall of 120 sample plots. Quantitative and qualitative factors of all trees were measured and recorded within each sample plot. The growing stock, basal area, diameter at breast height (DBH), tree height and regeneration were the main quantitative variables. The most important qualitative factors were stem vitality, crown symmetry and crown vitality. A unique identification code was aligned for each individual tree to minimize the measurement errors during the next sampling.

Tree height and DBH were measured with a Suunto Clinometer and Diameter Tape, respectively. The number of recruits was also counted for all sample plots. Tree basal area (BA) at breast height (1.3 m above the ground) was computed in square meters (m²) using Equation (1):

$$BA = \pi/4 \times DBH^2 \tag{1}$$

where:
DBH – diameter at breast height (cm).

Tree growing stock (or standing tree volume) was also calculated using Equation (2):

$$\text{Tree growing stock} = \pi/4 \times DBH^2 \times h \times f \tag{2}$$

where:
h – tree height (m),
f – form factor of the tree.

Stem vitality (healthy trunk, moderately healthy trunk and unhealthy trunk), crown symmetry (symmetrical crown, semi-symmetric crown and unsymmetrical crown) and crown vitality (healthy crown, semi-withered or moderately healthy crown and withered or unhealthy crown) were determined for the trees with three categories as mentioned in the brackets.

Data analysis methods. Prior to data analysis, all quantitative data were tested for statistical normality and then the data were log-transformed. The data related to DBH and height was already normal but the data of the growing stock, basal area and regeneration had to be normalized. Then, the analysis of variance (ANOVA) was performed in SPSS environment to determine the difference between the group means of quantitative factors at the different altitudinal and gradient categories. Duncan's multiple comparison procedures were performed to examine the extent of differences between the mean of each quantitative variable (e.g. growing stock, basal area, diameter at breast height, tree height and regeneration) and different altitude classes. The Kruskal-Wallis test was performed to understand the differences between the mean of each qualitative tree variable and various altitude and slope categories.

RESULTS

Distribution of Persian oak individuals in different diameter classes

Distribution of Persian oak individuals (the number of trees per ha) in different diameter classes is illustrated in Fig. 2. As shown in the graph, the upper boundaries of diameter class were 70 and 75 cm in the study area and the highest frequencies of trees were observed in 20 cm diameter class. After this
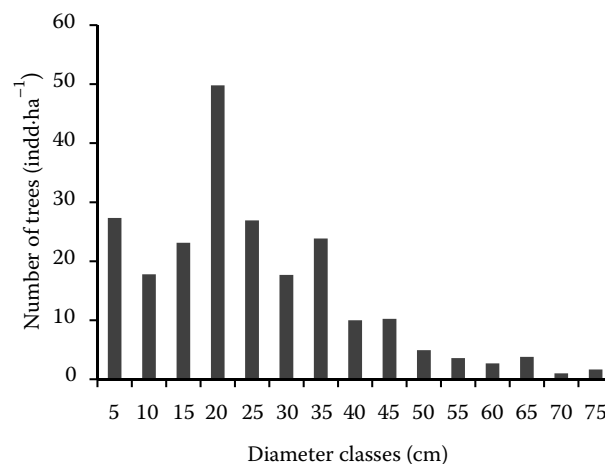

Fig. 2. Distribution of Persian oak individuals in different diameter classes

Table 1. The results of ANOVA test concerning the effect of altitude/slope on the quantitative characteristics of Persian oak

Source	df	Mean Square				
		DBH	tree height	basal area	growing stock	regeneration
Altitude						
Between groups	4	397.28**	150.28**	126.18**	117.48**	165.35*
Within groups	55	51.79	12.13	32.41	10.27	53.62
Total	59					
CV (%)		15.26	18.18	17.85	7.52	9.74
Slope						
Between groups	3	45.45^{ns}	2.04^{ns}	35.79^{ns}	15.68^{ns}	4.56^{ns}
Within groups	56	28.98	2.27	20.73	11.40	18.23
Total	59					
CV (%)		26.66	21.83	19.24	12.96	14

*significant at α = 0.05, **significant at α = 0.01, ^{ns}not significant

class, increasing other classes almost led to a gradual decrease in the number of tree individuals. This indicated that the trees have an uneven age structure in the study area.

The effect of altitudinal and slope gradient changes on the quantitative variables of Persian oak

The results of ANOVA test showed that there was a significant relationship between the altitude and quantitative variables (DBH, tree height, basal area, growing stock and regeneration) in different altitu-

Fig. 3. Status of oak: (a) basal area (m²) and (b) DBH (cm) in different altitude classes

dinal classes (Table 1). In contrast, according to the analysis, no significant relationship was observed between the slope and other dependent variables in different slope gradient categories (Table 1).

In Figs 3 to 5, Duncan's test determined the status of grouping quantitative variables. The results identified altitudinal groups for quantitative variables consisting of basal area, DBH, growing stock, tree height and regeneration. Duncan's test identified three main altitudinal groups for three quantitative variables consisting of basal area, DBH and growing stock. These groups comprised group *a* (800–1,000 and 1,400–1,600 m), group *b* (1,200–1,400 m) and group *c* (1,000–1,200 and 1,600–1,800 m). This demonstrated that there was not a significant difference between the basal area (Fig. 3) , growing stock (Fig. 4) and the two altitudinal classes in group *a* (800 to 1,000 m and 1,400–1,600 m) and *c* (1,000–1,200 and 1,600–1,800 m). The minimum and maximum basal area was observed at the lower (800–1,000) and higher altitudes (1,600–1,800), respectively. Persian oak showed the highest DBH at 1,000–1,200 m (with < 26 cm diameter), while the lowest DBH was observed at 800–1,000 m (with < 15 cm diameter) altitude classes. The highest growing stock belonged to the altitudes of 1,600–1,800 m (the maximum tree stock was > 72 m³), while the lowest growing stock was observed at 800 and 1000 m altitudes with the minimum of < 42 m³.

Based on the results, no significant difference was observed between tree heights in three altitude classes of 800–1,000, 1,200–1,400 and 1,400–1,600 m (Fig. 4). Therefore, these three altitudes classes were classified as one group (as displayed with *b*). Here, the fifth altitude class belonged to three main groups. The tallest trees were observed at 1,600–1,800 m, followed by 800–1,000 m above sea level. But the mini-
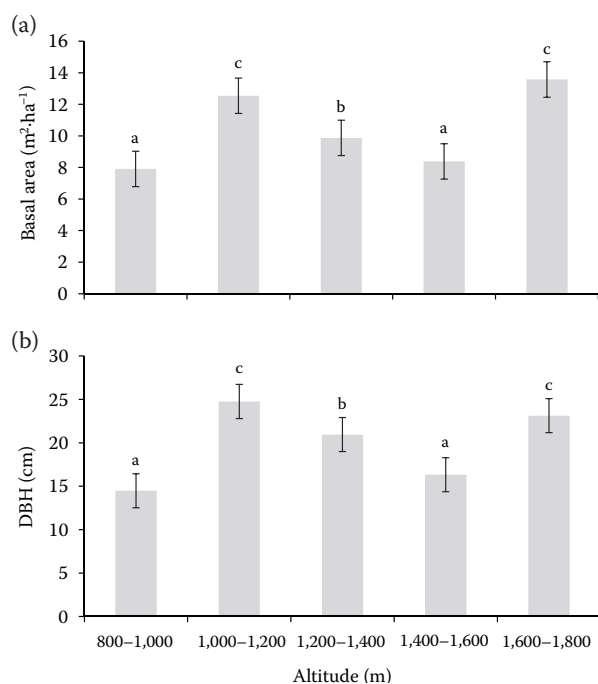
Fig. 4. Status of oak: (a) growing stock (m³) and (b) height (m) in different altitude classes
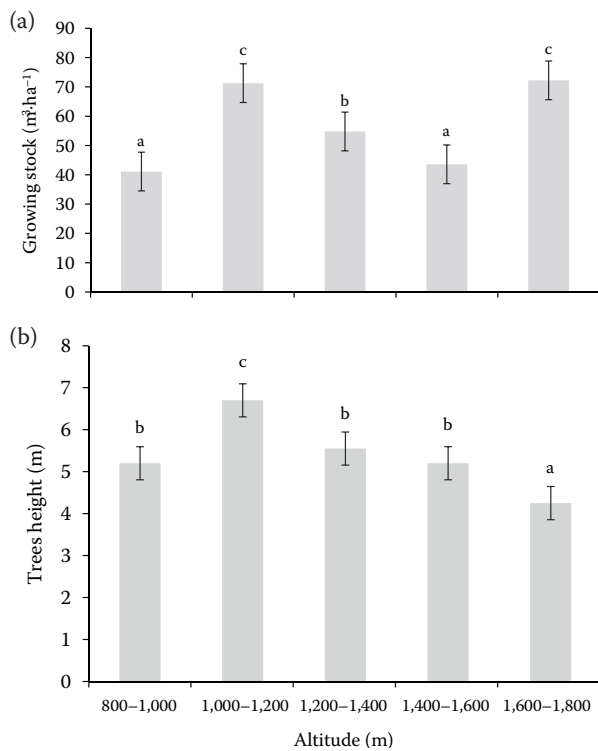

Fig. 5. The number of oak recruits in different altitude classes

mum and maximum of mean height of trees were obtained at 1,600–1,800 m and 1,000–1,200 m a.s.l., respectively. The tree height varied from 6 to 8 m in all altitudinal classes.

Concerning the regeneration of Persian oak, the lowest (800–1,000 m) and the highest altitudes (1,600–1,800 m) were classified as one group (*c*) and there were no significant differences between oak regeneration and the given altitudes. The altitude of 1,200–1,400 m was located between two groups (*a*) and (*b*). The highest and the lowest regeneration was at the 1,000–1,200 m and 1,600–1,800 altitude classes, respectively (Fig. 5).
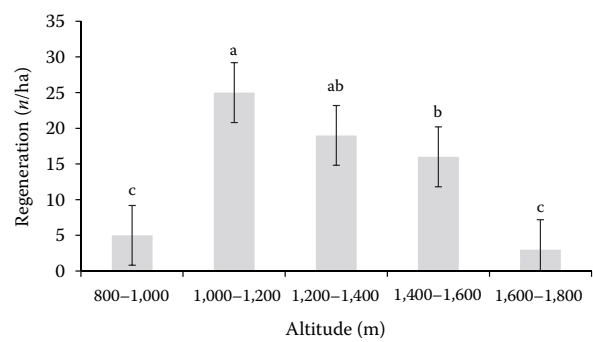
As it can be noticed from the regeneration and tree height (except the altitude of 800–1,000 m), increasing altitudes led to a significant decrease in the aforementioned variables. For the variables of basal area, DBH and growing stock almost the same trends can be observed except for the highest altitude (1,600–1,800 m) where an increase was observed in the variables.

The effect of altitudinal and slope gradient changes on the qualitative variables of Persian oak

Table 2. summarizes the effect of altitudinal changes on different qualitative variables of oak such as stem vitality, crown symmetry and crown vitality in the study area. The highest tree frequencies in terms of all three items were in the ranges between 1,200 and 1,400 m, while trees had lower frequencies based on the above-mentioned variables at the altitude of 800–1,000 and 1,600 to 1,800 m a.s.l. The obtained results showed that the majority of trees had good quality in terms of stem vitality and crown symmetry at the altitudes of 1,200–1,400 m above sea level. In contrast, sev-

Table 2. Altitudinal changes, gradient slope variations and qualitative characteristics of Persian oak (indd·ha⁻¹)

Tree characteristics	Slope categories (%)				Altitudinal classes (m)				
	< 20	20–40	40–60	> 60	800–1,000	1,000–1,200	1,200–1,400	1,400–1,600	1,600–1,800
Stem vitality									
Healthy	59	213	78	22	43	66	98	84	66
Moderate	18	50	21	5	43	19	23	11	13
Unhealthy	1	3	1	1	0	3	2	1	0
Crown symmetry									
Symmetrical	63	199	67	19	31	65	98	83	60
Moderate	14	65	32	9	53	22	25	13	19
Unsymmetrical	1	2	1	0	2	1	0	0	0
Crown vitality									
Healthy	20	79	31	2	31	33	19	13	39
Moderate	57	185	68	25	53	54	103	82	40
Unhealthy	1	2	1	1	2	1	1	1	0

Table 3. The results of Kruskal-Wallis test concerning the effects of altitude and slope on the qualitative characteristics of Persian oak

Variables	Rank			Chi-square			P		
	St.vi	Cr.sy	Cr.vi	St.vi	Cr.sy	Cr.vi	St.vi	Cr.sy	Cr.vi
Altitude classes (m)									
800–1,000	115.5	121.7	146.8						
1,000–1,200	177.2	202.9	191.8						
1,200–1,400	348.9	351.7	356.9	201.1	200.4	196.1	0.00	0.00	0.00
1,400–1,600	292.3	289.3	282.2						
1,600–1,800	191.5	155.5	141.0						
Slope categories (%)									
< 20	119.73	92.54	86.36						
20–40	311.46	321.60	337.90	229.7	297.2	379.1	0.00	0.00	0.00
40–60	180.41	180.80	139.80						
> 60	50.00	28.00	36.18						

St.vi – stem vitality, Cr.sy – crown symmetry, Cr.vi – crown vitality; in italics – outputs of chi-square and P for different altitude and slope classes

eral tree individuals showed moderate crown vitality in all altitudinal classes, however the maximum crown vitality was observed at the middle altitudes (1,200–1,400 m).

Table 2. also presents a summary of the effect of slope variations on different qualitative characteristics of Persian oak. The obtained results showed that more than 50% of all tree individuals were located on the slopes between 20 and 40%. In general, over 70% of tree individuals in the region were found on the slopes ranging from 0–20% to 20 to 40%. Particularly, the majority of trees maintained good stem vitality and crown symmetry between 20 and 40%. In fact, the given slopes lie at the altitudes of 1,200–1,400 m. Here, the only exception can be seen for the crown vitality where several trees showed moderate crown vitality. In general, the highest tree frequencies based on stem vitality, crown vitality and crown symmetry were in the gradient slope categories of 20–40%. Based on our results, an increase in slopes led to a gradual decrease in the number of tree individuals and the slopes of more than 60% restricted the oak population in the region.

The results of Kruskal-Wallis test showed a significant relationship between the mean of qualitative variables (stem vitality, crown symmetry and crown vitality) and different slope and altitude classes (Table 3). Slope and altitude can both affect the qualitative characteristics of Persian oak in the region, while the quantitative characteristics of trees were mainly influenced by the altitude rather than by the slope (as described in Tables 1 and 2).

DISCUSSION

The effects of altitudinal gradient on various quantitative and qualitative characteristics of Persian oak (*Q. persica*) were studied in the Zagros Mountains, west of Iran. Distribution of Persian oak individuals in different diameter classes showed that the upper boundaries of diameter class were in the range of 70–75 cm and the highest frequencies of trees were observed in the diameter class of 20 cm. Moreover, the forest stands have an uneven age structure. The ANOVA test did not recognize any significant relationship between the dependent variables (growing stock, DBH, tree height, generation and basal area) and the different gradient slope variations. Previous findings also confirmed this statement (e.g. Sheik-holeslami et al. 2005; Hassanzad Navroodi 2006; Pourbabaei, Haghgooy 2013). Many other studies have also proved that altitudinal variations can effectively influence the growth, photosynthesis and leaf traits of *Quercus* species as described by various authors (e.g. Cabrera et al. 1998; Rada et al. 1998; Zhang et al. 2005). The analysis of ANOVA test confirmed that there was a significant relationship between different altitude classes (as independent variables) and various quantitative classes for Persian oak in the study area. The habitat preferences of oak may have a close relationship with quantitative variables mentioned above so that Hosseini (2008) obtained similar results confirming that the growing stock is closely linked to the different altitudinal classes in Iranian forests. In the present study, the highest growing stock of oak was observed at 1,600–1,800 m altitudinal classes with standing volume of approxi-

mately 72 m³·ha⁻¹ and the lowest growing stock was observed at the altitudes of 8,00–1,000 m with standing volume of < 42 m³·ha⁻¹. This indicates that these altitudes (1,600–1,800) are considered as a protected forest for Persian oak.

The minimum values of basal area together with DBH and growing stock were observed at the lower altitudes (800–1,000 m). While the maximum DBH was found out at the altitudes from 1,000 to 1,200 m and the maximum basal area and growing stock were at the altitudes of 1,600–1,800 m. The results showed that even the higher altitudes (1,600–1,800 m) may provide almost the same condition for DBH. The altitudes of 1,000–1,200 m had almost the same condition for basal area and growing stock in the study area.

In fact, low human disturbances and very limited number of grazing cattle at the altitudes of 1,600 to 1,800 m can provide a good opportunity for the establishment of oak population in the region (Hassan-zad Navroodi 2000).

In contrast to the aforesaid quantitative characteristics, an increase in the altitudes led to a significant decrease in tree height and regeneration. However, the same trends for the given variables can be observed at the lowest altitudes (e.g. 800–1,000 m). At first glance, it seemed to be surprising because the latter altitude (800–1,000 m) might provide a better condition for the growth of oak. This can be justified by the fact that the anthropogenic activities and entrance of grazing cattle at the lower altitudes in the forests can be the main reasons to restrict the growth of oak in the regions (Hassanzad Navroodi 2000). The tallest trees were observed at 1,600–1,800 m followed by 800–1,000 m a.s.l. The tree height varied from 6 to 8 m in all altitudinal classes. But the minimum and maximum of the mean tree height was obtained at 1,600–1,800 and 1,000–1,200 m a.s.l., respectively. Under normal conditions, the tallest trees are found at the lower altitudes but in the study area it seemed to have a reverse trend. A possible reason is that due to human disturbances, the number of coppice trees increases when altitudes decrease. Persian oak is a dominant tree species in the study area but many Persian oak individuals have a low height (on average < 7 m) in their main habitats. Inadequate precipitation distribution and long drought periods can intensify the problems (Valipour et al. 2013).

In fact, high DBH and basal area at the higher altitudes may increase the growing stock of oak. Vali-pour et al. (2013) arrived at the same conclusion highlighting that human disturbances are the main reasons to limit the growth of oak in Iranian forests. The highest and lowest regeneration was in the 1,000–1,200 m and 1,600–1,800 altitude classes. The

highest regeneration in the range of 1,000–1,200 m a.s.l. may be due to better ecological conditions. In contrast, the lack of soil moisture at higher altitudes (Fatahi 2000; Ohsawa et al. 2008) together with soil erosion may inhibit the development and regeneration of *Quercus* species.

Pourhashemi (2001) found a negative relationship between the oak coppice regeneration (coppicing is still considered as a general regeneration method for the management of oak forests in the west of Iran) and physiographic variables such as aspect, gradient and altitude so that the regeneration of Persian oak reduces when the altitude increases.

Depending on the natural or anthropogenic factors, the oak distribution can vary from the altitudes 800 to 1,800 m above sea level. Previous studies (e.g. Jazirehi, Ebrahimi 2003) demonstrated that *Q. persica* grows at the altitudes between 1,000 and 2,300 m a.s.l. in the west of Iran and the most favourable habitat for this species is at the altitudes of 1,000 to 2,000 m. In the given ranges, the oak can mainly form pure stands. Very high altitudes reduce the photosynthetic rates and growth of *Quercus* species due to a significant increase in the thickness of leaf pubescence, lower stomatal conductance and leaf nitrogen content (Cabrera et al. 1998; Rada et al. 1998; Zhang et al. 2005).

As already stated, *Q. persica* also can coexist with other *Quercus* species such as *Q. brantii* in the study area (Zagros Mountains). This implies that Persian oak may require almost the same habitat as *Q. brantii* in the regions. For instance, Hosseini et al. (2008) studied the effect of elevation on the natural regeneration of *Q. brantii* in the Zagros forest, demonstrating that the forest stands at the altitude of 1,800 m are the most suitable habitats regarding tree density, DBH and trunk and crown quality. On the other hand, Bordbar et al. (2010) concluded that the natural distribution of *Q. brantii* varies from 1,050 to 2,550 m in all land forms. High density in *Q. brantii* in northern aspects may be partly due to soil fertility and mainly because of increasing the elevation from sea level, while stump sprouts of this species are higher in southern aspects and decrease with increasing overstorey (Mirzaei et al. 2007).

Duncan's test identified three main altitudinal groups for five quantitative variables like basal area, DBH, tree height, growing stock and number of recruits.

The effects of altitudinal and slope changes on different qualitative variables of oak (stem vitality, crown symmetry and crown vitality) showed that the highest tree frequencies were observed in the ranges between 1,200 and 1,400 m while the lowest frequencies were at the altitudes of 800-1,000 and 1,600–1,800 m. The majority of trees had good quality in terms of stem vi-

tality and crown symmetry at the altitudes of 1,200 to 1,400 m. Also the maximum crown vitality was observed at the altitudes of 1,200–1,400 m. More than 50% of all tree individuals were located on the slopes between 20 and 40% and over 70% of tree individuals in the region were found on the slopes ranging from 0–20% to 20–40%. The majority of trees maintained good stem vitality and crown symmetry between 20 and 40% (located at the altitudes of 1,200–1,400 m). In general, the highest tree frequencies based on stem vitality, crown vitality and crown symmetry were in the slope categories of 20–40%. Based on our results, an increase in slopes led to a gradual decrease in the number of oak trees in the region.

Based on the Kruskal-Wallis test, the qualitative variables can be influenced either by altitude or slope variations. Considering the different slope categories, it was concluded that the highest frequencies of oak trees were in the range between 20% and 40% since over 50% of the total number of individuals were recorded in this category. In fact, the given slopes mainly lie at the altitudes of 1,200–1,400 m where the trees had good stem vitality and crown symmetry. Here, the only exception can be seen for the crown vitality where many individuals had moderate crown vitality. It is worth mentioning that the lower slopes (e.g. < 20%) are not considered as good habitats to establish oak stands due to human and cattle disturbances (Valipour et al. 2013). Higher slopes (due to the lack of deep soil and other harsh environmental problems) can affect the quality, growth and normal distribution of trees (Hassanzad Navroodi 2000). Higher slopes together with increasing altitudes may intensify the problem. This will in turn affect the qualitative and quantitative characteristics of oak in the region (Marvi Mohajer 2005). In fact, high-quality seeds were normally found in the middle parts of the study area (including medium slopes and altitudes), therefore these types of tree individuals are considered as suitable mother trees (Mehdifar, Sagheb-talebi 2006).

CONCLUSIONS

Quantitative and qualitative characteristics of Persian oak were studied along an altitudinal gradient in Ilam Province, Darreshahr County (Iran). It can be concluded that altitude variations may have more significant effects than slopes on the quantitative characteristics of Persian oak in the western part of Iran. In contrast, the qualitative characteristics of Persian oak can be influenced by these two variables. Since the Zagros forest ecosystem is threatened by various problems, the identification of these changes and in

particular the knowledge of habitat requirements of Persian oak, which is an important tree species in this ecosystem, can be very important issues for forest conservation, restoration and management programs. The findings of the present study would be a guideline for Iranian Forests, Rangeland and Watershed Management Organization (IFRWO) to improve the degraded forests. Besides, the results can give a deeper insight into the relationship between the habitat preferences of Persian oak and other *Quercus* species which have similar eco-regions in the globe.

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