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Does diameter increment of Lebanon oak trees (*Quercus libani* Oliv.) affected by pollarding in Northern Zagros, Iran?

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Abstract Lebanon oak is one of the important oak species in the Northern Zagros forests, west of Iran, which exposed to severe pollarding in traditional silvopastoral management. The purpose of this study was to investigate the effect of pollarding on diameter increment of Lebanon oak trees. Therefore, a less-disturbed stand (0.7 ha) and a pollarded stand (1 ha) with similar physiographical conditions were selected. Full Callipering was performed in both stands and tree species; collar diameter and crown diameter for all trees (collar diameter $\geq$5 cm) were recorded. Moreover, total and trunk heights were measured in Lebanon oak trees as well. To evaluate the diameter increment of Lebanon oak trees, 20 and 15 tree samples were taken in the less-disturbed and pollarded stands, respectively. A pair of increment cores per sample tree was taken 100 cm above ground level, using increment borer. In the cores, annual radial increment was measured and the annual diameter increment was calculated by doubling that value. The diameter increment distribution of Lebanon oak trees in identical age classes was determined and used for comparison. The results indicated that the difference of the mean diameter increment of Lebanon oak in the same diameter classes was significant ($P < 0.05$) between two stands. The mean diameter increment in age classes of 57–81 years ($P < 0.01$) was significantly different ($P < 0.01$) between the two studied stands; however, in the age classes of 1–55 years, there was no significant difference ($P = 0.559$).

Keywords Northern Zagros forests · Pollarding · *Quercus libani* · Silvopastoral management

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Introduction

From a socio-economic perspective (soil conservation, water quality and other non-market ecosystem services), the Northern Zagros forests are a valuable forest ecosystem in Iran, expanding from West Azarbaijan to Fars provinces (Fattahi 1994; Valipour et al. 2014). These forests cover an area about 5440,494 ha (approximately 40 % of Iran's forests) as reported by F.R.W.O. (2015) and the main tree species include Persian oak (*Quercus brantii* Lindl.), Lebanon oak (*Quercus libani* Oliv.), and Gall oak (*Quercus infectoria* Oliv.). Based on the distribution of oak species, the Zagros forests have been divided into northern (including forests of West Azarbaijan, Kurdistan, and parts of Kermanshah and Lorestan provinces, which include mentioned three oak species) and southern Zagros (from Lorestan to the Fars provinces, which include only Persian oak) (Jazirehi and Ebrahimi Rostaghi 2003). The Iran's Forests, Range & Watershed Organization (FRWO) banned any utilization from these forests since 1962 and considers them as preserved and protected ecosystems (Shamekhi 2011); however, traditional uses (e.g., pollarding (disbranching and defoliation), fuel wood harvesting, livestock grazing, harvesting of non-wood forest products (i.e., oak acorns, gall varieties, manna: a sweet sap from oak trees (and agriculture in the forest floor) of these forests by local communities are still common. High dependence of the local forest dweller's livelihood to natural resources (especially forest) in such steepy mountainous and severe climates makes these utilizations inevitable (Ghazanfari et al. 2004). One of the problems of traditional livestock farming (in Zagros forests) is the shortage of rangelands and animal fodder, especially in cold seasons. In order to adapt their livelihood to natural difficulties and limitations, local people have innovated pollarding (in local term is called Galazani) of forest trees (Fattahi 1994; Ghazanfari et al. 2004; Valipour et al. 2014). In this traditional management, each rural family traditionally owns an area of the forest (in local term is called Galajar) and divide it into three or four parts (the local term for each part is ShaneGala). Each year a part is used to perform pollarding to provide winter fodder (Ghazanfari et al. 2003; Jazirehi and Ebrahimi Rostaghi 2003). Pollarding is a generic name for pruning (Turnbull 2005) with the aim of providing fodder (for domestic animals) and fuelwood. This tree management system is used in different countries and has been cited in various sources (Cantero 2012; Contratas Ancar 2012; Ferrini 2006; Read 2006). In study area, pollarding is conducted from mid-September onward (before the fall time) in a way that forest dwellers cut leafy branches (local term: Bakhe) of oak trees, which are mainly Lebanon oak and Gall oak, and store them on big trees (local term: Dargala), on the ground, or on rock fragments in a cone-shaped form often referred to as Gala or Loya Gala (Fig. 1). In winter, dried leafy branches from Loya Gala are used to feed livestock (especially Markhoz goat and sheep).

Despite the severe and widespread uses of forests in Northern Zagros, there are some stands located around cemeteries and holy places, which, due to traditional believes and their holiness to local people, have been protected from human exploitation and interference; therefore, their structure and vegetation have been rather intact. The area of these less-disturbed stands differs from less than 0.5 to more than 5 hectares (Jazirehi and Ebrahimi Rostaghi 2003; Shakeri 2006). These stands have been examined in this study as less-disturbed stands. Less-disturbed stands still have most structural and ecological characteristics of virgin Northern Zagros forests, which unfortunately, cannot be found today. These stands can be used as a model to perform restoration and management planning for degraded Zagros forests. Unfortunately, nowadays, the sacredness and respect to less-disturbed stands has been diminished between young generations and will face more encroachment and destruction.

Pollarding, like other operations performing on trees, can affect stand structure and architecture of trees (Ferrini 2006; Hodgkinson 1974; Khosravi et al. 2012; Pinkard et al. 1999; Pinkard and Beadle 1998; Salehian 2009; Shakeri 2006; Valipour et al. 2014). The first consequence of pollarding can be reduction of the crown area; reduced crown area can put the tree under stress and alter the normal pattern of its growth (Fattahi 1994; Pinkard and Beadle 1998; Ranjbar 2011). In recent years, the impact of traditional uses (pollarding and grazing) on stand structure and biometric indices of oak trees (Lebanon and Gall oaks) has been studied (Abbasi et al. 2014; Khosravi et al. 2012; Ranjbar et al. 2012; Salehian 2009; Shakeri 2006; Valipour et al. 2014). The results of previous studies indicated reduction in total and trunk heights, crown area, crown vitality and health, seed and coppice regenerations, and tree density in pollarded stands.

Sustainable forestry needs solid information about tree diameter increment (da Silva et al. 2002). Diameter increment could be used to examine the dynamics of natural forests, land-use changes (da Silva et al. 2002), assessment of climate change (Grace et al. 2002; Rozas 2005), and treatment performed on trees (Rozas 2005). Conducted studies on diameter increment of different oak species in the Zagros forests in recent years have reported various values. Diameter increment of Lebanon oak has been estimated to be 3.5 mm per year in pollarded stands (Ghazanfari et al. 2003) and 3.41 and 2.20 mm per year in pollarded and less-disturbed stands, respectively (Ranjbar et al. 2012). Diameter increment of Gall oak has been reported by Rostami Jalilian (2010): 2.23 mm per year in pollarded and 1.14 mm per year

Fig. 1 Collection of leafy branches stored on the ground (**a**) and on the tree (**b**) for winter feeding of livestock (**c**)

in less-disturbed stands, and by Valipour (2013): 2.00 mm per year in pollarded stand.

According to the reviewed studies, the consequences of pollarding on diameter increment have been examined in recent years, but the lack of attention to the impact of diameter and age of trees on this index has led to some ambiguities, so that it is impossible to distinguish the impact of pollarding and tree age on diameter increment. Due to higher palatability of Lebanon oak leaves than Persian oak and Gall oaks, this species is more suitable for pollarding in Northern Zagros. As a result, the main objective of this research is to examine and evaluate the impact of pollarding on diameter increment of Lebanon oak trees. A less-disturbed natural oak stand has been used as a baseline for comparison. We hypothesized that due to the pollarding; Lebanon oak trees in pollarded stand would show higher diameter increment in comparison to less-disturbed stand. Information on diameter increment of Lebanon oak in pollarded stands is useful to evaluate the effects and weaknesses of this kind of traditional management which can be used to do a sustainable management of these forests.

Materials and methods

Study area

The study was carried out in an oak forest growing at Zagros Mountains in northwest of Kurdistan province in west of Iran (latitude: 3,956,336–4,012,402, longitude: 575,206–612,307). The altitude of the study area ranges from 1200 to 2200 m above sea level. The study area has a mediterranean climate, with mean annual precipitation of 647 mm (average over 7 years of observation), most of which was in late autumn to early spring and average annual temperature 14 C. Lebanon oak (*Quercus libani* Oliv.), Gall oak (*Qercus infectoria* Oliv.), and Persian oak (*Qercus brantii* Lindl.) are the main tree species of the study area.

Methods

Two adjacent stands including a less-disturbed stand (about 0.7 hectare) and a pollarded stand (about one hectare) with similar physiographic conditions (slope, aspect, and altitude) were selected. In the examined stands, full Callipering of all trees (collar diameter $\geq$5 cm) was conducted; tree species was recorded; collar diameter and both large and small crown diameters were measured using caliper and measuring tape, respectively. In addition, the total and trunk heights of Lebanon oak trees were also measured using the clinometers (Suunto PM-5, Finland). The exact number of sample trees was calculated 20 and 15 trees in less-disturbed and pollarded stands, respectively, using Eq. (1) with the estimate error of 17 % (Cochran 1977).

$$n = \frac{t^2 \times S_{\mathrm{di}}\%^2}{E\,\%^2}, \qquad (1)$$

where t is t-Student coefficient; S_{di} % represents standard deviation percentage of diameter increment; and E % denotes the percentage of estimate error of diameter increment.

Sample trees were selected using the nearest-tree to the random point method (Vidal Ruiz 1986). The selection protocol contains three criteria: 1—diameter of sample trees in 1 m height between 18 and 28 cm; 2—the origin of sample trees must be coppice; 3—sample trees must be without external evidence of decay.

The diameters and bark thickness of the selected sample trees were measured using caliper and a bark thickness gauge, respectively, at the time of sampling in February 2012. According to the Schweingruber method, a pair of cores per sample tree was taken 100 cm above ground level, using increment borer (Grissino-Mayer 2003). Cores were moved to the laboratory, placed in prepared wooden frames, and surfaced with a series of successively finer sandpaper grits. Subsequently, a binocular microscope (AXIOM, Germany) was used to measure annual radial increment of samples; the annual diameter increment was calculated by doubling that value. The mean of the radial increment of two cores extracted from each sample tree was used in the calculations.

Data analysis

Data distribution normality was evaluated by Kolmogorov–Smirnov test. The independent samples *t* test was used to compare the diameter increment of Lebanon oak trees in the two examined stands. In order to minimize the effect of tree ages in two stands, diameter increment comparisons were conducted in identical age classes. All calculations and statistical analysis were performed using Microsoft Excel 2007 and SPSS 16 software packages.

Results

Main characteristics of investigated stands

The forest type according to tree number in less-disturbed stand is *Quercus libani–Quercus infectoria-Quercus brantii*, and in pollarded stand is *Q. brantii–Q. libani–Q. infectoria*. Moreover, the share of companion species wild pear (*Pyrus* spp.), hawthorn (*Crataegus* spp.), and almond (*Amygdalus* spp.) was 4 % in the less-disturbed stand and 1 % in the pollarded stand.

Based on the basal area per hectare, forest type in the less-disturbed stand is *Q. infectoria–Q. libani* with *Q. brantii*, and in pollarded stand is *Q. libani–Q. infectoria–Q. brantii*. The share of the companion species on the base on basal area per hectare in less-disturbed and pollarded stands was 1.5 and 0.1 %, respectively.

The mean collar diameter of all species in less-disturbed and pollarded stands is 28.1 and 17.8 cm, respectively. Total density in less-disturbed and pollarded stands was 593 and 559 trees ha^{-1} and total basal area was 21.1 and 11.2 m^2 ha^{-1}, respectively (Table 1). Statistical parameters of biometric indices of Lebanon oak in examined stands are presented in Table 2.

Diameter increment of Lebanon oak trees in age classes

The mean diameter increment of Lebanon oak trees in less-disturbed and pollarded stands in the age range of 1–81 years was 2.07 and 2.28 mm per year, in the age range of 1–55 years was 2.13 and 2.18 mm per year, and in the age range of 57–81 years was 1.93 and 2.50 mm per year, respectively (Table 3). Distribution of diameter increment in age classes showed that the highest diameter increment (2.69 mm per year) in the less-disturbed stand was belonged to the 1 year age class and the minimum value of this attribute (1.50 mm per year) was related to the 81 year age class. Maximum (3.59 mm per year) and minimum (1.73 mm per year) of diameter increment in the pollarded stand were related to the age classes of 1 and 83 years, respectively (Fig. 2).

The results showed that there was no difference between the mean diameter increment of Lebanon oak in the age classes (1–55 year) in two investigated stands ($P = 0.559$), but in age classes 1–81 and 57–81 years, mean diameter increment was more in pollarded stand than less-disturbed stand and the difference is significant ($P < 0.01$) (Table 4).

Discussion

This study uses diameter increment index to evaluate the effect of pollarding on Lebanon oak trees. In order to reduce the effects of known environmental factors affecting the diameter increment (slope, aspect, and

Table 1 Main characteristics of examined stands

Indices	Less-disturbed stand	Pollarded stand
Area (ha)	0.7	1.0
Aspect	SE	SE
Slope (%)	15–20	15–20
Altitude (m.a.s.l.)	1528	1528
Total density (tree ha^{-1})	593	559
Total basal area (m^2 ha^{-1})	21.1	11.2
Mean collar diameter ± SD (cm)	28.1 ± 13.0	17.8 ± 11.3

Table 2 Statistical parameters of biometric indices of Lebanon oak in examined stands

Stands	Biometric indices	Mean	SD	Min.	Max.	E (%)
Less disturbed	Collar diameter (cm)	29.9	12.2	5.0	65.0	6.1
	Total height (m)	7.4	2.4	1.9	13.9	4.8
	Trunk height (m)	2.2	1.1	0.3	7.1	7.4
	Crown height (m)	5.2	1.8	1.0	9.3	5.1
	Crown area (m^2)	18.1	12.9	0.3	72.4	10.6
Pollarded	Collar diameter (cm)	25.1	13.9	5.0	57.0	8.3
	Total height (m)	4.9	1.6	1.9	10.0	4.9
	Trunk height (m)	1.1	0.5	0.3	3.1	6.6
	Crown height (m)	3.8	1.4	0.9	8.0	5.5
	Crown area (m^2)	4.1	3.8	0.2	15.9	13.9

Table 3 Statistics of diameter increment of Lebanon oak in age classes in examined stands

Stands	Age classes (year)	Mean (mm/year)	Min. (mm/year)	Max. (mm/year)	SD (mm/year)	Error of estimation (%)
Less disturbed	1–81	2.07	1.50	2.69	0.25	3.80
	1–55	2.13	1.76	2.69	0.25	4.36
	57–81	1.93	1.50	2.28	0.21	6.67
Pollarded	1–81	2.28	1.73	3.59	0.36	4.94
	1–55	2.18	1.73	3.59	0.36	6.37
	57–81	2.50	2.04	2.80	0.25	5.94

altitude), stands with almost similar physiographic conditions were selected for this study.

Results of previous studies [Rostami Jalilian (2010) on Gall oak and Ranjbar et al. (2012) on Lebanon oak] showed the significant differences in diameter increment in identical diameter classes. Since trees with same diameter could have different ages, examining diameter increment in diameter classes can raise the question whether the diameter increment differences are due to age differences between sample trees; therefore in this study, in order to reduce the effects of tree's age, diameter increment distribution in age classes (1–81 years) was determined and used for comparison.

Our results showed that there was no difference between the mean diameter increment of Lebanon oak in the age classes (1–55 year) in two investigated stands, but in the age classes 1–81 and 57–81 years the mean diameter increment in less-disturbed stands was less than the mean of this index in pollarded stand (Tables 3, 4).

Due to the similar physiographic and climatic conditions in the examined stands, and using identical age classes to compare diameter increment, part of the

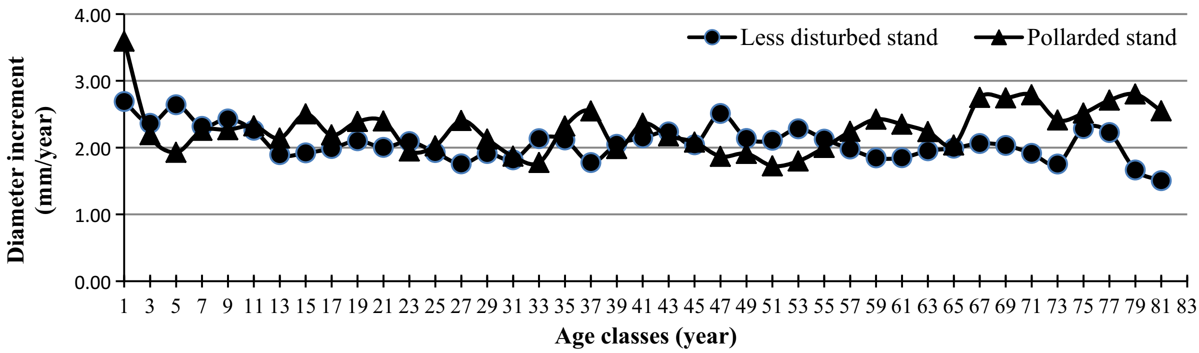

Fig. 2 Mean diameter increment of Lebanon oak trees versus age classes

Table 4 Results of student's *t*-test comparing diameter increment of Lebanon oak in age classes between examined stands

Diameter increment (mm/year)	Levene's test for equality of variances		*T*-test for equality of means	
	F	*P*	*t*	*P*
Age classes 1–81 years	3.025	0.086	−3.183	>0.01
Age classes 1–55 years	1.101	0.299	−0.588	0.559
Age classes 57–81 years	0.785	0.385	−6.430	>0.01

difference in diameter increment can be attributed to pollarding. Lebanon oak leaves produced in the first year after pollarding have the highest leaf area and specific leaf area compared to the second and third years after pollarding and to less-disturbed stands (Abbasi et al. 2015); this leads to physiological changes and increased photosynthesis rate in the larger leaves (Gill et al. 1998; Pinkard et al. 1999) and can increase diameter increment of pollarded trees.

Pollarding reduces crown volume (Ranjbar et al. 2012; Salehian 2009; Shakeri 2006) which leads to leaf area index reduction (Abbasi et al. 2015; Pinkard and Beadle 1998). In the other hand, unpollarded trees have more thick branches in the crown (i.e., devotion of a part of diameter increment to these branches), a larger number of dry branches (i.e., increased respiration) and located in denser stands (i.e., light limitation) (Salehian 2009; Shakeri 2006; Valipour et al. 2014) which altogether can cause diameter increment reduction in these trees (Ranjbar et al. 2012; Rostami Jalilian 2010).

Less-disturbed stands have at least three distinct dense stratum, while pollarded stands have only one stratum which made by separate trees (Ranjbar et al. 2012; Salehian 2009; Shakeri 2006). Multi-stratification in less-disturbed stands can decrease the diameter increment by increasing competition between trees (Uzoh et al. 1998).

The high presence of semi-parasitic plant (*Loranthus grewinki*) on Lebanon oak tree crowns, in less-disturbed stands (Ghalavand 2014; Shakeri 2006), can also decrease diameter increment (Glatzel and Geils 2008; Schulze et al. 1984).

The higher amount of diameter increment in the early stages of tree growth can be attributed to their coppice origin (Fig. 2 mean diameter increment of Lebanon oak trees vs. age classes). Coppice shoots use the nutrients and developed root system of mother trees and, as a result, have greater height and diameter increment in the early stages of their growth (Johnson et al. 2002). With increasing age, the competition between coppice shoots of a sprout-clump increases, which results in high mortality rate and reducing diameter increment in less-disturbed stands. After about 10 years, local users conduct the traditional treatment of thinning (in local term is called Shekhalgiri) on sprout-clumps; this treatment will continue on these trees. In age classes 57–81 years, pollarding enhances leaf flushing and rapid shoot growth which resulted in large diameter cells of the early wood types (Barnes et al. 1997).

Conclusions

In the common traditional management (pollarding and grazing) in Northern Zagros forests, to achieve silvopastural goals, Lebanon oak trees have a particular importance, by providing fodder and fuelwood for local people's livelihood. Our results showed that pollarding has positive effect on diameter increment of Lebanon oak trees. Moreover, the diameter increment of forest trees is also influenced by internal (physiology, tree age, genetic characteristics, and tree architecture) and environmental factors (slope, aspect, altitude, weather conditions, soil type and nutrients, competition, distance between the trees, and the vertical position of tree in the stand) (Barnes et al. 1997), so part of the difference in diameter increment could be linked to these factors. Alongside positive effect of pollarding on diameter increment and it's socio-economic importance, the main problem of this system is lack of regeneration and forest continuity. Since pollarding in Zagros forests is illegal, which leads to continuous conflicts between local people and the FRWO, we suggest that seed regeneration, maintenance, and warranty of regeneration establishment in pollarded stands by local people be a prerequisite for issuing of pollarding practices.

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