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Growth and Plant Diversity in a Man-Made Thinned *Cedrus atlantica* Stand

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Abstract: In order to study the growth characteristics of Atlas cedar (*Cedrus atlantica* Manetti) and to assess the plant diversity an investigation was carried out in a 30 year old man-made stand located in the Caspian mountain forests (north of Iran). In this stand a silvicultural treatment as thinning was operated in five replications of 200 m^2 for removing 25% of basal area. Likewise five replications of 200 m^2 were considered as control (unthinned). The results of 5 year investigation revealed that diameter growth of *C. atlantica* was two times greater in thinned stand than in unthinned stand ($p<0.05$). Height growth and basal area (b.a.) in thinned stand were not greater than those in controlled stand. Vitality quality in both treatments was fairly high. Fruit production was significantly more ample in thinned stand than in unthinned stand. Compared to unthinned stand, in thinned stand index of Simpson Diversity was greater but indices of Menhinic Richness and Peet Evenness were smaller. This study reveals that generally diversity has been increased in the managed stand. Besides that *C. atlantica* has been adapted to this region and therefore thinning practice can be a good measure for increasing timber production.

Key words: *Cedrus atlantica*, growth, diversity index, thinning

INTRODUCTION

The area of plantations is steadily increasing in proportion to total area of the world forests. They are not only established on lands previously not under forest but are, especially in the temperate and sub-tropical zones, also replacing natural forest ecosystems. In many areas, plantations are also established to help conserve natural and often complex forest ecosystems, through taking off pressure from these ecosystems and transferring their role as wood producers to fast-growing plantations. The world wood and timber production will thus increasingly come to depend upon the continued success of man-made plantations. Wherever plantations of forest trees are established, the question of which species and provenance should be used for the sites available, must field of species/provenance research, a dilemma nearly always arises when such a decision is to be taken. The species chosen must not only be adapted to the sites available for planting, but must at the same time satisfy the specific objectives for which they are established (Matziris, 1991).

In recent decades, deforestation of the northern (Caspian) forests of Iran has been highly increased. The main reason for this reduction in plains and margin of forest villages, as well as mountainous and sub-alpine regions, has been the need of local people for agriculture development. In fact, only a green band of the Caspian Sea margin with length of 800 km, situated mainly in middle heights, is preserving and running seriously by government, private companies and rural communities (Marvie Mohadjer, 2005). Moreover, annually 30000-40000 hectare natural and artificial regeneration is still performing in the deforested areas and in the natural regeneration compartments where the shelterwood cuttings or forest exploitation have been not well carried out (Hedayati, 2001). Since 1960s, in order to rehabilitate the deforested areas, conifers seed has been imported to country, especially from Europe, sown in nurseries and the seedlings produced replanted in the northern regions (Mehdipoor-Ataei, 1974; Jazirehi and Ebrahimi, 2003). During this period, compatibility and growth of most introduced species were satisfactory but a few ones suffered from pests and diseases (Asadollahi and Hedayati, 1991). One of the successful species semi-arid and semi-humid regions of country is *Cedrus atlantica* Manetti with seed origin of the Morocco Atlas Mountains. Nevertheless this species is not able to tolerate a wider range of soil pH and drought conditions than *Cedrus libani* (Alptekin *et al*., 1997), however there was attempted to examine it in dry and humid regions of the country with various levels of

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soil pH. The present investigation evaluates the results of compatibility and growth of this species planted in 1970 in a semi-humid deforested region and compares the influence of thinning on some qualitative and quantitative characteristics of this species, too. Generally it has been accepted that thinning improves physiological responses (Wang *et al*., 1995), microclimate responses (Weng *et al*., 2007), increases diameter growth (Simard and Hannam, 2000) and promotes biodiversity (Humphery *et al*., 1998; Sullivan *et al*., 2001; 2002, 2005; Cusack and Montagnini, 2004; Lindh and Muir, 2004; Hagar *et al*., 2004). In present research it is hypothesized that dbh growth as well as vegetation diversity is greater in thinned stand than in controlled stand.

MATERIALS AND METHODS

Site study: Site study is a 30-year-old afforested stand established in 1970 in a deforested area of the Caspian forests of Kelardasht region, north of Iran. Original and dominant species of this region were *Fagus orientalis* accompanying with *Acer campestre*, *Acer laetum*, *Carpinus betulus*. Elevation is 1400 m asl, slope gradient is approximately 25% and general aspect is faced north (340°). Mean annual temperature is 10°C. Average maximum temperature in the warmest month is 32°C and average minimum temperature in the coldest month is -14°C, occurring in August and February, respectively. Total precipitation is 600 mm year^{-1}, which the majority falls in autumn. Snow often occurs in winter and in some years reaches 50-60 cm in depth. Vital drought season, with xerothermique index of approximately 75 days year^{-1}, appears in summer (Poormadjidian, 1990). Based on the Emberger climatic classification this region with Q_2 = 46.2 (index of rain and temperature) conforms to semi-humid climate with very cold winters. Figure 1 illustrates the Emberothermique curve for the present investigated site. Soil is rich, deep, clay-loam, to some extent drained, pH of 6.2-7.9, lacking lime in upper and lower layers, corresponding with washed brown type. Table 1 gives some physico-chemical properties of soil profile.

Experiment design and measurements: Investigation site, established in 1970, is a 5000 m^2 man-made stand with plantation distances of 5 m in terrace and 2 m in row. In 1995, in part of this stand a rather light thinning was operated by removing about 25% of tree basal area. The removed trees were mainly as non-straight stems with small diameter at breast height (dbh). Simultaneously, in other part of the stand no intervention was made. Before thinning time (in 1995) a sampling (as line transect) with 10% inventory intensity was done to record some characteristics of *C. atlantica* trees [e.g., dbh and total height] in the whole stand. In 2000, in either of thinned and unthinned (control) stands five replications of 200 m^2 were selected and total height, dbh, number of fruit-carrying trees and vitality quality (ranked in good and very good classes) and ground vegetation were recorded

Table 1: Soil physico-chemical properties of the profile dug in the experimental site

Depth (cm)	Texture	Organic matter (%)	pH	EC (mM cm^{-1})	C (%)	Total N (%)	C/N
Ao	Loam-Clay	9.0	6.4	0.6	0.5	0.03	16.7
0-25	Loam-Clay	1.0	6.2	0.6	0.6	0.07	8.6
26-45	Clay	0.9	7.6	0.4	0.5	0.07	7.1
46-80	Clay	0.7	7.9	0.4	0.4	0.08	5.0
81-120	Clay	0.5	7.0	0.7	0.3	0.05	6.0

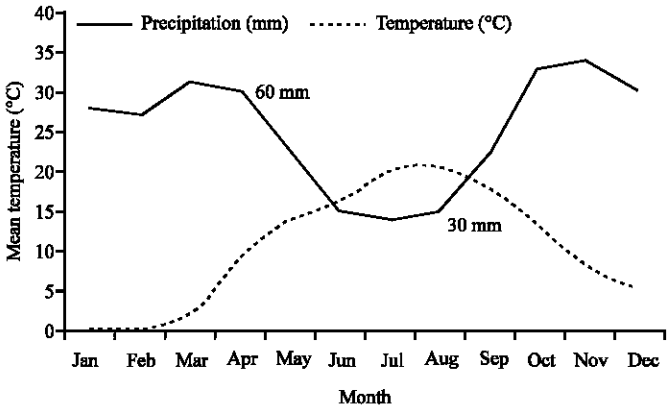

Fig. 1: Embrotermique curve of the site study - Precipitation is exhibited with right axis and its amount is 2 times as much as temperature, presented by left axis (P = 2T)

in which. Likewise, at the end of period by registering the number wooden plants indices of Simpson Diversity, Menhinic Richness and Peet Evenness were determined.

A two-tailed t-test was used to test the difference between means (Cochran and Cox, 1957) at the 5% level of significance by using the SPSS software. Figures were performed by using the EXCEL program.

RESULTS

Analysis in the first and second measurements (1995 and 2000) exhibited that the mean annual d.b.h. growth was two times greater in thinned stand than that in unthinned stand (df = 41, t = 4.87, p = 0.000) as shown at Table 2. This, indeed, can state the significant effect of thinning on d.b.h. of the *C. atlantica* trees. After 5 years basal area (b.a.) was almost equal in both treatments (Table 2). Annual height growth was 48 and 40 cm in unthinned stand and thinned stand, respectively; however there was no statistically difference of this term in two treatments (df = 41, t = 3.17, p = 0.090) (Table 3).

Frequency of vitality quality was found to be very high, whereas 95 and 90% of trees, respectively in thinned and unthinned stands, were benefited from such quality. The rest of trees were illustrated with good vitality grade (Table 4). Fructification was happened when the trees were 25 years old (1995). The number of trees carrying fruit was more abundant in thinning area than in control area. Table 4 clearly exhibits significant differences of this characteristic for *C. atlantica* trees in two treatments. In control area except *Ilex hyrcana* and a few wooden species, occupied in some small parts, not any ground vegetation could be detected. In contrast, shrub and tree species, such as *Acer laetum*, *Mespilus germanica*, *Crataegus monogina*, *Cornus* sp., *Frangula alnus* and *Prunus divaricata*, *Ilex hyrcana* together with ground vegetation, like *Primula* sp., *Viola alba*, *Cyclamen europaea*, *Frangula vesca* as well as some grasses and legumes were well found considerably in thinned area. Figure 2 also indicates the frequency of woody species in both stands As illustrated Fig. 3, generally in thinned stand, in compared with unthinned, index of Simpson Diversity was greater (t = -4.3, p = 0.008) but indices of Menhinic Richness (t = -5.2, p = 0.005) and Peet Evenness (t = 4.5, p = 0.002) were smaller.

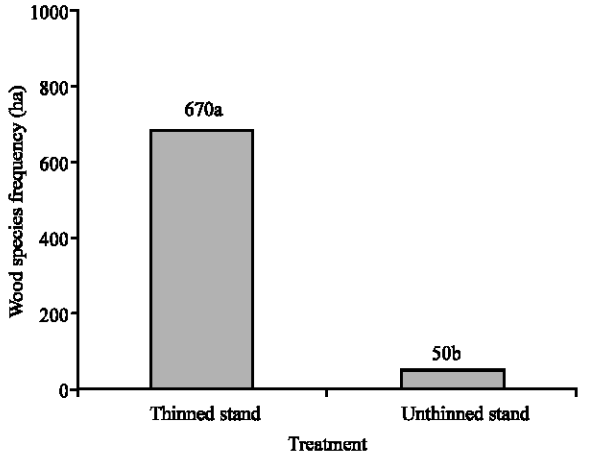

Fig. 2: Frequency of woody species in thinned stand and unthinned stand

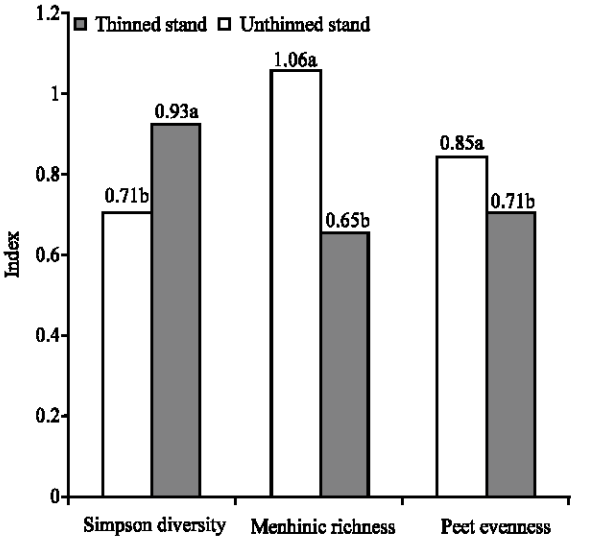

Fig. 3: Indices of diversity in thinned stand and unthinned stand -(Means, followed by different letters on the columns are statistically different at 0.01% probability level, according to t-test)

Table 2: Diameter at breast height (d.b.h.), mean annual d.b.h. growth and mean basal area of *C. atlantica* trees in thinned and unthinned stands

Treatment	d.b.h. in 1995 (cm)	d.b.h. in 2000 (cm)	5-year d.b.h. growth (mm)	Mean annual d.b.h. growth±SD (mm)	Mean basal area in 2000 (m^2 ha^{-1})
Unthinned stand	18.0	21.0	30	6±0.4b	34.6
Thinned stand	18.2	24.2	60	12±0.6a	34.5

Means±SD, followed by different letter(s) in subscribe are significantly different at 5% probability level, according to t-test

Table 3: Height and mean annual height growth of *C. atlantica* trees in thinned and unthinned stands

Treatment	Height in 1995 (m)	Height in 2000 (m)	5-year height growth (cm)	Mean annual height growth±SD (cm)
Unthinned stand	9.5	11.9	240	48±5
Thinned stand	9.6	11.6	200	40±4

Means±SD, followed by different letter(s) differ significantly at 5% probability level, according to t-test

Table 4: Values for variables of Vitality quality and fruit carrying in two studied stands of the *C. atlantica*

Variables	Unthinned stand	Thinned stand
Frequency of vitality quality (%)		
Very high grade	90	95
Good grade	10	5
Frequency of fruit carrying trees (%)	10b*	30a

*Means, followed by different letters in row are statistically different at 5% probability level, according to t-test

DISCUSSION

The present study reveals that a silvicultural intervention such as thinning practice affects promotion of some characteristics of *Cedrus atlantica* trees. Among these variables, specially, d.b.h. growth is substantially greater in thinned stand, though height growth, as well as basal area (b.a.), does not differ significantly in 2 trials ($p<0.05$). Regarding the results of this study it may be claimed that *C. atlantica* grown in sub-humid climate of the north of Iran has an approximate equal value of b.a. to same age *C. atlantica* reported by Masotti *et al.* (1995), situated in south of France (Mont Ventoux mountains) with a rainfall of 1000 mm year^{-1}. In other words, by the current investigation it can be implied that with increasing d.b.h. and standing volume, harvesting some trees by removing b.a. during the period, yield amount and income will be increased in thinned stand.

The majority of trees of both treatments appeared with very good vitality (> 90% of trees), therefore it is revealed that this term did not affect by thinning. Variety of ingrowth (herbaceous and wooden species and showed by index of Simpson Diversity) is apparently better in thinned stand whereas it can be stated that as a whole species variety increased with radiation supply created by thinning. The results of many researchers such as Sullivan *et al.* (2002, 2005), Lindh and Muir (2004), Hagar *et al.* (2004) and Memarian *et al.* (2007) on plant diversity are similar to what we found in this study. Likewise it can be referred to studies of Humphrey *et al.* (1998), Virolianen *et al.* (1998, on *Pinus sylvestris*) and Cusack and Montagnini (2004) who found that plant diversity promoted in plantations. Of course, the opposite results can be observed in reports of Ito *et al.* (2004, on *Cryptomeria japonica* and *Chamaecyparis obtusa*).

In investigation Evenness index, as well as Richness index, is smaller in thinned stand. This can be due to the higher frequency of woody species in thinned stand compared to that in controlled stand. The opposite results can be found in the report of Nagaike *et al.* (2003), who displayed that in Larix kaempferi plantations plant species richness was advanced after removing the trees.

Number of fruit-carrying trees was completely more abundant in thinned area, showing the lighting induced by thinning affected the fructification potential. In Serbia fructification of exotic *C. atlantica* starts at 30 years old (Kitic and Bojovic, 1990), about 5 yeas later than that in present experimental site. This can demonstrate the suitability of *C. atlantica* site in the north of Iran, compared to that in Serbia.

Generally, the present investigation reveals that during a 30-year period, *C. atlantica* is able to well adapt with environmental conditions and obtain favorable growth. Considering the facts given above and the results presented by Poormadjidian (1991), Mirbadin and Sagheb-Talebi (1991), it can be asserted that in such sites *C. atlantica* is able to well compete and overtake *P. abies* planted in neighboring of this site. Such comparison of *C. atlantica* may also be applied to *P. abies* reported by Rezaiee (2000), planted in Ladjim forest region (north of Iran) with humid climate and semi-cold winters. Likewise, in agreement with results presented by Asadollahi and Hedayati (1991) on *C. atlantica* experimented in a semi-arid region of the north of Iran (Golidagh), it is confirmed that like *P. abies*, plantation of this tree is remarkably successful and satisfactory. It should be also cited that unlike *C. atlantica* planted in semi-arid region which is involving with cracking wood and excreting white sap in some drought years, neither such problems nor pests damages are observed with this tree in the present investigated site.

Considering the above results, although in north of Iran the growth of *C. atlantica* in semi-humid region is definitely more favorable than that in semi-arid region; its plantation can be recommended for restoration of deforested areas in both regions. In conclusion, by this research it is revealed that *C. atlantica* has been acclimatized successfully, particularly in the Kelardasht investigation site and thinning practice can be a good operation for increasing timber yield.

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