[Short Communication]

Effects of initial spacing on some allometric characteristics of 12-year-old *Quercus castaneifolia* plantation in central Mazandaran, Iranian Caspian forests

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ABSTRACT
The effects of initial spacing layout on some allometric characteristics of 12-year-old *Quercus castaneifolia* trees grown in Central Mazandaran, north of Iran were examined. Trees were planted in 5 different layouts (1×1, 1.5×1.5, 2×2.5, 2×3 and 4×4 m). Tree height, diameter at breast height, natural pruning height and the survival of trees were recorded in each sample plot. Tree basal area and H/D ratio and standing volume were calculated for all trees. The results of statistical analysis showed that increasing in spacing level from 1×1 to 4×4 significantly increased the average diameter at breast height from 6.93 to 12.42 cm and survival from 53% to 85%. The average tree basal area per ha decreased from 19.98 m²ha⁻¹ to 6.43 m²ha⁻¹ and H/D ratio from 151 to 77 when the distance between trees increased from 1 × 1 to 4 × 4 m. but spacing regime had no significant effect on tree height and natural pruning height. It can be concluded that on the basis of standing volume, H/D ratio and survival rate, the best plantation spacing in this research station was 2 m × 3 m. Statistically, about 95% of the changes in sediment yield was due to the effect of increased dry land farming area in the basin (R²= 0.95, α < 0.05).

Keywords: Allometric characteristics, Hyrcanian Forests, Plantation, *Quercus castaneifolia*, Plantation Spacing.

INTRODUCTION
Forest plantation is a common action in order to restore the degraded forests in the Caspian region (Mohammadnezhad Kiasari et al. 2009) which are also called as Hyrcanian forests and are located on the southern parts of the Caspian Sea (Bonyad et al. 2012). The genus *Quercus* contains around 530 species worldwide (Rix & Kirkham 2009). Several species of deciduous oaks including *Quercus castaneifolia*, *Q. infectoria*, *Q. brantii* and *Q. libani* are grown in Iran (Ehsanpour & Zahedi 2006, Panahi et al. 2011). *Quercus castaneifolia* is one of the typical Hyrcanian species inhabiting the humid forests which curve around the southern coast of the Caspian Sea (Rix & Kirkham 2009). This species also plays an important role in the local industry as well as in folk medicine (Mamedova et al. 1993). Spacing and planting layout influence tree growth and form (Cochran et al. 1991; Gerrand et al. 1997; Williams et al. 2006; Hegazy et al. 2008). Spacing also has a major impact on the acceptance of timber for products such as sawlog or veneer as it is associated with branch size and number of branches (Neisen & Gerrands 1999; Henskens et al. 2001). Other characteristics such as wood density and strength, visually graded wood quality, crown shape and stem taper can also be affected (Deans & Mihe 1999; Henskens et al. 2001). *Quercus castaneifolia* in Iran is mostly planted to reforest degraded stands and to produce timber for industry. Many publications investigated the effect of spacing on some qualitative and quantitative characteristics of planted trees. In this direction Cochran et al. (1991) studied spacing effect on growth of ponderosa pine. Results showed that larger spacing produced larger trees but less volume per hectare than closer spacing. The effect of spacing on yield and some wood properties of *Cupressus lusitanica* in
Northern Tanzania were examined by Malimbwi et al. (1992). They reported that with increasing spacing, mortality and total volume decreased while branch diameter and breast height diameter increased. Henskens et al. (2001) in an investigation entitled “physiological basis of spacing effects on tree growth and form in Eucalyptus globulus” have found that with increasing spacing, stand leaf area index and the proportion of aboveground biomass in stem declined, while mass in foliage and branches increased. Also Hegazy et al. (2008) studied the effect of spacing on the biomass production and allocation in Conocarpus erectus L. trees grown in Saudi Arabia. The mentioned trees were planted at three different square spacings of 0.7, 1.4 and 2.1 m. The results indicated that the highest yield was produced from close spacing (0.7 m). But total tree biomass was lowest in close spacing and was higher in spacing of 2.1 m. The main objective of this study was to investigate the effects of different initial spacing layout on some allometric characteristics of Quercus castaneifolia C. A. M. plantation in lowlands of Hyrcanian forests, Northern Iran.

MATERIALS AND METHODS
Study site description
This study was carried out in Chamestan area, located in central Mazandaran, north of Iran (36° 25’ to 36° 29’ N, 51° 55’ to 51° 59’ E) (Fig. 1). The elevation of the site is about 100 m a.s.l. and its slope ranges from 0 to 3%. The mean annual temperature is 16.3 °C and annual precipitation is about 864 mm. General soil order is Inceptisol.

Data collection and experimental design
Experiments were conducted in 2006 in a plantation of Quercus castaneifolia which was established in 1994. The aforementioned plantations were in 5 different spacing levels of 1×1, 1.5×1.5, 2×2.5, 2×3 and 4×4. The experimental design of the study was randomized complete block design with 3 replicates and 5 treatments (5 spacing levels). 3 plots were designed in each spacing layout. The area of each plot was 400 m². In order to eliminate potential edge effects, all sample plots were considered at center of plantations. Due to different spacing layouts, the number of trees in each sample plot was different and ranged from 27 trees in 4×4 m layout to 49 trees in 1×1 m layout. In each plot some allometric characteristics such as diameter at breast height, tree height, natural pruning height (a segment of the stem naturally was pruned due to light shortage) of all trees were recorded. Considering the value of tree height (H) and its diameter (D), H/D ratio was calculated for all trees. As a consequence of tree number per hectare and their diameter (at breast height) the average of tree basal area per hectare was calculated.
for all spacing levels. In addition, mortality in each sample plot was recorded in order to compare the survival of trees in different spacing levels.

**Statistical analysis**
The obtained data were statistically analyzed through analysis of variance for a randomized complete block design using SPSS software. The table and graphs drawing were done in Excel computer program.

**RESULTS**
The statistical analysis showed that spacing had a significant effect ($P<0.05$) on the average diameter at breast height of *Quercus castaneifolia* trees (Table 1). The diameter at breast height significantly increased from 6.93 to 12.42 cm by increasing the distance between trees from 1×1 to 4×4 m. But increasing in spacing had no significant effect on the average tree height, although it trended to decrease slightly from 10.56 m for spacing of 1×1 to 9.6 m for spacing of 4×4 m (Table 2). Statistical analysis also revealed that the average natural pruning height was not significantly influenced by the spacing level ($P<0.05$), but insignificantly decreased from 5.36 m in 1×1 to 3.63 m in 4×4 m spacing level. There also was a significant difference ($P<0.05$) between spacing levels in tree basal area (Table 2). The greatest tree basal area per ha found in spacing level of 1×1 m was 19.98 m$^2$ha$^{-1}$ and the lowest amount observed in spacing level of 4×4 m was 6.43 m$^2$ha$^{-1}$ (Table 2).

Regarding the percent of mortality, spacing treatment had a significant effect on the survival percent of trees in different spacing layout ($P < 0.05$). The average value for tree survival increased significantly from 53% to 85% as spacing increased from 1×1 to 4×4 m. The statistical analysis also showed that the H/D ratio of *Quercus castaneifolia* is significantly different among spacing layouts ($P<0.05$). The value of H/D ratio for 5 different spacing levels of 1×1, 1.5×1.5, 2×2.5, 2×3 and 4×4 were 151, 133, 109, 86 and 77 respectively which show a considerable decrease from 151 to 77. There was also a significant difference in standing volume among the spacing levels the highest of which was 111.8 m$^3$ in 1×1 layout and the lowest was 52.5 m$^3$ in 4×4 layout ($P<0.05$) (Table 2).

<table>
<thead>
<tr>
<th>Variables</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree diameter (m)</td>
<td>4</td>
<td>0.779</td>
<td>0.195</td>
<td>58.088 *</td>
<td></td>
</tr>
<tr>
<td>Tree height (m)</td>
<td>4</td>
<td>0.013</td>
<td>0.003</td>
<td>0.894 ns</td>
<td></td>
</tr>
<tr>
<td>Natural pruning height (m)</td>
<td>4</td>
<td>7.998</td>
<td>1.999</td>
<td>4.483 ns</td>
<td></td>
</tr>
<tr>
<td>basal area (m$^2$ ha$^{-1}$)</td>
<td>4</td>
<td>288.421</td>
<td>72.105</td>
<td>59.704 *</td>
<td></td>
</tr>
<tr>
<td>Survival (%)</td>
<td>4</td>
<td>2652.6</td>
<td>656.4</td>
<td>37.295 *</td>
<td></td>
</tr>
<tr>
<td>H/D ratio</td>
<td>4</td>
<td>11499.733</td>
<td>2874.933</td>
<td>76.87 *</td>
<td></td>
</tr>
<tr>
<td>Standing volume</td>
<td>4</td>
<td>7128.744</td>
<td>1782.186</td>
<td>1.782 *</td>
<td></td>
</tr>
</tbody>
</table>

* indicates the significant difference and ns indicates non significant different

<table>
<thead>
<tr>
<th>Spacing (m)</th>
<th>Tree diameter (cm)</th>
<th>Tree height (m)</th>
<th>Natural pruning height (m)</th>
<th>basal area (m$^2$ ha$^{-1}$)</th>
<th>Survival (%)</th>
<th>H/D ratio</th>
<th>Standing volume (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1×1</td>
<td>6.93 c</td>
<td>10.56 a</td>
<td>5.36 a</td>
<td>19.98 a</td>
<td>53 b</td>
<td>151 a</td>
<td>111.8 a</td>
</tr>
<tr>
<td>1.5×1.5</td>
<td>7.74 c</td>
<td>10.32 a</td>
<td>4.92 a</td>
<td>12.54 b</td>
<td>60 b</td>
<td>133 b</td>
<td>77.65 b</td>
</tr>
<tr>
<td>2×2.5</td>
<td>9.27 b</td>
<td>10.08 a</td>
<td>3.72 a</td>
<td>10.93 b</td>
<td>81 a</td>
<td>109 c</td>
<td>89.2 b</td>
</tr>
<tr>
<td>2×3</td>
<td>11.16 a</td>
<td>9.72 a</td>
<td>3.67 a</td>
<td>13.52 b</td>
<td>83 a</td>
<td>86 d</td>
<td>109 a</td>
</tr>
<tr>
<td>4×4</td>
<td>12.42 a</td>
<td>9.6 a</td>
<td>3.63 a</td>
<td>6.43 c</td>
<td>85 a</td>
<td>77 d</td>
<td>52.5 c</td>
</tr>
</tbody>
</table>

**Discussion**
The relationships between spacing layout and allometric characteristics in *Quercus castaneifolia* at the age of 12 years were in agreement with patterns frequently reported in trees of temperate forests. In this study spacing slightly and insignificantly affected the height growth of trees. The
result is in consistent with most of other observations of no or little effect of spacing on the tree height growth (Cochran et al. 1991; Nielsen and Gerrand 1999; Henskens et al. 2001; Hegazy et al. 2008)

But tree diameter (at breast height) significantly increased in wider spacing which is a response to more resources availability. According to size-density theory, diameter growth decreases with increasing tree density (Drew & Flewelling 1979; Willcocks & Bell 1995). Despite low average diameter at breast height of trees in lower spacing levels, due to high density, spacing layout of 1×1 m had the greatest tree basal area per ha. Wider spacing reduced mortality rate and H/D ratio. Lower tree density, and as a result, greater availability of resources such as soil water, and nutrient reduced competition among trees and consequently declined mortality. More resources availability also resulted in greater diameters of trees in wider spacing plots and consequently lower H/D ratios. H/D ratio is one of the most important factors in tree stability against natural disturbances specially wind and snow. Mayer (1984) proved that an H/D ratio of more than 100 increases vulnerability of trees against natural disturbances. He also suggested that an H/D ratio of 80 to 100 is ideal. The natural pruning height of trees significantly increased by decreasing spacing, which is due to less light availability in plots with high density that causes in natural pruning. The standing volume was the highest in 1×1 spacing layout which is due to high tree density and basal area in 1×1 layout. Regarding the standing volume, H/D ratio and survival, the spacing layout of 2×3 m is the most suitable layout for Quercus castaneifolia. The natural pruning height of trees in wider spacing plots causes more competition and less survival among the trees.

REFERENCES


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تأثیر تراکم اولیه بر روي برخی خصوصیات اومتری چنگلگاری ۱۲ ساله بلوط

در مرکز مازندران، چنگل‌های خرزی ایران

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(تاریخ دریافت: ۳۱/۵/۹۰ - تاریخ پذیرش: ۹/۱۱/۹۰)

چکیده

در این مطالعه، ما اثر طرح فاصله بندي اوليه را بر روي برخی خصوصیات اومتری درخت ۱۲ساله در چنگل چنگلگاری استان مازندران، در شمال ایران، مورد آزمایش قرار گرفت. درخت‌ها در ۵ فاصله مختلف، (۱×۱)، (۲×۱)، (۲×۲)، (۴×۲)، و (۴×۴) متری کاشته شدند. ارتفاع درخت و قطر درخت در فاصله ۱/۴ متری از زمین، ارتفاع هر سرب برای تمامی درخت‌های محاسبه شد. نتایج حاصل از تجزیه و تحلیل آماری نشان داد که افزایش در ارتفاع توسط H/D سطح فاصله ۱×۱ تا ۴×۴ متر به طور معنی‌داری سبب افزایش میانگین قطر درخت در فاصله ۱/۴ متری از زمین از ۹/۳ تا ۹۲/۴۲ سانتی‌متر در یک فاصله رسانده و همچنین ماندنی درخت در ارتفاع ۵/۳ بر هر ۸۵/۵٪ افزایش می‌یابد. با افزایش فاصله بین درخت‌ها از ۱×۱ تا ۴×۴ متر، میانگین سطح مقطع درخت به ارایه هر هکتار از ۹۳/۶ رشد می‌یابد. ارتفاع درخت و ارتفاع هر سرب در نهایت است. ولی رژیم فاصله هیچ اثر معنی‌داری در روند افزایش توسط H/D سطح فاصله ۱×۱ تا ۴×۴ متر به طور معنی‌داری سبب افزایش می‌یابد. میزان ارتفاع درخت به طور معنی‌داری در روند افزایش می‌یابد. همچنین در این مطالعه، نتایج نشان داد که با توجه به حجم سرب برای درخت در این سنگرده ۳ متر در ۳ متر است.