Comparison of survival and growth of Loblolly Pine (Pinus Taeda L.) and Sugi (Cryptomeria japonica D.) plantations in South coast of Caspian Sea

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Abstract

In this research growth and survival rate of two 36 years old plantations with exotic coniferous species (Pinus taeda and Cryptomeria japonica) were studied in the South coast of Caspian Sea in the North of Iran. Systematic sample plots (20 × 20 m) were used to collection of data in each plantation site. The results showed stand volume in Pinus taeda and Cryptomeria japonica plantations were about 291.6 and 250.3 m³ ha⁻¹. The survival rate in Pinus taeda and Cryptomeria japonica plantations were 73.1 and 60.8 percent. The mean of tree height in Pinus taeda and Cryptomeria japonica plantation were about 18.7 and 17.2 m. The mean of crown length and crown diameter in Cryptomeria japonica plantation was higher than Pinus taeda plantation. The mean annual increment of stand volume in P. taeda plantation (8.12 m³ ha⁻¹ yr⁻¹) was higher than Cryptomeria japonica plantation (6.95 m³ ha⁻¹ yr⁻¹). The results indicated survival and growth rates of these plantations are high and these tree species are suitable for timber production plans in these areas.

Key words: Caspian Sea, conifer species, stand volume, tree crown, tree height.

Introduction

Plantations can provide significant economic, environmental and social benefits (Solberg, 1996). Forest plantations may help reduce logging pressure on natural forests in areas in which unsustainable harvesting of wood is a major cause of forest degradation and where logging roads facilitate access that may lead to deforestation (Carle et al, 2002). Plantations are recognized as being significant in future global wood supply and in the development of forest and environmental policy (Jaakko Pöyry, 1999). Currently 3% of the world’s forests are plantations, comprised of 60 million hectares in developed nations and 55 million hectares in developing nations (Hartley, 2002). Five countries, China, United States, Russian Federation, India and Japan have each established more than 10 million hectares of plantation forests. These five countries collectively account for 65 percent of the global plantation resource (Brown and Ball, 2007). Plantations established for site rehabilitation on degraded land can increase biodiversity, provide improved soil structure, increased soil organic matter and fertility, and improve the local microclimate. They can be used to provide corridors between protected areas, control water runoff, provide shelter from wind, heat and sand storms, and lower water tables in saline areas. Forest plantations in New Zealand met 99% of the country's needs for industrial round wood in 1997 (Carle et al, 2002). The purposes of industrial plantations are supplying round wood for sawn timber, veneer and pulp³. Evans (1997) shows that plantation forestry is sustainable in terms of wood yield in most situations, if plantation managers maintain good management practices. The selection of suitable species for specific growing conditions is important in maximizing the productivity and quality of a plantation. The primary purpose of most conifer plantations is timber production. Globally, the dominant forest plantation
The genus is *Pinus*. More than 40 percent of the world’s forest plantations are planted with pines (Brown and Ball, 2007). The different exotic species such as Loblolly pine (*Pinus taeda* L.) and Sugi (*Cryptomeria japonica* D. Don) are planted in lowland of South coast of Caspian Sea in the North of Iran. Loblolly pine (*Pinus taeda* L.), also called Arkansas pine, North Carolina pine, and old field pine and is the most commercially important forest species in the southern United States. It is a medium-lived, intolerant to moderately tolerant tree with rapid juvenile growth. Loblolly pine is an adaptable species that has been successfully planted along the periphery of its natural range and has been introduced on other continents with varying degrees of success. Also, Sugi (*Cryptomeria japonica* D. Don) is one of the main plantation species in Japan (Ishiguri et al, 2009). Sugi is endemic to Japan and it is a very large evergreen tree, reaching up to 70 m tall and 4 m trunk diameter, with red-brown bark which peels in vertical strips. Sugi has been so long-cultivated in China that it is thought by some to be native there. Sugi grows in forests on deep, well-drained soils subject to warm, moist conditions, and it is fast-growing under these conditions. It is intolerant of poor soils and cold, drier climates. Timber of sugi has been used mainly for construction of traditional wooden houses. Growth of sugi trees is relatively fast compared to other coniferous plantation species. From these reasons, sugi has been extensively planted throughout Japan after World War II (Ishiguri et al, 2009). The growth and survival rate of a specific tree species on a specific site is critical in determining its suitability as a plantation species. The first criterion of plantation success is high initial survival. The purpose of this study was evaluation and comparison of growth and survival rate of Loblolly pine (*Pinus taeda* L.) and Sugi (*Cryptomeria japonica* D. Don) plantations in South coast of Caspian Sea in the North of Iran.

**Material and Methods**

**Study area**

This study was carried out in the South coast of Caspian Sea, 35 km from Talesh city in the North of Iran (Fig. 1). The area is located in plateau with the approximate altitude of 20 meters above sea level. The climate is temperate on based Demarton climate classification and the climate is very wet, with a mean annual temperature of 15.7 °C and mean annual precipitation of 1306 mm for along with the 1990 to 2008 years. The soil of plantations is poor drainage and has a silty-loam texture with pH 6.6–7.1. The species of Loblolly pine (*Pinus taeda* L.) and Sugi (*Cryptomeria japonica* D. Don) were planted in this area in 2 m × 2.5 m and in year of 1976, where previously covered by natural stands dominated by *Alnus glutinosa*, *pterocarya fraxinifolia* and *Parota persica*. In reality, the plantations were 36 years in research time. Two plantation sites were thinned in years of 1992, 2000 and 2008 and removed 10 to 20 percent of individuals in each thinning operation.

![Study area in the South coast of Caspian Sea](image-url)
Research method

In each stand, 10 plots 20 × 20 m were selected in regular distances from each other (50 m) and in each plot diameters of trees at 1.3 m height (D.B.H.) and half total height, tree height (H), Crown length (CL) and crown diameter (CD) were measured for all of the trees. Also survival rate (SR) and basal area (BA) was calculated for each plot. The survival rate (SR) for each plot was calculated using equation 1.

\[ SR = \left(\frac{N_i}{N}\right) \times 100 \]  

Where SR is survival rate (%), \( N_i \) is number of live and safe trees and \( N \) is total number of trees per plot area. The basal area for each tree was calculated using equation 2.

\[ BA = 0.785 \times DBH^2 \]

Where BA is basal area (cm\(^2\)) and DBH is diameter at breast height (cm).

Individual tree volume was calculated using the equation 3 (Bonyad, 2006).

\[ V = G \times H \times F \]

Where \( V \) is individual tree volume (m\(^3\)), \( G \) is basal area at breast height (m\(^2\)), \( H \) is total tree height (m) and \( F \) is form factor that was calculated using equation 4 (Bonyad, 2006).

\[ F = \frac{(d_{0.5})^2}{(d_{1.3})^2} \]

Where \( F \) is form factor, \( d_{0.5} \) is the diameter at the half total height and \( d_{1.3} \) is diameter at breast height (Bonyad and Rostami shahrarj, 2005). Independent samples t test were used to compare survival rate, diameter, height, basal area and volume of trees in experimental sites by SPSS 19.0 statistical software.

Results and Discussion

The mean of number of trees per hectare in \( P. taeda \) and \( C. japonica \) plantation was about 741 and 559 trees ha\(^{-1}\) that have statistically differences at \( \alpha = 0.05 \) level (Table 1). The thinning intensities and survival rates effect on stand density and volume. The mean of survival rate in \( P. taeda \) plantation was higher than \( C. japonica \) plantation. The mean of survival rate in \( P. taeda \) and \( C. japonica \) plantations were computed 73.1 and 60.8 percent that have statistically difference at \( \alpha = 0.05 \) level (Table 1). Survival rate of exotic tree species is one of important factors to selection for plantations. Also, site preparation and silvicultural operation are important that influence on plantation survival and growth (Nilsson and Orlander, 1999). The survival rates of \( P. taeda \) and \( C. japonica \) plantation are high in this area. Farrokhnia et al, (2006) in Hamadan province (1770 m from sea level and 370 mm annual precipitation), reported that survival rate of Picea abies after 4 years of plantation was 33 to 40%.

<table>
<thead>
<tr>
<th>Variables</th>
<th>( P. taeda )</th>
<th>( C. japonica )</th>
<th>Calculated t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (trees ha(^{-1}))</td>
<td>741 ± 25 A*</td>
<td>559 ± 32 B</td>
<td>3.51</td>
<td>0.022</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>73.1 ± 4.6 A</td>
<td>60.8 ± 3.5 B</td>
<td>2.13</td>
<td>0.040</td>
</tr>
<tr>
<td>DBH (cm)</td>
<td>35.1 ± 0.9 A</td>
<td>38.6 ± 1.0 B</td>
<td>-2.33</td>
<td>0.034</td>
</tr>
<tr>
<td>Height (m)</td>
<td>18.7 ± 0.4 A</td>
<td>17.2 ± 0.4 B</td>
<td>2.72</td>
<td>0.021</td>
</tr>
<tr>
<td>Crown length (m)</td>
<td>4.7 ± 0.08 A</td>
<td>5.5 ± 0.12 B</td>
<td>-5.38</td>
<td>0.000</td>
</tr>
<tr>
<td>Crown diameter (m)</td>
<td>3.1 ± 0.10 A</td>
<td>3.6 ± 0.09 B</td>
<td>-3.65</td>
<td>0.000</td>
</tr>
<tr>
<td>Volume (m(^3))</td>
<td>0.61 ± 0.01 A</td>
<td>0.72 ± 0.01 B</td>
<td>-7.01</td>
<td>0.000</td>
</tr>
<tr>
<td>Basal area (m(^2) ha(^{-1}))</td>
<td>30.1 ± 1.91 A</td>
<td>25.5 ± 1.27 B</td>
<td>1.57</td>
<td>0.028</td>
</tr>
<tr>
<td>Volume (m(^3) ha(^{-1}))</td>
<td>291.6 ± 10.6 A</td>
<td>250.3 ± 9.5 B</td>
<td>2.902</td>
<td>0.009</td>
</tr>
</tbody>
</table>

*Different letter in rows indicates statistically significant differences at \( \alpha = 0.05 \).

The mean of diameter at breast height (DBH) in \( C. japonica \) plantation was higher than \( P. taeda \) plantation. The mean of DBH in \( P. taeda \) and \( C. japonica \) plantations were computed 35.1 and 38.6 that have statistically differences at \( \alpha = 0.05 \) level (Table 1). The mean of DBH in 26 years old of \( P. taeda \) plantation in North of Iran were reported 30.5 cm in moderate thinned stand\(^1\). The mean of tree height in \( P. taeda \) plantation was about 18.7 m, while in \( C. japonica \) plantation was 17.2 m (Table 1). The mean of tree height in plantation of \( P. taeda \) was significantly lower than \( C. japonica \). The height of trees in plantations very depends on tree species, stand density, site quality and silvicultural operation. These results indicated that site quality is high and area is suitable to develop plantation with \( P. taeda \) and \( C. japonica \).
The mean of crown length and crown diameter of *P. taeda* plantation was significantly lower than *C. japonica*. The mean of crown length and crown diameter in *P. taeda* plantation were computed 4.7 and 3.1 m, while in the *C. japonica* were computed 5.5 and 3.6 m (Table 1).

Increasing the live crown ratio and branches may decrease wood quality around the top diameter of trees. The ratio of crown length to tree height in *P. taeda* and *C. japonica* plantation were measured 25 and 32 percent. The mean of basal area in *P. taeda* and *C. japonica* plantation was about 30.1 and 25.5 m² ha⁻¹ that have statistically difference at α=0.05 (Table 1).

The basal area in plantations depends on stand density and DBH of trees. However the mean of DBH in *C. japonica* plantation was higher than *P. taeda* plantation, but density of trees in *P. taeda* plantation was higher than *C. japonica* plantation. The mean of individual tree volume in *P. taeda* plantation was significantly lower than *C. japonica* plantation. The mean of individual tree volume in *P. taeda* and *C. japonica* plantation were computed about 0.61 and 0.72 m³ (Table 1). The mean of stand volume in *P. taeda* plantation was significantly higher than *C. japonica* plantation (t=2.9, p<0.00). The mean of stand volume in *P. taeda* and *C. japonica* plantation were computed 291.6 and 250.3 m³/ha (Table 1).

![Fig. 2. Mean annual increment (MAI) of DBH (A), Height (B), Basal Area (C) and Volume (D) in 36 years old of *P. taeda* and *C. japonica* plantation sites. Different letters within columns show that values are significantly different (α = 0.1).](image)

The mean annual increment (MAI) of DBH in *P. taeda* and *C. japonica* plantation sites were measured 0.976 and 1.023 cm yr⁻¹ that have statistically difference at α=0.05 (t=2.677, p<0.015). The mean annual
increment (MAI) of height, basal area and volume in *P. taeda* plantation was significantly higher than *C. japonica* plantation (Fig. 2). The mean annual increment (MAI) of volume in *P. taeda* plantation was 8.12 m$^3$ ha$^{-1}$ yr$^{-1}$, while in the *C. japonica* plantation was 6.953 m$^3$ ha$^{-1}$ yr$^{-1}$ (Fig. 2). Bonyad (2006) showed that moderate thinning significantly influenced increased growth rates of planted loblolly pine stands, in the North of Iran. The MAI of basal area at 27 years old of *p. taeda* plantation in unthinned, lightly thinned and moderate thinned were reported 0.915, 1.091 and 1.104 m$^2$ ha$^{-1}$ yr$^{-1}$ in South coast of Caspian Sea (Bonyad, 2006). The stand volume at 18 years old of *p. taeda* plantation in control and mechanical preparation site were reported 129 and 223 m$^3$ ha$^{-1}$ in Southeastern United States (Cerchiaro, 2003). The stand volume at 27 years old of *P. taeda* plantation was reported 276 m$^3$ ha$^{-1}$ in South coast of Caspian Sea (Bonyad, 2006). The stand volume and mean annual increment of Turkish pine (*P. brutia*) plantation at 17 years old were reported 95 m$^3$ ha$^{-1}$ and 5.6 m$^3$ ha$^{-1}$ yr$^{-1}$ in Golestan province (625 m from sea level) in North of Iran (Sadeghzadeh Hallaj and Rostaghi, 2011). Trousdell et al, (1974) studied stand volume of Loblolly pine (*P. taeda*) 30 yr old plantation in Southeastern U.S. and reported 156, 288 and 324 m$^3$ ha$^{-1}$ at different site indexes. Technological advances in tree breeding and genetic improvement, site preparation, weed control and silviculture have resulted in improvements in commercial yield, health and vigor. In mechanical forest vegetation control, the timing of the operation is critical. Further improvements in productivity, generating higher economic returns, can be achieved with the introduction of fast growing exotic species and genetically improved planting stock.

**Conclusion**

In this research growth and survival rate of two plantations with exotic coniferous species (*Pinus taeda* L. and *Cryptomeria japonica* D.) were studied in the South coast of Caspian Sea in the North of Iran. The results indicated after 36 years from plantation the growth and survival rates are high and these species are suitable for plantation in this area. Iran is an importer of wood. Projections of global round wood demand indicate an increase of around 35 per cent from current levels by 2040 (Jaakkko Pöyry, 1999). There is increasing community pressure to improve forest management and harvesting practices, and to ensure sustainability of all natural forest values. This has increasingly limited the volume of wood harvested from natural forests. Today, the Caspian forests of Iran are depleting rapidly due to population growth, and associated socio-economic problems, industrial development and urbanism (Poorzady and Bakhtiari, 2009). Plantation managers can improve the economic benefits by careful species and provenance selection and by using silvicultural regimes that increase wood production and improve rates of return. The potential for forest plantations to partially meet demand for wood and fiber for industrial uses is increasing. The development of industrial plantations usually depends on factors such as the suitability of land and the proximity to markets and existing infrastructure. Industry usually develops in conjunction with the plantation resource. Species selection for industrial plantations is driven by market demands, site suitability and land availability. Recent trends indicate that introduced, fast growing species are favored over the more traditional long rotation species. This trend has largely developed to accommodate the rapidly expanding pulp and paper industry. Forest plantations also provide additional non-wood forest products, from the trees planted or from other elements of the ecosystem that they help to create. They contribute environmental, social and economic benefits. Forest plantations are used in combating desertification, absorbing carbon to offset carbon emissions, protecting soil and water, rehabilitating lands exhausted from other land uses, providing rural employment and, if planned effectively, diversifying the rural landscape and maintaining biodiversity. The role of plantations in the international trade in industrial wood and wood products has increased over recent years, and is likely to grow further in the future. Increasing access costs to natural forests for wood production will make plantations more viable as an alternative source of wood fiber. In north of Iran, Caspian forests have been under continuous degradation over the last few decades and there is an urgent need to maintain the functions of this unique forest ecosystem. Plantations provide an economically viable and environmentally sustainable log resource that can be used to make timber products. They can also rehabilitate land, improve water quality and meet other environmental and economic objectives. Consequently, plantations can now be established on a wider range of sites with varying silvicultural regimes, reducing the costs of management, harvesting and processing. The development and successfully of forest plantation depends on suitability of land, careful site and species selection, good management and silvicultural techniques. Not all forest plantation development has positive economic,
environmental, social or cultural impacts. There is a need to integrate strategies for tree improvement programs, nursery practices, site and species matching, appropriate silviculture (site preparation, establishment, weeding, fertilizing, pruning, thinning) and forest protection (Curt et al, 2001; Bonyad, 2006; Callesen et al, 2006; Huuskonen and Hynynen, 2006; Mallik et al, 2008; Uotila et al, 2012). Pest, disease and fire control procedures can also be included to reduce the risk of damage to a plantation and to maintain its productive potential.

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