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Comparison of Plant Diversity and Stand Characteristics in Alnus subcordata C.A.Mey and Taxodium distichum (L.) L.C. Rich

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Abstract. Stand characteristics and understory plant diversity were investigated in low-drained man-made stands of *Alnus subcordata* C.A.Mey and *Taxodium distichum* (L) L.C. Rich. The trees were planted with distances of 3 × 3 m and 4 × 4 m in northern Iran. In these stands, herbaceous and woody species were counted in plots of 20 × 20 m. Then, indexes of richness, *H/* diversity, *J/* equitability and Jaccard similarity (*JI*), tree growths, cover crown percentage, and litter layer thickness of each stand were assessed following 17 years after planting. The results revealed that the greatest diameter at breast height (D.B.H) and stem height were observed in *Alnus* 4 × 4 m. By contrast, crown cover percentage and litter thicknesses were greater in *Taxodium* stands. Species richness, *H/* diversity and *J/* equitability indexes, Jaccard similarity (*JI*) of *Alnus* stands were greater than those of *Taxodium* stands. In reality, small and light canopy of *Alnus* is the main reason that the solar radiation can penetrate easily to forest ground and affect understory plant diversity. *Alnus* as a native tree species, due to greater growth attributes and higher diversity indices in their stands are proposed for plantations in such low-drained sites of northern Iran.

Keywords*:* *Alnus subcordata* C.A.May, Plant diversity, Plantations, *Taxodium distichum* (L) L.C. Rich.

Introduction

In recent years, concern for the extinction of species and populations due to human activities has stimulated a number of observational and experimental studies on the relationships between species richness and ecosystem functioning (SINGH *et al.,* 2005). Maintaining of biodiversity in young stands established after clear-cutting is a challenge to foresters and wildlife biologists. Biodiversity is often used to compare the forest ecosystems ecological status and evaluate the forest communities and ecosystems (ESMAILZADEH & HOSSEINI, 2008).

Owing to the dominant position of trees in forests and their impact on various ecological gradients, the identity and composition of tree species can be expected to influence plant biodiversity, *i.e.* understory vegetation diversity and composition (BARBIER *et al.,* 2008). Plant species diversity in the forest understory extensively has been studied because the understory is a major component of forest ecosystems and plays an important role in many ecological functions and processes (POORBABAEI & POORRAHMATI, 2009). High species diversity in ecosystems led to high food chain and more complex network environment (EMBERLIN, 1983). In this regard, plantation by woody species and prevention of inappropriate harvesting plays an important role in maintaining diversity of forest ecosystems (CARNUS *et al.,* 2006).

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Plantations compared with natural stands, particularly by changes of light and nutrient can affect habitat conditions and plant species composition (LEGARE *et al.*, 2001). Light is commonly considered to be the major limiting factor of forest vegetation cover and (or) richness (BARBIER *et al.*, 2008). GILLIAM & TURRILL (1993) showed that understory layer is more limited by light availability when canopy is closed; and MESSIER *et al.*, (1998) found that shade-intolerant tree species, such as aspen, white birch and jack pine, transmit further light than shade-tolerant tree species like balsam fir and white spruce. Indeed, in full light conditions, when the canopy is removed, or on poor site, nutrient availability become more critical to the understory and the better adapted species should be more competitive and productive (LEGARE *et al.*, 2002). Temporal changes in species diversity in a managed forest show the effects of forest management on small-scale colonization and extinction. Overall, plantations with non-native species as well as coniferous species in most areas differently affects vegetation and produce the requisite approve to ecologically sustainable forest management requires understanding the effects of forest management on plant and plant species diversity (NAGAIKE *et al.*, 2003). However, high species diversity of understory plants has been reported within plantations in surrounding natural forests (YIRDAW, 2001, NAGAIKE, 2002, NAGAIKE *et al.*, 2006). Also some assumptions are often made, e.g., that hardwoods are more favorable to biodiversity than conifers (BARBIER *et al.*, 2008). The aim of plantations has changed from a single objective (wood production) studies on biodiversity in plantations have been increasing (HARTLEY, 2002, NAGAIKE, 2002). Therefore, studies of species diversity in managed forests are required to predict and manage the transition of species diversity in such forests.

North of Iran has been covered by a deciduous temperate commercial forest on the northern slopes of the Alborz Mountains overlooking the Caspian Sea. Between mountain region and Caspian Sea, there are low-drained plain areas whereas during last decades have been involved in agriculture, reforestation or deforestation activities. Development in plantations of native species such as Caucasian alder (*Alnus subcordata* C.A.May) and exotic woody species, like bald cypress (*Taxodium distichum* (L) L.C. Rich), has occurred in these areas in recent decades. The purpose of this study is to examine plant species diversity and similarity of understory species in these plantations with 3 × 3 m and 4 × 4 m planting distances and determine how some stand characteristics can effect on plant diversity. The results of this study can also declare which tree species is more suitable for plantation in these sites.

Material and methods

Site Characteristics

Site study is located in southern coast of the Caspian Sea, 10 Km from Amol city, north of Iran (34°36′N″, 19°52′E″, 10 m above sea level. Rainfall with wetter months occurs between September and March, and a dry season from April to August. The climate is temperate on based Demarton climate classification, with a mean annual temperature of 16.9 °C and mean annual precipitation of 883 mm for along with the 1990 to 2008 years. The soil of plantations is poor drainage and has a silty-loam texture with pH 7.6–8.1.

The species of *Alnus subcordata* C.A. Mey (Caucasian alder) and *Taxodium distichum* (L.) L.C. Rich. (Bald cypress) were planted in this area in 1992, where previously covered by natural stands dominated by *Carpinus betulus* and *Parrotia perssica.* In reality, the plantations were 17 years in research time. *Alnus subcordata* and *Taxodium distichum* were planted with two planting distances of 3 × 3 m and 4 × 4 m. Not any thinning operations were made in these plantations.

Research method

In each stand, 6 plots 20 × 20 m were selected in regular distances from each other (KENT & COKER, 1992) and in each plot; diameters of trees at 1.3 m height (D.B.H.)

and tree heights were measured. Crown covers percentage of each stand as an expression of the light conditions for the ground vegetation (HARDTLE *et al.*, 2003). Litter thickness was measured in four selected points of plot corners and its average was calculated (POORBABAEI & POORRAHMATI, 2009). In each plot of 20 m × 20 m abundance sociability of herbaceous and woody species was visually estimated following modified Braun Blanquet scale (KENT & COKER, 1992).

Biodiversity indexes were used to evaluate plant diversity. Species diversity and richness in each plot were quantified using three indexes: the Shannon–Wiener diversity index ($H^{/}$), Equitability ($J^{/}$), and richness, r = the number of species per unit area - data in percent was use in indexes, $H^{/}$ and $J^{/}$ (BARBOUR *et al.*, 1999). The $H^{/}$ and $J^{/}$ values were calculated from the frequency of occurrence of each species per plot (i.e., 1–6) using the following formula based on MAGURRAN (2004):

$$J^{/} = \frac{H^{/}}{\ln m} \qquad H^{/} = -\sum_{i=1}^{m} pi \ln pi \, ,$$

where *pi* is the frequency of occurrence of each species relative to the total frequency of occurrence of all species in each plot, and m is the number of species in each plot.

Jaccard similarity index *(JI)* was selected for clarify of similarity species between each tree stand (with specified plantation density) with another stand (with specified plantation density) (LUDWING & RENOLDS, 1988):

$$JI = \frac{a}{a+b+c} \, ,$$

where *a* is the species in common in two stands, *b* is the only number of species identified in first stand and c is the only number of species identified in second stand.

For all the analyses, SPSS v.11.5 software was used. Normality of the data distribution was checked by Kolmogorov–Smirnov test, and Levene's test was used to examine the equality of the variances. One-way analyses (ANOVA) of variance were used to compare stands with normal distribution data (herbaceous diversity; stands characteristic; litter thickness; crown cover percentage). H Kruskal-Wallis was used to compare nonparametric data of the stands (woody diversity). Tukey-HSD (stand characteristic) and Duncan (herbaceous diversity; litter thickness; crown cover percentage) tests were used to separate the averages of the dependent variables which were significantly affected by the stands. In nonparametric data, Mann-Whitney U tests were used to separate the averages of the dependent variables which were significantly affected by stands (woody diversity).

Results

Stand characteristics, crown cover percentage and litter thickness

Results showed that diameter in breast height (D.B.H) in stands of 4 × 4 m planting distance was the highest and in stands of 3 × 3 m planting distance was the lowest ($P < 0.01$, Tukey-HSD) (Table 1). In both planting distances *Alnus* had greater diameter in breast height (D.B.H) and height compared to *Taxodium* (Table 1). In both planting spacing *Taxodium* plantations had the higher crown cover and litter thickness in comparison with *Alnus* plantations (Table 1).

Herbaceous and Woody species diversity

In herbaceous layer, $H^{/}$ diversity index and richness index were significantly higher in *Alnus* stands than *Taxodium* stands ($P < 0.01$, Duncan), but $J^{/}$ equitability index did not differ in stands (Table 2). In woody layer, diversity index $H^{/}$, richness indexes and equitability index $J^{/}$ were significantly higher in *Alnus* stands ($P < 0.05$, H Kruskal-Wallis) than *Taxodium* stands (Table 3).

Floristic composition and similarity (JI)

There were 19, 21, 10 and 12 herbaceous species in *Anus* 3×3, *Alnus* 4×4, *Taxodium* 3×3 and *Taxodium* 4×4 plantations, respectively (cumulative numbers) (Table 4). Number of woody species was 14, 13, 7 and 7 in the same order previous forests (Table 5). Both in herbaceous layer and woody layer the higher similarity *(JI)* was found between *Alnus* 3×3 m and *Alnus* 4×4 m, and between *Taxodium* 3×3 m and *Taxodium* 4×4 m. *Alnus* 3×3 m and *Alnus* 4×4 m had higher similarity *(JI)* than *Taxodium* 3×3 m and *Taxodium* 4×4 m (Table 6 and 7).

Table 1. The mean of D.B.H. and height of trees, litter thickness and crown cover percentage (± sd) in the plantations

Plantation	D.B.H (cm)	Height (m)	Litter thickness (cm)	Crown cover (%)
Alnus 3×3 m	22.79 ±0.39 a	17.38±0.74 a	0.26 ± 0.07 c	43.16 ± 8.30 b
Alnus 4×4 m	27.21±1.12 b	19.52±0.44 a	0.18 ± 0.06 c	48.66 ± 7.66 b
Taxodium 3×3 m	19.68±1.29 c	10.72±0.79 b	7.41 ± 0.65 a	91.66 ± 4.57 a
Taxodium 4×4 m	24.57±0.67 ab	12.34±0.39 b	5.16 ± 0.47 b	83.50 ± 6.55 a
P Sig.	**	**	***	***

** $P < 0.05$ (ANOVA) *** $P < 0.01$ (ANOVA)

Table 2. Herbaceous species diversity indexes in the plantations

Stand	*Diversity* Index ($H^{/}$)	*Richness* Index	*Equitability* Index ($J^{/}$)
Alnus 3×3 m	1.66 a (0.14)	11.50 a (0.56)	0.68 (0.05)
Alnus 4×4 m	1.62 a (0.09)	11.33 a (0.49)	0.66 (0.02)
Taxodium 3×3 m	1.10 b (0.14)	5.16 b (0.60)	0.68 (0.07)
Taxodium 4×4 m	1.20 ab (0.07)	6.16 b (0.40)	0.66 (0.04)
F	5.71	41.32	0.077
P Sig.	0.005**	0.000**	0.972 ns

ns treatment effect not significant.** $P < 0.01$ (ANOVA) * $P < 0.05$ (ANOVA)

Table 3. Woody species diversity indexes in the plantations

Stand	*Diversity* Index ($H^{/}$)	*Richness* Index	*Equitability* Index ($J^{/}$)
Alnus 3×3 m	1.25 a (0.11)	5.00 a (0.36)	0.77 a (0.04)
Alnus 4×4 m	0.91 a (0.11)	4.50 a (0.56)	0.62 ab (0.06)
Taxodium 3×3 m	0.55 b (0.13)	3.16 b (0.16)	0.46 b (0.08)
Taxodium 4×4 m	0.49 b (0.10)	3.00 b (0.25)	0.43 b (0.09)
F	9.12	7.14	4.62
P Sig.	0.001**	0.002**	0.013*

** $P < 0.01$ (H Kruskal-Wallis), * $P < 0.05$ (H Kruskal-Wallis)

Discussion

Stand characteristics, crown cover percentage and litter thickness

Light is commonly considered to be the major limiting factor of forest vegetation cover and (or) richness (BARBIER *et al.,* 2008). In full light conditions, when the canopy is removed, or on poor site, nutrient availability may become more critical to the understory, the better adapted species should be more competitive and productive (LEGARE *et al.,* 2002). Thus, in the present study *Taxodium* stands that have more closed canopy than *Alnus*, light can play important role in diversity indexes. As a result, higher crown cover percentage in *Taxodium* plantations causes the increase of litter thickness. There are several researches for conifer stands have been well documented where canopy layer values were high; the cover of vascular plants and ground layer vegetation was reduced through shading (SAKURA *et al.,* 1985, HILL, 1986, SCHOONMAKER & MCKEE, 1988, FAHY & GORMALLY, 1998).

Table 4. List of herbaceous species in each stand

Herbaceous species	*Alnus* 3×3 m	*Alnus* 4×4 m	*Taxodium* 3×3 m	*Taxodium* 4×4 m
Calystegia sepium	×	×		
Cardamine impatiens	×	×		
Carex remota	×	×	×	×
Carex sylvatica	×	×	×	×
Conyza canedensis				
Cyperus sp.	×	×	×	×
Equisetum maximum	×	×	×	×
Galium aparine	×	×		
Humulus lupulus				
Iris sp.	×	×		
Juncus sp.	×	×		
Lamium album	×	×		
Mentha aquatic		×		
Mentha piperita				
Oplismenus undolatifolius				
Oxalis acetosella			×	×
Plantago major				
Poa sp.	×	×		×
Primula hecterochroma	×	×		
Pteris cretica		×		×
Ruscus hyrcanus	×	×	×	×
Sambacus ebulus	×	×		
Smilax excels	×	×	×	×
Solanum dulcamara	×	×	×	×
Stelaria media	×	×		
Urtica dioica	×	×	×	×
Viola alba	×	×	×	×
	19	21	10	12

Table 5. List of woody species in each stand

Woody species	*Alnus* 3×3 m	*Alnus* 4×4 m	*Taxodium* 3×3 m	*Taxodium* 4×4 m
Acer velutinum	×	×		
Alnus glutinosa	×	×		
Alnus subcordata	×	×		
Cornus australis			×	×
Crataegus monogyna	×	×	×	×
Diospyrus lotus	×			
Ficus carica	×	×	×	×
Gleditschia caspica	×	×	×	×
Mespilus germanica	×	×		
Morus alba	×	×	×	×
Petrocaria fraxinifoilia				×
Populus caspica	×	×		
Populus deltoids				
Prunus divaricate	×	×		
Quercus castaneifolia	×	×	×	
Salix aegyptiaca	×	×		
Taxodium distichum			×	×
Ulmus carpinifolia	×	×		
	14	13	7	7

Table 6. Jaccard's similarity index *(JI)* (in percent) of woody species in the plantations

Stand	*Alnus* 3×3 m	*Alnus* 4×4 m	*Taxodium* 3×3 m	*Taxodium* 4×4 m
Alnus 3×3 m		0.92	0.31	0.23
Alnus 4×4 m			0.33	0.50
Taxodium 3×3 m				0.75

Table 7. Jaccard's similarity index *(JI)* (in percent) of herbaceous species in the plantations

Stand	*Alnus* 3×3 m	*Alnus* 4×4 m	*Taxodium* 3×3 m	*Taxodium* 4×4 m
Alnus 3×3 m		0.90	0.45	0.47
Alnus 4×4 m			0.40	0.50
Taxodium 3×3 m				0.83

Litter also has physical effects on understory vegetation: seed under litter are deprived of light and seeds on it cannot root easily (BARBIER *et al.,* 2008). In our study broad-leaved and conifer plantations had lower and higher crown cover percentage respectively. Also, the litter thickness in *Taxodium* stands was higher than that in

Alnus stands. PIOTTO *et al.,* (2003) declared high overstorey transmission led to increase the litter decomposition. In this relation, WESENBEECK *et al.,* (2003) underlined that high crown cover in *Pinus patula* causes to decreased in diversity and alter the composition of native species. LEUSCHNER (1999) came to similar conclusions in an analysis of beech stands in central and north-west Germany, during which he also established a close negative correlation between the number of species and the density of fine roots from the tree layer in the humus horizons. PARITSIS & AIZEN (2008) suggest that plantations with more open canopy could favor plant diversity by increasing individual abundance and species richness. NAGAIKE *et al.,* (2006) observed young plantations (just before canopy closure and just after weeding) had the highest species diversity, richness, and light levels of the three ages of plantation. Greater species diversity and richness during the initial phase of vegetation development, before canopy closure (NIEPPOLA, 1992, HANNERZ & HAENELL, 1997) is caused primarily by colonization of many ruderal species (HALPERN, 1989, MILLER *et al.*, 1995).

Herbaceous and Woody species diversity

In herbaceous and woody layers, H' index diversity was highest in *Alnus* stands. These results may be for high budget light in crown (DEAL, 1997) and rich soil N *Alnus* stands (Eshter *et al.,* 2006). The higher diversity in plantations was mainly due to invasive species. Such patterns imply increased species diversity after severe human disturbance (POORBABAEI & POORRAHMATI, 2009). On the other hands, NAGAIKE *et al.,* (2006) in their investigation revealed that plantations 40 years of age had significantly lower species diversity and richness than young plantations, possibly as a result of declining light levels after canopy closure (BARBIER *et al.,* 2008). In herbaceous layer, there was not any significant difference between *Alnus* 3×3 and *Alnus* 4×4 m also in *Taxodium* stand. In this relation, our work seems to be consistent with that of LEGARE *et al.,* (2002), who describe the absence of significant variation of herb layer related to forest composition could be explained by the fact that light availability at the forest ground floor level and at 50 cm above the forest floor is not significantly different among the different stands.

Species richness is one measure of biodiversity and it is very important for ecosystem functioning, stability and integrity (COROI *et al.,* 2004). It is widely accepted that broad-leaved forests have higher plant species richness than conifer stands (BARBIER *et al.,* 2008). Also COROI *et al.* (2004) reveled that plant species richness in the broad-leaved riparian stands was almost double that of the alien conifer plantations. Such a result was found in present study, particular in *Alnus* stands. WELCH & SCOTT (1997) reported a strong decline of shade-tolerant understory plant species in a 20-year old pine plantation in England and they predicted that colonization would be the main factor limiting further development of understory plant diversity in the plantation. This trend may be one of the reasons of decline in understory plant species in *Taxodium* stands investigated in our study whereas the diversity indices in these stands was lower than those in *Alnus* stands. MICHELSEN *et al.,* (1996) found that most of the understory herbs in Ethiopian highland plantations of *Pinus*, *Eucalyptus* and other alien tree taxa were widespread. Incoherence reasons for this result and result of present study can be affirmed that such study was conducted in lowland, while the study of MICHELSEN *et al.* (1996) it was conducted in highland. High plant species richness in alder stands also has been reported in coastal Oregon (FRANKLIN & PECHANEC, 1968, DEAL, 1997).

Floristic composition and similarity (JI)

There were 19, 21, 10 and 12 herbaceous species in *Anus* 3×3 m, *Alnus* 4×4 m, *Taxodium* 3×3 and *Taxodium* 4×4 plantations, respectively. Also number of woody species was 14, 13, 7 and 7 in the same order above mentioned stands. Low number of herbaceous and woody species in plantations compared to other studies may be owing to low drainage soil (VANN &

MEGONIGAL, 2002). This trend was found in POORBABAEI & POORRAHMATI (2009) study, who reported low number of herbaceous and woody species on poor drainage site.

All plantation stands of the present study exhibited low similarity *(JI)* of woody species composition. A similar result, i.e. low similarity among different plantation species was reported by PANDE *et al.*, (1998). SENBETA *et al.*, (2002), who found that the intensity of light reaching the forest floor may differ in accordance with the intensity of crown cover, and this may influence understory plants colonization.

Conclusions

From this investigation it can be concluded that in comparison with *Taxodium*, *Alnus* stands have higher growth attribute, less crown cover percentage and litter thickness, higher diversity indices, and can maintain plant diversity and facilitate succession process better than *Taxodium* stands. These are because of small and light canopy of *Alnus* trees, whereas light penetrates easily to forest ground, or may be for higher concentrations of total nitrogen and ammonium in its litter (ESHTER *et al.*, 2006, GLAESSENS *et al.*, 2010). On the base of the results of this investigation, it seems that *Alnus subcordata* as a fast-growing species can be proposed for plantations in plain areas of northern Iran where the site is a low-drained.

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