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Full Length Research Paper

Plant species diversity in loblolly pine (*Pinus taeda* L.) and sugi (*Cryptomeria japonica* D. Don.) plantations in the western Guilan, Iran

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The purpose of this study was to quantify plant species diversity in three plantations composed of loblolly pine (*Pinus taeda*) (two stands) and Sugi (*Cryptomeria japonica*) (one stand) species, located in western Guilan, Iran. Sampling procedure was systematic-random method, and with regard to the homogeneity of plantations 20 sampling plots were taken in each plantation and the surrounding natural forest. The size of sample plot was 20 × 20 m to survey woody species. The diameter of breast height of all trees was measured and individuals of shrubs and saplings were enumerated within the plot. In order to survey herbaceous layer, sampling plot area was determined using nested plot sampling at the center of the large plot and species/area curve was plotted in each forest. Coverage percent of herbaceous species was estimated using Domin criterion and type of herb species were identified. In addition, Crown cover percentage was visually estimated in each large sampling plot. Litter thickness was measured in four selected points of large plot corners. Several diversity indices and Jaccard's similarity index were used for data analyses. Results indicated that basal area in Sugi plantation was the highest amongst the studied forests. The highest degree of similarity of woody species was found between *P. teada* 72 (that is planted in 1972 year) and *P. taeda* 91, and between Sugi and *P. taeda* 91 plantations. Moreover, the highest degree of similarity of herbaceous species was between *P.teada*72 and Sugi plantations. *P. taeda* 91 plantations showed the highest values of species diversity in woody and herbaceous layers, while *P. teada* 72 and Sugi plantations had the lowest diversity in woody and herbaceous layers, respectively. The highest and lowest values of litter thickness were found in the *P. taeda* 91 plantation and the nearby natural forest, respectively.

Key words: Plant species diversity, *Pinus taeda*, *Cryptomeria japonica*, plantation, Guilan

INTRODUCTION

Although the total area of plantation (187 million ha) currently represents only 5% of the global forest cover, their importance is rapidly increasing as countries move to establish sustainable sources of woody fiber to meet the increasing demand for wood pulp and energy. This is especially the case in Asia, where an estimated 62% of the global plantation estate is located (Carnus et al., 2006).

Iran is climatically located in arid and semiarid belts of the world and natural forests cover 12.2 million hectare, of which 1.8 million hectare belongs to northern forests. The northern forests of Iran have been considered to provide commercial timber for use in wood industries and paper factories. Given that these forests are composed of slow-growing broad-leaved trees, these forests can not completely meet the wood requirements of the country. Thus, it is necessary to establish plantations of exotic fast-growing species such as pine species (e.g., loblolly pine). Species in the genera *Pinus* and *Eucalyptus* are the most commonly used trees in plantations (that is 30%), although the overall diversity of planted tree species is increasing (Carnus et al., 2006). In addition, the plan-

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tations have been established to restore degraded lands, to enhance standing crop of disturbed forests and to inhibit deforestation from long time in Iran. The plantations in Guilan province (north of Iran) were mostly carried out with *Pinus taeda*, *Pinus pinaster*, *Pinus pinea*, *Pinus sylvestris*, *Picea abies*, *Larix deciduas Cryptomerai japonica*, *Eucalyptus* sp. and *Cupressus sempervirens* var. *horizontalis* (native species), of which *P. sylvestris*, *P. abies* and *L. decidua* species are planted in the gaps created in the mountainous forests, and the remaining species are planted in the lowlands of Guilan. The loblolly pine (*P. taeda*) has been planted in these regions since 1968, and it has ecologically shown comparatively good adaptation in western Guilan (Pourbabaei and Roostami, 2007). Moreover, this species produces wood biomass almost equal to its original sites in the United States (Bonyad, 2006).

Plant species diversity has been widely studied in the plantation ecosystems (Yirdaw, 2001, Kamo et al., 2002; Nagaike, 2002; Nagaike et al., 2003; Yirdaw; Luukkanen, 2003; Pourbabaei and Roostami, 2007). Plant species diversity in the forest under-story has extensively been studied because the under-story is a major component of forest ecosystems and plays an important role in many ecological functions and processes (e.g., Yirdaw, 2001; Roberts, 2002; Nagaike et al., 2006). Plantations of single tree species are often considered to be associated with the lowest biodiversity among forests. However, high species diversity of under-story plants has been reported within plantations in surrounding natural forests (Yirdaw, 2001; Nagaike, 2002; Nagaike et al., 2006).

The purpose of this study was to examine plant species diversity in plantations of *P. taeda* and *C. japonica* and the effects of these plantations on under-story species diversity. The obtained results of this study could be used in planning of plantations (especially, in species selection) and managing of biodiversity in them.

MATERIALS AND METHODS

Study area

Study areas are located in Pilamber region about 30 km in the south-east of Hashtpar city and 40 km in the northern of Anzali city (37° 34´ 30″ N and 49° 4´50″ E, respectively). This study was carried out in three plantations and in the surrounding mixed hardwood natural forest. The plantations are of loblolly pine (*P. taeda*) and Sugi (*C. japonica*) species. The loblolly pines and Sugi species were planted in 1972 (*P. taeda* 72), 1991 (*P. taeda* 91) and 1973, respectively. The thinning treatment has been performed in the loblolly pine planted in 1972 year. The slope ranges from 0 to 5 %. Mean annual precipitation and temperature are 1211.4 mm and 21.2ºC, respectively. Edaphically, soil consists of heavy texture with weak drainage and pH ranges from 6.5 to 7.2 in the studied compartments.

Field survey

At first, a map of the study areas with scale 1:10000 was provided and then a random systematic inventory network was set up on it. Regarding homogeneity of plantations, 20 sampling plots were taken in each forest. The size of sample plot was 20 × 20 m to survey woody species. The diameter of breast height (DBH) of all trees (≥ 5 cm DBH) was measured and individual shrubs and saplings (<5 cm DBH) were enumerated within the plot. In order to survey herbaceous layer, sampling plot area was determined using nested plot sampling at the center of the large plot and species/area curve was plotted in each forest, and plot area was varied from 32 to 64 m^2 in terms of forest type. Coverage percent of herbaceous species was estimated using Domin criterion (Mueller and Ellenberg, 1989) and type of herb species were coded and then identified in Herbarium of Faculty of Natural Resources at University of Guilan. Crown cover percentage was visually estimated in each large sampling plot. Litter thickness was measured in four selected points of large plot corners and the average was recorded. Totally, 80 sampling plots were taken from the studied forests.

Data analysis

Several diversity indices were used to measure the woody and herbaceous species diversity in plantations and the natural forest. These diversity indices included Simpson (1-D), Hill's N_2, Shannon-Wiener (H´) and McArtthur's N_1. Evenness value was calculated using Wilson and Smith's index (E_{var}) (Krebs, 1999) and number of species was considered as species richness (S). Jaccard's index was used to measure the similarity in species composition among plantations and natural forest. Kolomogrov-Smirnov test showed that diversity, evenness and richness data were followed of normal distribution. A one-way ANOVA was used to detect variations in diversity, evenness, richness, basal area, crown cover and litter thickness among the plantation species and the natural forest, while Tukey's HSD was used for pair wise comparison. All diversity calculations and statistical analyses were conducted using Ecological Methodology (Krebs, 1999) and SPSS13.0 softwares.

RESULTS

Floristic composition and similarity

There were 28, 40, 35 and 45 herbaceous species in non-thinned (*P. taeda* 91), thinned (*P. taeda* 72) loblolly pine, *C. japonica* plantations and natural forest, respectively. Also, number of woody species was 16, 15, 16 and 17 in the same order previous forests. The herbaceous species of *Alopecurus pratensis* L., *Brachiaria cruciformis* (SM.) Griseb, *Cyclamen coum* L., *Eryngium bungei* Bioss., *Fragaria vesca* L. and *Primula heterochroma* Stapt. were restricted to natural forest and also woody species of *Buxus hyrcana* Pojark and *Hedera pastuchovii* Woren.ex. Grossh. found only this forest. Naturally regenerated tree species were *Acer cappadocicum* Gled., *A. insigne* Bioss., *Albizzia julibrissin* Durazz., *Carpinus betulus* L., *Ficus carica* L., *Fraxinus coriariifolia* (L.) Scheele., *Gleditschia caspica* Desf., *Morus nigra* L., *Parrotia persica* (DC.)C. A. Mey., *Pterocarya fraxinifolia* (Lam.) Spach., *Quercus castaniefolia* Gled., *Ulmus glabra* Hudson. and *Zelkova carpinifolia* (Pall.)Dipp. in the plantations. In addition, the shrubs species were *Crataegus microphylla* C. Koch., *Ilex spinigera* Loes., *Mespilus germanica* L., *Prunus divaricata* Ledeb and *Ruscus hyrcanus* Woron and one climber found(*Smilax excelsa* L.) in the plantations. The mean basal area per hectare in Plantations of *P. taeda* 91, *P. taeda* 72, *C.* and in the natural forest were 16.559 ± 3.509, 14.720 ± 4.021, 35.593 ± 71.449 and 14.204 ± 7.521 m^2, respectively.

Table 1. Jaccard's similarity index (in percent) and the number of common woody species (shown in parenthesis) for plantations and the natural forest

Forest type	*P. taeda* 72	*P. taeda* 91	*C. japonica*	Natural forest
P. taeda 72		55 (11)	39.1 (9)	43.5 (10)
P. taeda 91			55 (11)	52.4 (11)
C. japonica				50 (11)
Natural forest				

P. taeda 72: that is planted in 1972 year; *P. taeda* 91: that is, planted in 1991year.

Table 2. Jaccard's similarity index (in percent) and the number of common herbaceous species (shown in parenthesis) for plantations and the natural forest

Forest type	*P. taeda* 72	*P. taeda* 91	*C. japonica*	Natural forest
*P. taeda*72		55.8 (24)	64.4 (29)	61.5 (32)
*P. taeda*91			43.2 (19)	44.2 (23)
C. japonica				60 (30)
Natural forest				

Considering that basal area data did not follow normal distribution, Kruskal- Wallis test showed that there were significant differences in basal area among plantations and natural forest (P<0.05). In general, there was not much variation in the degree of similarity of the woody undergrowth between plantation species, except in the case of *P. taeda* 72 and *C. japonica*, where the similarity was the lowest (39.1%). The number of common woody species among plantations varied from 9 to 11, while it varied from 10 to 11 between plantations and the natural forest. From the total woody under-story vegetation identified, about 33.33% (corresponding to 7 species) were common in all plantations, while 58.33% (14 species) were also found in the adjacent natural forest. On an average, 44.44% of the species from each plantation was also found in the nearby natural forest (Table 1).

In addition, no noticeable differences were detected in the degree of similarity of the herbaceous species between plantations, except in the case of *P. taeda* 91 and *C. japonica*, where the similarity was the lowest and *P. taeda* 72 and *C. japonica*, where the species similarity was the highest. The number of common herbaceous species among plantations varied from 19 to 29, while it varied from 23 to 32 between plantations and the natural forest. From the total herbaceous species identified, 36.73% (corresponding to 18 species) were common in all plantations, while 60% (36 species) were also found in the adjacent natural forest. On an average, 47.22% of the species from each plantation was also found in the nearby natural forest (Table 2).

Diversity measures in woody species (shrubs and saplings) layer

The mean values of species diversity were significantly higher in plantation of *P. taeda* 91 than that in other forests, and the lowest species diversity was detected in plantation of *P. taeda* 72. Significant differences were observed in diversity indices amongst studied forests (P< 0.05), although the differences in E_{var} were not significant (Figures 1 and 2). The mean species richness was significantly higher in *P. taeda* 91 plantation than that in other forests, and the lowest species diversity was in plantation of *P. taeda* 72. There were significant differrence in species richness between plantation of *P. taeda* 91 and other forests, but there was no significant difference among other forest types (Figure 2).

Diversity measures in herbaceous layer

There were significant differences in mean diversity, richness and evenness measures among studied forests (P< 0.05). Simpson's index and Hill's N_2 values were the highest in plantation of *P. taeda* 91 and the lowest in the Sugi plantation. On the other hand, Shanonn-Wiener and McArtthur's N_1 values were the highest in plantation of *P. taeda* 72 and the lowest in the Sugi plantation (Figure 3). The highest and lowest values of mean richness were in *P. taeda* 72 and *P. taeda* 91 plantations, respectively. In addition, the highest and lowest values of mean evenness were in *P. taeda* 72 and Sugi plantations, respecttively (Figure 4).

The average of crown cover percentage in *P. taeda* 91, *P. taeda* 72, *C. japonica* plantations and the nearby natural forest are shown in Table 3. There were considerable variations in the crown cover percentage between sampling plots of studied forests, except *P. taeda* 91 plantations. Therefore, there were significant difference among plantations and the natural forest (P<0.05) respectively. It

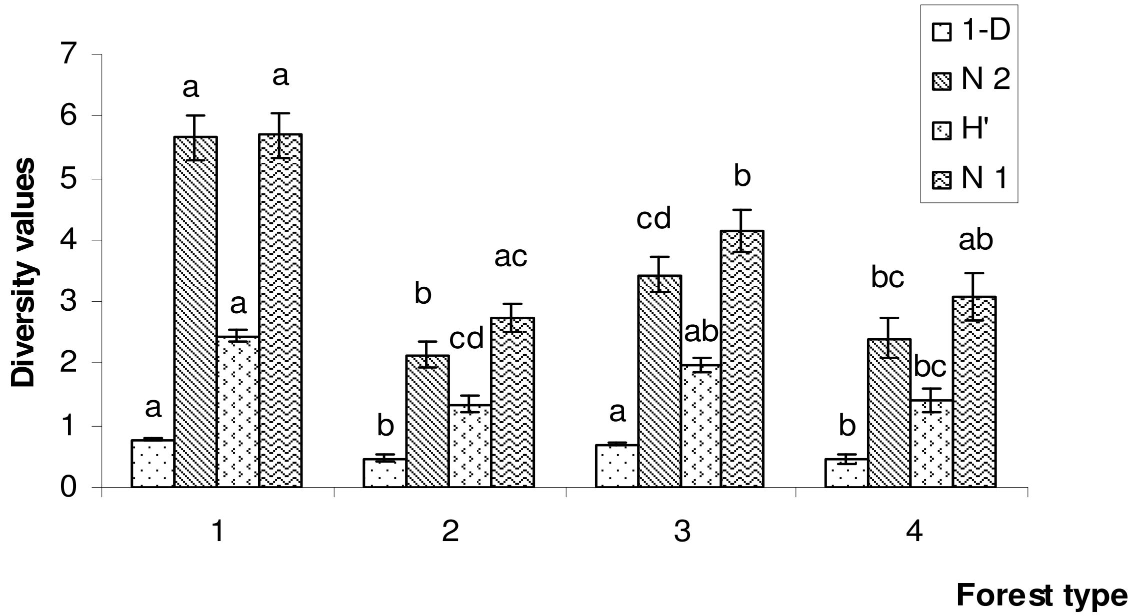

Figure1. Mean diversity measures in the different plantations and natural forest (that is 1: *P. taeda* 91; 2: *P. taeda* 72; 3: *C. japonica* and 4: a surrounding natural forest. Error bars represent standard error of mean. Means sharing the same letter are not significantly different at *P*=0.05 for each computed indices).

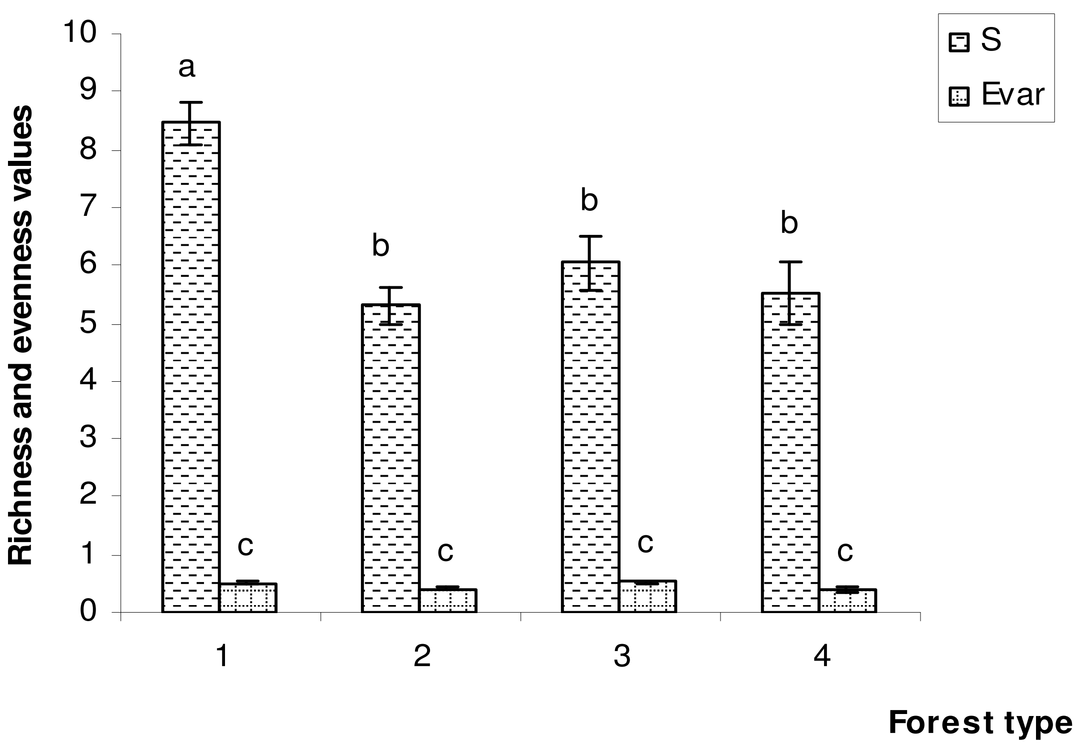

Figure 2. Mean species richness and evenness measures in the different plantations and natural forest.

The mean litter thickness in *P. taeda* 91, *P. taeda* 72, *C. japonica* plantations and the surrounding the natural forest were 3.131 ± 0.091, 1.651 ± 0.117, 1.245 ± 0.082, 0.825 ± 0.041 cm, respectively. *P. taeda* 91 had the highest and the natural forest had the lowest litter thickness, and was significantly different among the studied forests (*P*< 0.05).

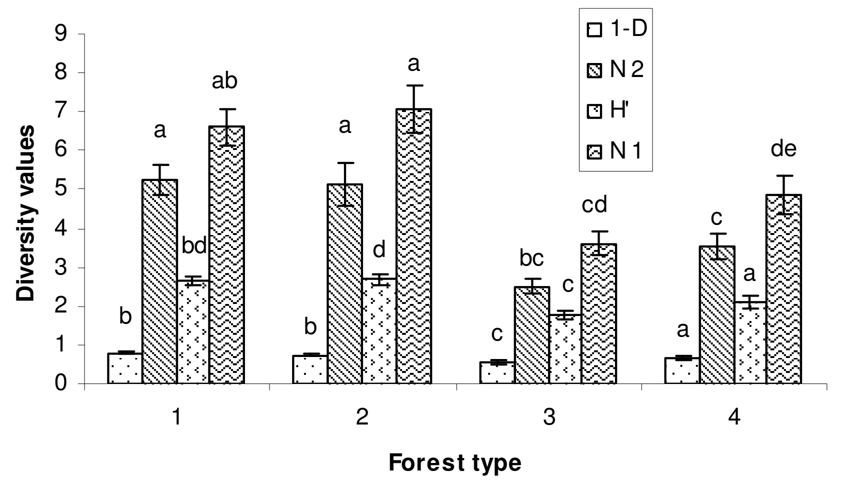

Figure 3. Mean diversity measures in the different plantations and natural forest.

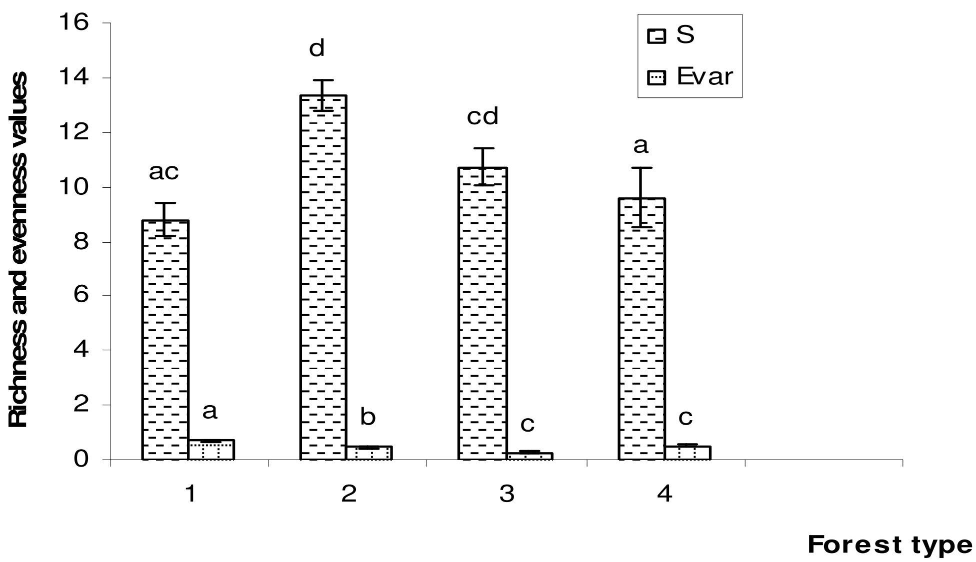

Figure 4. Mean species richness and evenness measures in the different plantations and natural forest.

Table 3. The mean of crown cover percentage and standard error in the studied forests.

Forest type	Mean	Std. Error	Minimum	Maximum
*P. taeda*91	88.500	± 1.032	80	95
*P. taeda*72	47.100	± 6.006	5	80
C. japonica	46.100	± 4.249	10	75
Natural forest	73.050	± 4.895	20	98

DISCUSSION

The aim of this study was to quantify plant species diversity in the loblolly pine (*P. taeda*) and Sugi (*C. japonica*) plantations in western Guilan, north of Iran. In order to do this research we also sampled from natural forest in the proximity, since primary natural forests close to a restoration site can provide baseline data that can be used in the evaluation of the extent and rate of plant species regeneration and establishment in plantations. Comparative studies of species diversity between plantations and other forest types have shown that plantations have higher (Nagaike, 2002; Nagaike et al., 2006; Koonkhunthod et al., 2007) or lower (Yirdaw, 2001; Roberts, 2002; Muňoz-

Reinoso, 2004; Pourbabaei and Roostami, 2007) diversity. The higher diversity in plantations was mainly due to invasive and ruderal species. Such patterns imply increased species diversity after severe human disturbance. The highest and lowest basal area was in the Sugi and *P. taeda* 72 plantations,

It seems that thinning cut had decreased the basal area in *P. taeda* 72 plantations, while this cutting was not accomplished in the Sugi plantation. The degree of similarity of woody species was high among plantations due to neighboring with natural forest. This finding is consistent with the findings in forest plantations in the Ethiopian highlands (Yirdaw, 2001). The highest value of similarity of herbaceous species was between *P. taeda* 72 and Sugi plantations and the lowest was between *P. taeda* 91 and Sugi plantations, since species richness was high in both plantation of *P. taeda* 72 and Sugi, and also thinning cut has increased herbaceous richness in *P. taeda* 72. Although there was a difference in relative abundance of species between the plantations and the adjacent natural forest, the similarity in species composition between them was high. This high similarity in species composition suggests that the natural forest was the main source of seeds in plantations.

The number of herbaceous species was highest in the nearby natural forest, since litter decomposition is fast there, due to varied leaves. Also, woody species richness was the highest in the natural forest and the lowest in the *P. taeda* 72 plantation. It sounds that thinning cut has caused a decline in undergrowth woody species in the *P. taeda* 72 plantation. The *P. taeda* 91 plantation showed the lowest species richness of herbs because of having the highest litter thickness (3.131 cm) and the paucity of light. This finding has been corroborated in the plantations of Ethiopian highlands (Yirdaw, 2001). Woody species diversity was the highest in the *P. taeda*91 plantation, since mean species richness per sampling plot was highest value in it, and also because of early succession species have been established in that condition. In addition, neighboring of this plantation with natural forest has been resulted in dispersion of hardwood trees seeds within the plantation, which causes increase in the woody species regeneration.

The lowest value of woody diversity was in *P. taeda* 72 plantations due to the least values of richness and evenness. In the herbaceous layer, Simpson and Hill's N_2 indices were the highest in *P. taeda* 91 plantations due to the highest value of evenness, for these indices are more sensitive to evenness (Ludwig and Reynolds, 1988; Krebs, 1999, Magurran, 2004). In addition, the lowest value of these indices was obtained in Sugi plantation because of the least value of evenness. On the other hand, Shannon-Wiener and McArthur's N_1 indices were the highest in *P. taeda* 72 plantations due to the highest value of richness, for these indices are more sensitive to richness (Ludwig and Reynolds, 1988; Krebs, 1999). The lowest value of these indices was obtained in Sugi plantation because of the least value of evenness. In general, sensitivity of diversity indices to evenness is higher than species richness (Ludwig and Reynolds, 1988; Magurran, 1988). In general in this study, plant species diversity was found higher in plantations than in the nearby natural forest. This is corroborated by findings of conifer plantations in Japan (Nagaike, 2002; Nagaike et al., 2006).

Furthermore, variations in crown cover percentage per sampling plot were high in all forest types (that is from 5 to 98%) except in *P. taeda* 91 plantation, where this plantation had the lowest value of variation. The highest value of litter thickness belonged to in the *P. taeda* 91 plantation due to the least variations in crown cover (that is from 80 to 95%). High value of crown cover percenttage causes a decline in light penetration to the forest floor. On the other hand, pine leaves have more acidic elements and decompose slower. Consequently, it causes the increases of litter thickness in this plantation. In addition, the lowest value of litter thickness was observed in the nearby natural forest due to its fast decomposition. Therefore, we can conclude that biological activities are high in the natural forest floor.

Although the main purpose of these plantations was timber production, the diversity and abundance of woody regeneration found in the plantation under-story indicated that these plantations could be effective tools in rehabilitating tree diversity. The recovery of native forest plant species is a measure of restoration success (Yirdaw, 2001; Koonkhunthod et al., 2007). On the other hand, some studies have shown that plantation management may have severe consequences on biodiversity compared with naturally regenerated forest, since the former system has usually replaced canopy tree composition with valuable timber species (Wesenbeeck et al., 2003; Ito et al., 2004; Maestre and Cortina, 2004; Nagaike et al., 2006; Pourbabaei and Roostami, 2007). Because the plantation canopies were completely replaced by *P. taeda* and *C. japonica*, they would have affected species diversity and composition. High woody species richness in plantations indicates the high potential of plantations for restoring biodiversity in the studied site, this finding has been confirmed by Yirdaw (2001) in the Ethiopian highlands. Therefore, these plantations have not decreased plant species diversity in the studied area. It is recommended that the degraded lands or clear- cut areas to be planted with these tree species.

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