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The Regeneration Structure and Biodiversity of Trees and Shrub Species in Understory of Pure Plantations of Oak and Mixed with Hornbeam in the Hyrcanian Forests of Iran

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Abstract: The regeneration structure and biodiversity of trees and shrub species in under story of pure and mixed Oak plantations were investigated in Chamestan Forest and Rangeland Research Station of Iran. Planted species including Oak (as main species) and Hornbeam (as associated species). This species were planted in five proportions (100Q, 70Q:30C, 60Q:40C, 50Q:50C, 40Q:60Z) in Northern of Iran in 11 years ago. All of regenerating seedlings and saplings of woody plants were divided into two height classes of 15-200 cm and more than 200 cm. In biodiversity study dominance index of Berger-Parker, diversity index of Fisher alpha, richness index of Margalef and evenness index of Equitability J were used. The results showed that abundance and diversity of regenerated species in under story of all plantations of oak were more than unplanted control plots and also under 50Q:50C were more than pure stand of oak. The presence of primary forest species in under stories of mixed plantation showed the usage of these plantations in development of succession in natural forests.

Key words: Abundance of regeneration, biodiversity, plantation, hyrcanian forests

INTRODUCTION

The presence of trees, either in plantation, in groups, in lines or in isolated from may contribute to the recovery of environmental conditions favorable to tree regeneration processes (Parrotta, 1995; Guariguata *et al*., 1995). The establishment of tree plantations in degraded areas may facilitate regeneration of native species that could not otherwise establish in open microsites or in competition by herbaceous species (Lugo, 1992). Several authors report on the role of tree plantations as catalizers of natural succession (Parrotta, 1992; Jussi *et al*., 1995; Keenan *et al*., 1999; Otsamo, 2000; Carnevale and Montagnini, 2002). Results of some studies also suggest that tree plantations have a good potential for accelerating the processes leading to recovery of biodiversity in degraded soils (Guariguata *et al*., 1995; Powers *et al*., 1997; Parrotta, 1999; Jogiste *et al*., 2005; Ohara and Waring, 2005).

Mixed plantations could promote the regeneration of a greater diversity of species in their understory than pure-species plantations by controlling the spontaneous competitive species (Balandier *et al*., 2005) and also by creating a greater variability of habitat conditions that may favor seed dispersers and germination and growth of tree species (Guariguata *et al*., 1995).

Stand structure is a key factor in the growth, function and disturbance regimes of forests. Forest restoration and management based on natural disturbance ecology, has highlighted the value of a clearer understanding of the role of structure in mediating key ecosystem processes (Boyden *et al*., 2005). Traditional descriptions of stand structure have focused on stand-level collective attributes such as average tree size, density and basal area. However, the horizontal and vertical heterogeneity of forest structure influences tree growth, plant species diversity, wildlife habitat and fire behavior (Harrod *et al*., 1999; Waltz *et al*., 2003; Youngblood *et al*., 2004). Species diversity is the best known, but by far not the only level of diversity (Turner, 1995). Within forestry genetic diversity and structural diversity are also important facets (Neumann and Starlinger, 2001).

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In the present research we investigated tree regeneration under plantations of native species in pure and mixed designs, at Chamestan Forest and Rangeland Research Station in the Hyrcanian (or Caspian) Forests of Iran. The species of this research were Oak (as target species); *Quercus castaneifolia* C.A.Meyer (Fagaceae) and Hornbeam (as native component species); *Carpinus betulus* L. (Corylaceae). In the present research the following hypothesis were tested. (1) Tree regeneration of native species is more abundant under the canopy of the plantations than in adjacent areas without trees (control) and (2) tree regeneration is more diverse under the mixed plantations than under the pure-species plantations.

MATERIALS AND METHODS

Site description: The study area is located at the Chamestan experiment station, in Mazandaran province, on the northern parts of Iran (36°29/ N, 51°59/ W). Experimental plots were located at an altitude of 100 m above sea level. The area is on flat, uniform terrain with low slope (0-3%). Annual rainfall averages 803 mm, with wetter months occurring between September and February and a dry season from April to August monthly rainfall usually averages <40 mm for 4 months. Average daily temperatures range from 11.7°C in February to 29.5°C in August.

The soils are deep, stone-free and have a silty clay loam and clay loam textures with a pH 6.0-7.5. Previously (approximately 50 years ago) this area was dominated by natural forests containing native tree species such as *Quercus castaneifolia* C.A.Meyer., *Gleditschia caspica* Desp., *Carpinus betulus* L., *Zelkova carpinifolia* (Pall.) Dipp., etc. The surrounding area is dominated by agricultural fields and commercial building.

Experimental design: Experimental plantations were established in 1995 using a randomized complete block design that included three replicate 25×25 m plots of each of the following treatments:

- *Quercus castaneifolia* C.A.Meyer (100Q);
- 70% *Q. castaneifolia* + 30% *Carpinus betulus* L. (70Q:30C);
- 60% *Q. castaneifolia* + 40% *C. betulus* (60Q:40C);
- 50% *Q. castaneifolia* + 50% *C. betulus* (50Q:50C);
- 40% *Q. castaneifolia* + 60% *C. betulus* (40Q:60C);
- Unplanted control

Tree spacing within plantations was 1×1 m and two species were systematically mixed within rows. The stands were never fertilized and weeded.

Tree and shrub regeneration studies: Tree and shrub regeneration in this research was investigated for each plantation plot, without two marginal planted rows. All woody seedlings and saplings were identified and counted and were sorted by height classes: class 1:15 cm^{-2} m, class 2: >2.0 m. Similar sampling procedures were used in the adjacent natural regeneration controls.

Biodiversity studies: The following concepts were considered for biodiversity studies in this research.

Species richness: Species richness can refer to the number of species present in a given area or in a given sample, without implying any particular regard for the number of individuals examined in each species (Sanjit and Bhatt, 2005). Species richness can be numerical (or simply species richness; Hurlbert, 1971) or be related to area (or simply species density, namely the number of species present in a given area; Simpson, 1964). Margalef index (Eq. 1) was used in this study to calculate of species richness (Margalef, 1958).

$$R = \frac{S-1}{LnN} \tag{1}$$

where S is number of taxa, N is number of individuals.

Species evenness: Species evenness can refer to the equitability or distribution of individuals among species present (Pielou, 1966). Evenness index of Equitability J is calculated as (Eq. 2):

$$E = \frac{H}{LnS} \tag{2}$$

where H is Shannon diversity index and S is number of taxa.

Species diversity: Species diversity is a function of the number of species present (i.e., species richness or number of species) and the evenness with which the individuals are distributed among these species (i.e., species evenness, species equitability, or abundance of each species) (Margalef, 1958; Lloyd and Ghrlardi, 1964; Pielou, 1966; Spellerberg, 1991). Measures of diversity vary in the relative emphasis they place on the number of species and their relative abundance. Moreover, species diversity, as it is usually measured, is an aspect of community structure (Sanjit and Bhatt, 2005).

Fisher's alpha index (Fisher *e al.*, 1943) was used in this study to calculate of species diversity (Eq. 2).

$$S = aLn(1 + n/a) \quad (3)$$

where S is number of taxa, N is number of individuals and a is the Fisher's alpha.

Species dominance: Species Dominance can refer to the number of individuals in the dominant taxon relative to the total number of individual. The Berger-Parker index was used for this study. This index accounts for both richness and relative abundance, presents the proportional importance of the most dominant species and is simple and easy to calculate. It is expressed as (Eq. 4):

$$d = \frac{N_{max}}{N} \quad (4)$$

where N_{max} is the number of individuals in the most abundant species and N is the number of all individuals (Magurran, 1988). The Berger-Parker index is expressed in the reciprocal from (1/d) so that increases in the index value follows an increase in species diversity or a decrease in dominance.

Data analysis: One-way analysis of variance (ANOVA) was used to compare abundance of regenerating individuals among the different treatments, for each height class and for the totals (sum of the individuals in the two height classes) and also to compare the total number of tree species regenerating under each treatment. LSD tests were used for comparisons among means (Scheffe, 1959). PAST software was used to calculate the biodiversity indices of regenerating woody species in the understory of different treatments.

RESULTS

Regeneration of woody species under each treatment abundance: The lowest average of total numbers of tree individuals (seedling and sapling, sum of the two height classes) was found in the control natural regeneration plots with only 312 individuals/ha (Table 1). Sorting the regenerating individuals by height classes, in class 1:15 cm^{-2} m the lowest numbers of seedlings were also found in the control (Fig. 1). The number of tree regenerating individuals corresponding to height class 2: >2 m, ranged from 79 under the pure plantation to 249 individuals/ha under 60Q:40C treatment, with no significant differences among treatments (Fig. 1).

Number of tree species: The number of tree species at 11 years was significantly greater under 50Q:50C and 40Q:60C treatments than in the control (Table 1).

Biodiversity indices: In this study, diversity (Fisher alpha) and dominance (Berger-Parker) indices showed any significant differences among planting and control treatments (Table 2). Margalef's richness index was higher under 50Q:50C and lower in the control than pure oak, 70Q:30C, 60Q:40C and 40Q:60C treatments. In contract, Evenness index of Equitability J was higher in the control plots. This index was lower under 70Q:30C and intermediate under pure oak, 60Q:40C, 50Q:50C and 40Q:60C treatments (Table 2).

Principal tree species in the six treatments: In this research, *Quercus castaneifolia* represented greatest percent of the total regenerating individuals under different plantations and so *Morus alba* in the control plots. Table 3 shows the total number of regenerating individuals of each species, under pure and mixed plantations and in natural regeneration plots.

Table 1: Abundance of regenerating individuals and number of species under pure and mixed plantations and in natural regeneration plots (means and standard errors between parenthesis)[a]

Treatments	Total No. of seedling/sapling ha^{-1}	No. of species/441 m^2
100Q	3020 (274)a	7.17 (0.47)ab
70Q:30C	2850 (927)a	8.00 (1.73)ab
60Q:40C	2903 (802)a	7.00 (1.52)ab
50Q:50C	2215 (587)ab	9.33 (1.45)a
40Q:60C	2653 (170)a	9.00 (0.57)a
Natural regeneration	312 (72)b	3.75 (0.75)b

Differences among means are statistically significant when the standard error is followed by different letter(s) (p<0.05)

Table 2: Biodiversity indices of regenerating species under pure and mixed plantations and in natural regeneration plots (means and standard errors between parenthesis)[a]

Treatments	Fisher alpha	Margalef	Equitability J	Berger-Parker
100Q	1.65 (0.156)a	1.27 (0.11)ab	0.55 (0.03)ab	0.67 (0.02)a
70Q:30C	1.92 (0.37)a	1.45 (0.27)ab	0.51 (0.04)b	0.68 (0.06)a
60Q:40C	1.77 (0.53)a	1.30 (0.36)ab	0.68 (0.05)ab	0.50 (0.06)a
50Q:50C	2.56 (0.32)a	1.82 (0.22)a	0.60 (0.02)ab	0.62 (0.02)a
40Q:60C	2.28 (0.20)a	1.68 (0.12)ab	0.57 (0.04)ab	0.62 (0.04)a
Control	1.91 (0.53)a	1.01 (0.22)b	0.78 (0.13)a	0.56 (0.13)a

Differences among means are statistically significant when the standard error is followed by different letter(s) (p<0.05)

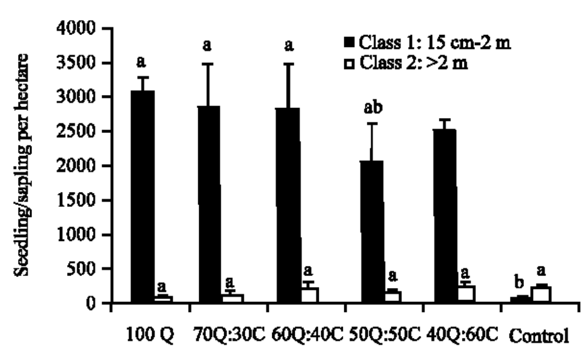

Fig. 1: Total number of regenerating treee seedling by height class and treatment. Different letters significant differences among treatments (p<0.05)

Table 3: Total number of regenerating individuals of each species, under pure and mixed plantations and in natural regeneration plots

Species	100Q	70Q:30C	60Q:40C	50Q:50C	40Q:60C	Control
Quercus castaneifolia	2032	1896	1384	1307	1668	11
Prunus avium	478	264	310	277	304	57
Mespilus germanica	140	76	98	106	49	6
Morus alba	130	121	325	108	136	158
Crataegus ambigua	93	38	15	113	55	0
Albizia julibrissin	60	23	45	15	136	51
Acer velutinum	52	226	650	33	144	0
Diospyros lotus	11	23	0	23	23	0
Jasminum officinale	8	121	15	80	91	6
Gleditschia caspica	8	8	0	8	0	23
Carpinus betulus	8	8	15	45	8	0
Juglans regia	0	30	23	8	8	0
Celtis ausralis	0	8	0	0	0	0
Acer cappadocicum	0	8	0	23	15	0
Ficus carica var genuina	0	0	23	8	8	0
Ulmus glabra	0	0	0	38	0	0
Ulmus carpinifolia	0	0	0	0	0	0
Parrotia persica	0	0	0	23	0	0
Punica granatum	0	0	0	0	8	0
Total number	3020	2850	2903	2215	2653	312

DISCUSSION

Already a few years after tree establishment, an increase in floral and faunal diversity develops according to the status quo antes and possibilities for recolonization of species. This increase in biodiversity is of great importance due to the functional role, especially of soil fauna, for soil properties and self-regulation potential of intensive forest ecosystems (Makeschin, 1994; Jug *et al*., 1999).

The results of this research confirm the first hypothesis, that tree regeneration was more abundant in the understory of the plantations that in areas free of trees in the Hyrcanian Forests of Iran. This coincides with results of other published research on the subject (Parrotta, 1992; Mc Clanahan and Wolfe, 1993; Guariguata *et al*., 1995; Powers *et al*., 1997; Holl, 1999; Parrotta, 1999; Keenan *et al*., 1999; Jug *et al*., 1999; Carnevale and Montagnini, 2002; Yirdaw and Luukkanen, 2003).

The second hypothesis of this research, that tree regeneration was more diverse under the mixed plantations than under the pure oak plantation, was slightly confirmed, since the 50Q:50C treatment had the higher number of species and higher Margalef's richness index than pure oak plantation.

Due to more presence of Hornbeam trees in treatments of 50Q:50C and 40Q:60C and its lighter crown in comparison with oak, these treatments shows more species diversity than other treatments. Maybe a part of this more species diversity and richness is result of litter quality of hornbeam. The most amount of evenness index in control treatment maybe due to least amount of richness index.

The presence of a greater proportion of individuals of height class 1:15 cm^{-2} m in the under story of the all plantations suggests that the relatively high shading conditions and higher litter depth and presence of perches for seed dispersers in this treatments are favorable for arrival and germination and recruitment of tree seeds (Parrotta, 1992; Parrotta *et al*., 1997; Lugo, 1997; Carnevale and Montagnini, 2002) and also the spontaneous competitive species (mainly grasses and Rubus sp.) were be controlled (Balandier *et al*., 2005).

In the case of plantations established primarily for rehabilitation of severely disturbed sites, watershed stabilization and/or native forest restoration, additional knowledge of how planted trees can facilitate, or inhibit, natural success ional processes that lead to the development of structurally diverse and functionally stable forest ecosystems is also needed (Parrotta, 1999). The costs and benefits of managing the regenerating seedling and saplings as an alternative to clearing and replanting should be assessed. In addition to considering the ecological factors influencing tree regeneration, the socioeconomics feasibility of these plantations as practical systems for the recovery of biodiversity in deforested landscapes in the region should be also examined (Carnevale and Montagnini, 2002).

REFERENCES

Balandier, P., B. Prevosto and J. Guitton, 2005. Forest Restoration in the French Massif Central Mountains. In: Restoration of Boreal and Temperate Forests. Stanturf, J. and P. Madsen (Eds.). CRC Press, pp: 569.

Boyden, S., D. Binkley and W. Shepperd, 2005. Spatial and temporal patterns in structure, regeneration and mortality of an old-growth ponderosa pine forest in the Colorado Front Range. For. Ecol. Manage., 219: 43-55.

Carneval, N.J. and F. Montagnini, 2002. Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species. For. Ecol. Manage., 163: 217-227.

Fisher, R.A., A.S. Corbet and C.B. Williams, 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Anim. Ecol., 12: 42-58.

Guariguata, M., R. Rheingans and F. Montagnini, 1995. Early woody invasion under tree plantations in Costa Rica: Implications for forest restoration. Restor. Ecol., 3: 252-260.

Harrod, R.J., B.H. McRac and W.E. Hartl, 1999. Historical stand reconstruction. For. Ecol. Manage., 114: 433-446.

Holl, K., 1999. Factores limiting tropical rain forest regeneration in abandoned pastures: Seed rain, seed germination, microclimate and soil. Biotropica, 31: 229-242.

Hurlbert, S.H., 1971. The non-concept of species diversity: A critique and alternative parameters. Ecol., 52: 577-586.

Jogiste, K., A. Vares, U. Veiko and H. tullus, 2005. Baltic Afforestation. In: Restoration of Boreal and Temperate Forests. Stanturf, J. and P. Madsen (Eds.). CRC Press, pp: 569.

Jug, A., F. Makeschin, K.E. Rehfuess and C. Hofmann-Schielle, 1999. Short-rotation plantations of balsam poplars, aspen and willows on former arable land in the Federal Republic of Germany. III. Soil ecological effects. For. Ecol. Mange., 121: 85-99.

Jussi, K., A. Goran, J. Yasuf, O. Antti, T. Kari and V. Risto, 1995. Restoration of natural vegetation in degraded *Imperata cylindrica* grassland: Understorey development in forest plantations. J. Veg. Sci., 6: 205-210.

Keenan, R.J., D. Lamb, J. Parrotta and J. Kikkawa, 1999. Ecosystem management in tropical timber plantations: Satisfying economic, Conservation and social objectives. Sustainable For., 9: 117-134.

Lloyd, M. and R.J. Ghelardi, 1964. A table for calculating the equitability component of species diversity. Anim. Ecol., 33: 217-225.

Lugo, A.E., 1992. Tree plantations for rehabilitating damaged forest lands in the tropics. In: Ecosystem rehabilitation. Wali, M.K. (Eds.). SPB Academic Publishing, The Hague, The Netherlands.

Lugo, A.E., 1997. The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. For. Ecol. Manage., 99: 9-19.

Magurran, A.E., 1988. Ecological Diversity and It's Measurement Princeton. Princeton University Press.

Makeschin, F., 1994. Soil Ecological Effects of Energy Forestry. Biomass Bioenergy, 6: 63-79.

Margalef, R., 1958. Information theory in Ecology. Genetic and Systematic, 3: 36-71.

Mc Clanahan, T.R. and R.W. Wolfe, 1993. Accelerating forest succession in a fragmented landscape: The role of birds and perches. Conser. Biol., 7: 279-285.

Neumann, M. and F. Starlinger, 2001. The significance of different indices for stand structure and diversity in forests. For. Ecol. Manage., 145: 191-106.

Ohara, K. and K.M. Waring, 2005. Forest Restoration Practices in the Pacific Northwest and California. In: Restoration of Boreal and Temperate Forests. Stanturf, J. and P. Madsen (Eds.). CRC Press, pp: 569.

Otsamo, R., 2000. Secondary forest regeneration under fast-growing forest plantations on degraded *Imperata cylindrica* grasslands. New Forests, 19: 69-93.

Parrotta, J.A., 1992. The role of plantation forests in rehabilitating degraded tropical ecosystems. Agric. Ecosyst. Environ., 41: 115-133.

Parrotta, J.A., 1995. Influence of understory composition on overstory composition on understory colonization by native species in plantations on a degraded tropical site. Vegetation Sci., 6: 627-636.

Parrotta, J.A., J. Turnbull and N. Jones, 1997. Catalyzing native forest regeneration on degraded tropical lands. For. Ecol. Manage., 99: 1-8.

Parrotta, J.A., 1999. Productivity, nutrient cycling and succession in single- and mixed-species plantations of *Casuarina equisetifolia*, *Eucalyptus robusta* and *Leucaena leucocephala* in Puerto Rico. For. Ecol. Manage., 124: 45-77.

Pielou, E.C., 1966. Species diversity and pattern diversity in the study of ecological succession. Theorical Biol., 10: 370-383.

Powers, J.S., J.P. Haggar and R.F. Fisher, 1997. The effect of overstory composition on understory woody regeneration and species richness in seven year old plantation in Costa Rica. For. Ecol. Manage., 99: 43-54.

Sanjit, L. and D. Bhatt, 2005. How relevant are the concepts of species diversity and species richness. Bioscience, 305: 101-104.

Scheffe, H., 1959. The Analysis of Variance. Wiley, New York.

Simpson, G.G., 1964. Species diversity of North American recent mammals. Systematic Zool., 13: 57-73.

Spellerberg, I.F., 1991. Monitoring Ecological Change. Cambridge: Cambridge University Press.

Turner, S., 1995. Scale, Observation and Measurement: Critical Choices for Biodiversity Research. In: Measuring and Monitoring Biodiversity in Tropical and Temperate Forests. Boyle, T.J.B. and B. Boontawee (Eds.), Cifor, Bogor, Indonesia, pp: 97-111.

Waltz, A.E.M., P.Z. Fule, W.W. Covington and M.M. Moore, 2003. Diversity in ponderosa pine forest structure following ecological restoration treatments. For. Sci., 49: 885-900.

Youngblood, A., T. Max and K. Coc, 2004. Stand structure in eastside old- growth ponderosa pine forests of Oregon and northern California. For. Ecol. Manage., 199: 191-217.

Yirdaw, E. and O. Luukkanen, 2003. Indigenous woody species diversity in *Eucalyptus globules* plantations in the Ethiopian highlands. Biodiver. Conserv., 12: 567-582.