PLANTATION CONTRIBUTION TO RESTORATION OF DEGRADED ECOSYSTEMS IN THE ALLIANCE OF OSTRYO-CARPINION

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ABSTRACT

This paper examines the results of plantations of the Mediterranean pine species, *Pinus halepensis* Miller and *Pinus pinea* L., in the hilly area of Livadi-Vasilika, North Greece, which were accomplished in order to mitigate the degradation process of the area. Plantations were carried out in randomized blocks using two-year old paper-pot seedlings. Data were taken from three permanent plots established for each species during the five years after plantations. Field data analysis showed that *P. halepensis* exhibited quite high survival and growth rate while *P. pinea* follows with medium ones. The changes in plant cover, vegetation composition, community structure and species diversity showed that the plantations improved the ecological characteristics of the ecosystems.

ΣΥΜΒΟΛΗ ΤΩΝ ΦΥΤΕΥΣΕΩΝ ΣΤΗΝ ΑΝΟΡΘΩΣΗ ΥΠΟΒΑΘΜΙΣΜΕΝΩΝ ΟΙΚΟΣΥΣΤΗΜΑΤΩΝ ΣΤΗΝ ΥΠΟΖΩΝΗ ΤΟΥ OSTRYO-CARPINION

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ΠΕΡΙΛΗΨΗ

Η εργασία αυτή εξετάζει τα αποτελέσματα των φυτεύσεων των μεσογειακών πευκών, χαλεπίου και κουκουναριάς που πραγματοποιήθηκαν στη λοφώδη περιοχή Λιβαδίου-Βασιλικών, στη Βόρεια Ελλάδα. Οι φυτεύσεις πραγματοποιήθηκαν σε τυχαιοποιημένες ομάδες και χρησιμοποιήθηκαν διετή βωλόφυτα φυτάρια. Μετρήσεις λήφθηκαν από τρεις μόνιμες επιφάνειες για το κάθε είδος κατά τη διάρκεια πέντε ετών μετά τις φυτεύσεις. Η ανάλυση των δεδομένων έδειξε ότι η χαλέπιος πεύκη παρουσίασε υψηλή επιβίωση και αύξηση ενώ η κουκουναριά έδωσε μέτρια αποτελέσματα. Η μελέτη των αλλαγών στην εδαφοκάλυψη, στη σύνθεση και δομή της βλάστησης και της ποικιλότητας των ειδών έδειξε ότι οι φυτεύσεις, η κατεργασία του εδάφους και η περίφραξη για προστασία από βόσκοντα ζώα βελτίωσαν τα οικολογικά χαρακτηριστικά των οικοσυστημάτων.

1. INTRODUCTION

Restoration of degraded ecosystems is of high importance in Mediterranean countries where the degradation has a long history [1]. Degradation usually appears in areas of low elevation which human has colonized for centuries [2]. The ecosystems of Ostryo-carpinion occupy extensive area in Greece and they so far are characterized by heavy degradation due to the above-mentioned long-time human activities. This degradation is a result of a secondary vegetation succession and the existing ecosystems assumed that are coming from oak woods [3]. The restoration of these ecosystems can be carried out either by natural methods or by artificial interventions [4]. Data concerning the success of restoration methods in that conditions are still missing, especially in Greece, where the problem of rehabilitation of these ecosystems is of high importance [5]. In the case of reforestation, main attention should be paid to species selection, since in these areas it is difficult for many forest species to give good results. Seed origination also, and site preparation methods play an important role to restoration success [6,7].

Traditionally, evaluation of reforestation was focused on yield data, but recently it has been recognized its contribution to the ecosystems secondary succession towards a native vegetation [8]. Thus, as reforestation benefits could be considered values such as the enhancement of biodiversity, the improvement of the stability of ecosystems, the protection from soil erosion etc.; values on which many research studies have been focused on last years [9, 10]. This consideration is more obvious in Mediterranean basin where many reforestation efforts aimed at no wood products [6].

The aim of this paper was to evaluate the results of the restoration performed with plantations of Mediterranean pine species *Pinus halepensis* and *P. pinea*, in the hilly area of Livadi-Vasilika, North Greece. We made the hypothesis that thermophyllus coniferous species can be selected in restoration projects of Ostryo-carpinion, since they are quite tolerant to the low temperatures appearing during the winter in this zone, and also, they are favored by the better soil conditions existing during the summer (due to the higher amount of precipitation). The limitation of overgrazing also would help the ecosystems to recover. Plant establishment was measured in order to evaluate the success of restoration as well the vegetation differences between the degraded ecosystem's previous state and the new state following restoration [11,12,13]. The last was accomplished by measuring vegetation at the same time in the adjacent degraded area that was used as control.

2. MATERIAL AND METHODS

The plantations were carried out in December 1996, on the hilly area of Livadi-Vassilika, North Greece, 28 Km far from Thessaloniki. The experimental area was degraded public land used for grazing and covered by low shrubs subjected to overgrazing. The altitude is of 200-300 m asl. The soils are shallow with many erosion problems. The natural vegetation of the general area belongs to zone Quercetalia pubescentis and the alliance of Ostryo-carpinion [3]. The bedrock belongs to magmatic series of Chortiatis and consists of green schists and epigneisses. The climate is Mediterranean with five months dry period and mean annual rainfall 416 mm (period 1978-1995), according to the nearest meteorological station of Loutra Thermi, 8 Km far.

Winter plantations were carried out in randomized blocks using two-year old paper-pot seedlings following mechanical site preparation (before planting, a sub-soiling was applied by a heavy Machine, Caterpillar D8). Two native pine species *Pinus halepensis* and *Pinus pinea* that are characterized as early successional species, were planted on 2m X 3m spacing. The planting material was produced at the public forest nursery of Thessaloniki. All the reforestated area was fenced.

Data were taken from three permanent plots established for each species located in three different positions. A number of 90 seedlings per species (30 seedlings in each plot) were selected for field data sampling. The seedlings were numbered and their total height and root collar diameter were measured just after the planting. Monitoring of the seedlings' characteristics as well as species survival was carried out once a year (in autumn) during the next five years. Furthermore, in the fifth year (2001) we measured the dimensions of the seedlings crown and we computed their contribution to total vegetation cover. Furthermore, due to the extreme low temperatures observed during the winter of the year 2001-02, an additional survival recording was carried out in February of the year 2002, in order to estimate the influence of the winter cold on species survival.

An overall evaluation of the restored area was carried out in the fifth year when, except for the plantations performance, we measured the following plant communities parameters: Composition, total plant cover, planted species cover, native woody and grass species cover, plant species richness, Shannon-Weiner index, community structure and dominant height; these were recorded within the 6 selected plantations monitoring plots in a sample area of 50 m^2 (5X10 m) [14] for the evaluation of restoration process, and 5 plots in the adjacent control area (which has been suffering from overgrazing until now). In each plot all the plant species were recorded during the summer months of the year 2001 in the level of species. Species were distinguished into native in Greece and exotics. Nomenclature is according to Flora Europea [15]. An optical estimation of each species cover was carried out and consequently we estimated the total and woody species cover in each plot [16]. For the estimation of the grass species cover, five subplots (2m X 2m) were randomly selected within each plot [17]. The average of the five values was then used for the grass cover percentage. Species richness and Shannon-Weiner index were estimated for each plot [18]. Mean dominant height was estimated by measuring the five tallest individuals per plot of the native woody and grass species, while all the planted trees within the plots were measured. The community structure was evaluated by analyzing the above information appeared in each case.

Statistical analysis was performed using the SPSS package, version 11.5 for windows, and the t-test procedure was used for comparison of the growth rate between the planted species and for the detection of significant differences in vegetation features between the restored and control area [19,20,17].

3. RESULTS

3.1. Planted species survival

Analyzing the survival rate of the planted species five years after the plantations establishment (Figure 1), it seems that *Pinus halepensis* is the more successful species in the area than *P. pinea*, exhibited a survival rate of 81.8%. The seedling mortality was observed mainly during the first two years after planting and especially during the first summer due to the high drought. After the second year only a very low mortality was observed at both species. This mortality happened during the extreme cold winter of the year 2001-02; however, the cold influence was not too strong to cause stem necrosis. Parts of some *Pinus halepensis* trees were defoliated, but when the next growing season started new needles appeared and, in fact, only very few individuals died. The recorded high survival shows that this species is of high plasticity and it can successfully cope with the low temperatures (-11.1^{o} C) that were recorded during the winter of the year 2001-02. *Pinus pinea* exhibited lower survival rates reaching 70.3% five years after planting. This species was more affected by the low temperatures of the winter of the year 2001-02. As in *Pinus halepensis,* the *P.*

pinea trees presented the same symptoms of partial or entire defoliation, but new needles appeared in the spring; however, the stem necrosis appeared locally and it did not exceed a total percentage of 5%. The mechanical preparation seems to favor the seedlings survival of both species, mainly by loosing the soil and thus, allowing the easy expansion of seedlings root system to natural soil [21].

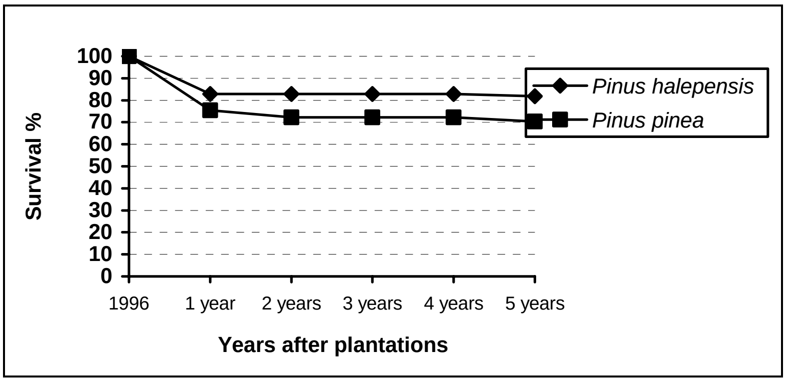

Figure 1. Performance of the planted pine species five years after the plantations.

3.2. Planted species growth

Average growth rate in terms of height and diameter was statistically greater at *Pinus halepensis* trees which exhibited 1.94 m total height and 4.93 cm diameter at ground level, 5 years after planting (Table 1). *Pinus pinea* presented lower values reaching 0.99 m height and 4.00 cm diameter. A great difference between the species was in their cover; *Pinus halepensis* contributes to ground cover in a percentage 26.6%, and *Pinus pinea* has significantly lower contribution (10.32%). However, the best all-round performance, including survival, was secured by *Pinus halepensis* seedlings.

TABLE 1. Morphological characteristics (height, diameter at ground level, dimensions of crown and canopy cover) of the studied species, five years after planting; values in parenthesis are standard error of mean.

Species	Total shoot height (m)	Diameter at ground level (cm)	Dimensions of crown (cm)		Canopy cover (%)
			Length	Width	
Pinus halepensis	1.94(0.06)a*	4.93 (0.12)a	135.51(3.64)a	144.92(13.20)a	26.60a
Pinus pinea	0.99(0.02)b	4.00(0.11)b	82.79(2.22)b	81.25(2.37)b	10.32b

* Values in the same column followed by a different letter are significantly different at the 95% level of confidence (t- test).

3.3. Changes in vegetation composition, species diversity and community structure

The floristic elements in both ecosystems (restored area and control) are similar except for the two species planted and a few species such as *Globularia alypum* L. that were recorded only in the reforestated area. However, the number of species recorded in each plot was significantly higher in the reforestated area due to the above reason (Table 2); the average species richness per plot reached 47.4 species in the restored area and 41.8 in the control area. The number of woody species was also higher in the restored area compared to the control (9 and 7 species per plot respectively). The Shannon-Wiener index was also significantly greater in the restored area (2.98) than in the control area (2.60). There were also some differences in species abundance between the reforestated and control area. For instance, *Chrysopogon gryllus* (L.) Trin. was the dominant grass species in the first case comprised 18% of total plant cover, but it was less abundant in the last case (6%)(Figure 2). In contrast, *Cynodon dactylon* (L.) Pers. was the common dominant species in the control area comprised 20% while in the reforestated area its present was low (5%). The total number of species recorded in both ecosystems was 96 species. Only one species, *Solanum elaeagnifolium* Cav. was exotic (alien species), while the rest ones belong to the native flora. This species was mainly recorded in the reforestated area but it was also found in some cases in the control area. However, this species was more abundant in the reforestated area due to its trait to colonize disturb soils [22].

TABLE 2. Differences in plant species diversity and dominant height between the restored and control plots, five years after plantations; values in parenthesis are standard error of mean.

Vegetation characteristics	Restored area	Control
Species richness	47.4(0.81)a*	41.8(1.20)b
Number of woody species	9.0 (0.6)	7.0 (0.4)
Shannon-Wiener index	2.98(0.04)a	2.60 (0.09)b
Mean dominant height of planted species (m)	1.69 (0.091)	-
Mean height of the dominant native woody species *Quercus coccifera* (m)	1.26(0.024)a	1.12(0.019)b
Mean height of the dominant grass *Chrysopogon gryllus* and *Cynodon dactylon* (m)	1.15(0.018)a	0.84(0.016)b

*values in the same row followed by different letter are significantly different at the 95% level of confidence (t - test).

Concerning the vegetation height, this was greater at the restored area not only due to the presence of the planted pine species, but also due to the greater height of the native species; the plants were taller and in better conditions in the restored area than in the control (Table 2). However, the plants still suffer from overgrazing by goats in the control area, and thus they are in bad conditions, heavily damaged. The mean dominant height of *Quercus coccifera* was 1.26 m and 1.12 m in the restored and control area respectively. Similar results were observed for the main grass species *Chrysopogon gryllus* and *Cynodon dactylon*; their mean dominant height reached 1.15 m in the restored area and 0.84 m in the control.

The restored area exhibited in all cases higher vegetation cover than the control areas (Figure 2); the average cover across all the reforestated area was 81.5%, while in control was 76.3%. Much of this increase in total cover was the participation of the planted species (Table 1). By far the most common (and dominant) species found in all cases was *Quercus coccifera* L. which cover averaged 17% in the reforestated area and 24.6% in control (Figure 2), followed by *Phillyrea latifolia* L. and *Anthyllis hermanniae* L., while the rest common woody species *Erica manipuliflora* Salisb., *Juniperus oxycedrus* L.*,* *Cistus incanus* L. had a low percentage in all cases (below of five percent of total cover). Cover of the grasses was consistently the same in the restored and control area, averaged 40.3% and 37.3% respectively (Figure 2).

3.4. Restoration evaluation

Even though, the flora seems to be almost the same in both ecosystems, species diversity and cover were significantly higher in the reforestated area than in the control. The vegetation cover in first case ranged from 75% to 90%, while in the last from 70% to 80% and in some cases 60%. The mean plant height of the native vegetation was below one meter in the control areas and over in the reforestated areas. All woody species in the control area were heavily damaged by goats and only few in the reforestated area (because in some cases goats passed to the fence). Generally, the species (both woody and grasses) were significantly higher in the reforestated area than in the control area. Vertical structure was also improved in the restored area, since the planted trees in combination with the tallest native woody species (*Quercus coccifera* and in some cases *Phillyrea latifolia*) started to create a two-storey community with an overstorey of the above species and an understory of the rest species. This more complex vertical structure usually favors biodiversity [23,24,25]. Native vegetation species exhibit also more dense foliage and better stem and crown increment. Another important difference was the seed production recorded in many species in reforestated area; many species both native and planted (especially *Quercus coccifera* and *Pinus halepensis*) produced many seeds which contributes to the higher diversity of the ecosystems [26] and to a high ability to be self-renewing or autogenic; that considered a common goal for many restoration projects [27]. Furthermore, acorn production by *Quercus coccifera* comprises the basis of many food-webs. On the contrary, the abundance of the species *Solanum elaeagnifolium*, the only exotic (alien) species found, in the reforestated area may show that the plantations may increase habitat invasibility by exotics. However, this species is more abundant in the reforestated area mainly due to the soil preparation as it prefers bare soils and open habitats [22]; as soon as canopy closure takes place it will probably disappear.

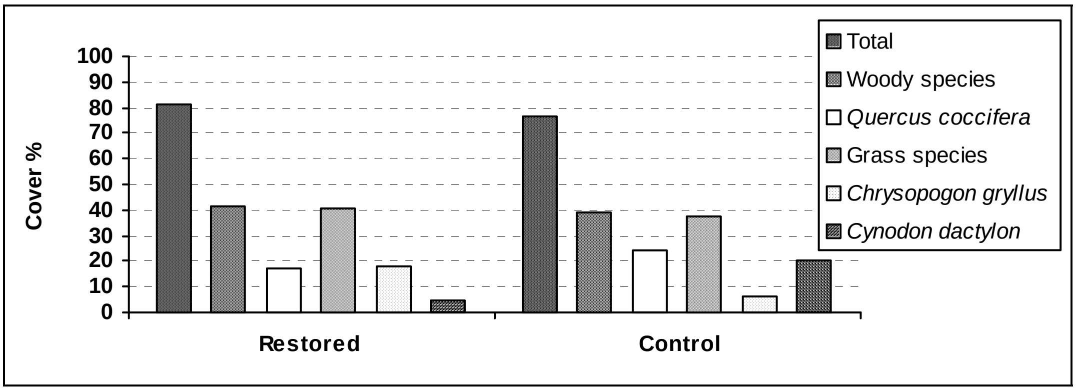

Figure 2. Vegetation cover in the restored and control area five years after the plantations.

4. DISCUSSION-CONCLUSSIONS

The quite high survival rates of the used pine species reflect low difficulties experienced by young outplants on the Ostryo-carpinion alliance in the hilly area of Livadi-Vasilika, North Greece, in the presence of sufficient site preparation. Both species presented quite high survival rates and medium growth rate. However, *Pinus halepensis* exhibited the higher survival and growth rate comparing to *Pinus pinea*. It must be particularly mentioned that the planted pine species were affected by the extreme low temperatures of the winter of the year 2001-2002, but this influence was not so great. Some individuals were damaged while only very few died. The greater damages appeared in *Pinus pinea* but, even in this case, the damages appeared only locally and they did not exceed a total percentage of 5%. Thus, it can be concluded, that the studied pine species are relative tolerant to the extreme cold, at least at the age of 7 years.

Similar results reported Zagas and Ganatsas [28], who studied the same and other species in an experiment carried out in an Arboretum of Vasilika, North Greece at a lower elevation. Both results support that between the studied pines species, *Pinus halepensis* presents the best all-round performance in the conditions of Ostryo-carpinion. Vidacovic et al. [29] also reported the same results for the same species in Croatia (South Europe) in similar climatic conditions where they recorded that *Pinus halepensis* and *Pinus brutia* were the most successful species.

Changes in vegetation characteristics showed that the restored area exhibited higher plant diversity, higher vegetation cover, taller plants and more complex community structures. However, it must be stressed that these results reflect current conditions (five years after plantations) and that the ecosystem status is quite temporal, since it is subjected to the long gradual process of secondary succession [11,27]; after the first years of plant establishment, the understorey vegetation will be suppressed due to the shading effect of young dense coniferous stands [30], and later more shade-tolerant native species will colonize the reforestated area. Vegetation changes after plantations were recorded also by others in different conditions using other woody species [13,12]; however, the changes depend upon the native vegetation and the planted species as well.

Habitat invasibility by exotics is another point for the estimation of the ecosystem status. *Solanum elaeagnifolium*, the only exotic species found, was more abundant in the reforestated area, may due to its strategy to colonize disturb soils; however, more research is needed to explain this observation. Increase of habitat invasibility after plantation may be is true when site preparation results in a high soil disturbance. Greater number of alien plant species was recorded in disturbed plots than in undisturbed ones in North American forests [31].

In conclusion, from the findings of this study, it seems that the studied Mediterranean pine species, and especially *Pinus halepensis*, can be used successfully in restoration projects of degraded areas in the alliance of Ostryo-carpinion in Greece. However, this should be validated by long-term studies which should examine the ecosystems changes through several successional stages. These studies should be on priority in Mediterranean countries where reforestation in many cases comprises a tool to mitigate degradation even the desertification process [7] and furthermore it could contribute to the nature conservation as well [8]. Finally, several limitations should be set out: i) site preparation should be done either by soft machines or better by hands, avoiding in such a way the great disturbance of the soil in the whole planted area (this means that the best planting technique is in pits by hands), ii) when the process of natural rehabilitation is quite fast, there is no need for artificial interventions, as in this case the natural method is preferred for ecosystem restoration.

REFERENCES

1. Perez-Trezo F., (1994) '**Desertification and Land Degradation in the European Mediterranean',** European Commission DG XII, Luxeburg.
2. Thirgood J.V. (1981) '**Man and the Mediterranean Forest',** Academic Press, New York.
3. Dafis S. (1973) '**Classification of forest vegetation of Greece'** Sch. Agric. and For. Sci. Yearb, 15, pp. 75-90 (in Greek).
4. Tsitsoni T., P. Ganatsas, T. Zagas and A. Hatzistathis (1999) '**Rehabilitation of degraded forest ecosystems'** AUTh, Lab. of Silviculture, Thessaloniki, Greece, Technical Report, pp.16.
5. Zagas T., A. Hatzistathis, T. Tsitsoni and P. Gkanatsas (1998) 'Degradation of Mediterranean forest ecosystems and silvicultural measures for their restoration' **European Environmental Research**, Volume I, No 2, pp. 53-60.
6. Hatzistathis A. and S. Dafis (1989) '**Reforestation-Forest Nurseries',** Giahoudis-Giapoulis, Thessaloniki (in Greek).
7. Vallejo V.R., S. Bautista and J. Cortina (1999) 'Restoration for soil protection after disturbances' In: Trabaud L. (ed.) **Life and Environment in the Mediterranean. Advances in Ecological Sciences** 3. WIT Press, pp. 301-343.
8. Honnay O., B. Bossuyt, K. Verheyen, J. Butaye, H. Jacquemyn and M. Hermy (2002) 'Ecological perspectives for the restoration of plant communities in European temperate forests' **Biodiversity and Conservation** 11, pp. 213-242.
9. Tilman D. (1996) 'Biodiversity: population versus ecosystem stability' **Ecology,** 77(2), pp. 350-363.
10. Schwartz M.W., C.A. Brigham, J.D. Hoeksema, K.G. Lyons, M.H. Mills and P.J. van Mantgem (2000) 'Linking biodiversity to ecosystem function: implications for conservation ecology' **Oecologia** 122, pp. 297-305.

11. Hobbs R.J. and Norton D.A. (1996) 'Towards a conceptual framework for restoration ecology' **Restoration Ecology** 7, pp. 93-110.
12. Atsamo A. (2002) 'Early effects of four fast-growing tree species and their planting densisty on ground vegetation in Imperata grasslands', **New Forests** 23, pp. 1-17.
13. Yirdaw E. (2002) 'Diversity of naturally-regenerated native woody species in forest plantations in the Ethiopian highlands', **New Forests** 22, pp. 159-177.
14. Barbour M.G., J.H. Burk, W.D. Pitts, F.S. Gilliam and M.W. Schwarzt (1999) '**Terrestrial Plant Ecology'** Third Edition, Addison Wesley Longman, Inc.
15. Tutin T.G., V.H. Heywood, N.A. Burges, D.M. Moore, D.H. Valentine, S.M. Walters and D.A. Webb (eds.) (1993) '**Flora Europaea'** ed. 2, Vol. 1-5, Cambridge Univ. Press, Cambridge.
16. Ganatsas P., T. Tsitsoni and T. Zagas T. (2001) 'Forest plant diversity in the Aspropotamos Site (GR 1440001) of the Natura 2000 network', In: Proc. Int. Conf. **Ecological Protection of the Planet Earth I**, Xanthi, Greece, Vol. I, pp. 399-407.
17. Rebele F. and C. Lehmann (2002) 'Restoration of a Landfill Site in Berlin, Germany by Spontaneous and Directed Succession' **Restoration Ecology** 10(2), pp. 340-347.
18. Magguran A.E. (1988) '**Ecological Diversity and its Measurement**' Univ. Press, Cambridge.
19. Fahnestock J.T. and J.K. Detling (1999) 'The influence of herbivory on plant cover and species composistion in the Pryor Mountain Wild horse range, USA', **Plant Ecology** 144, pp. 145-157.
20. Norusis M.J. (1994) '**SPSS Professional Statistics 6.1'**, SPSS Inc., Chicago, Illinois, USA.
21. Hatzistathis A., P. Ganatsas and A. Georgiou (2000) 'Research on the improvement of reclamation techniques of mine land in Gerakini, North Greece', In: V.A. Tsihritzis, G.P. Korfiatis, K.L. Katsifarakis, A.C. Demetrakopoulos (eds), Proc. Int. Conf. '**Protection and Restoration of the Environment V**', Thassos, 3-6 July 2000, Vol. II, pp. 699-706.
22. Economidou E. and A. Yiannitsaros A. (1975) 'Studies on the alien flora of Greece III. Morphology, development and phenology of *Solanum elaeagnifolium*', **Cav. Candollea,** 30, pp. 29-41.
23. Pitkänen S. (1997) 'Correlation between stand structure and ground vegetation: an analytical approach' **Plant Ecology,** 131, pp. 109-126.
24. Ferris R., A.J. Peace, J.W. Humphrey and A.C. Broome (2000) 'Relationship between vegetation, site type and stand structure in coniferous plantations in Britain', **Forest Ecology and Management,** 136, pp. 35-51.
25. Kerr G. (1999) 'The use of silvicultural systems to enhance the biological diversity of plantation forests in Britain', **Forestry**, Vol. 72, No3, pp. 191-205.
26. Huston M.A. (1998) '**Biological Diversity: The Coexistence of Species on Changing Landscapes',** Cambridge University Press, Cambridge.
27. Society for Ecological Restoration Science & Policy Working Group (2002) '**The SER Primer on Ecological Restoration',** www.ser.org/.
28. Zagas T. and P. Ganatsas (2001) 'Results of a forest species trial in an Arboretum of North Greece' **Silva Gandavensis** 66, pp. 76-88.
29. Vidacovic M., A. Krstinic, P. Durasovic and D. Kajba D. (1990) 'Thriving of some species and hybrids of two-needle pines in the Arboretum Trsteno', **Annales pro Experiments Foresticis**, Vol. 26, Zagreb in Jugoslavia MXM, pp. 331-339.
30. Augusto L., J. Duponey, J. Ricard and J. Ranger (2001) 'Potential contribution of the seed bank in coniferous plantations to the restoration of native deciduous forest vegetation' **Acta Oecologia** 22, pp. 87-98.
31. Stapanian M.A., S.D. Sundberg, G.A. Baumgardner and A. Liston (1998) 'Alien plant species composition and associations with anthropogenic disturbance in North American forests' **Plant Ecology,** pp. 49-62.