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Restoration of high-degraded forest ecosystems in Sithonia Chalkidiki, North Greece

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ABSTRACT

This study deals with the results of the experiment carried out in the Porto Koufo area, Sithonia, Chalkidiki, aiming at the restoration of the highly degraded forest land. The experiment consisted of three experimental plots, in which two plant species (*Pinus halepensis, Spartium junceum)* were planted, three replications in three different locations. The results showed: regarding *Pinus halepensis* plantations, one or two year old seedlings are recommended of good quality, 20-30 cm height, with rich and fine root system. *Spartium junceum* can be used either as containerized or as bare root seedlings and the seedlings must have at least 25 cm height. The parent material (bedrock) strongly affected the species survival having better results in schists comparing to the results in the granites. The protection from grazing is necessary at least for a period of 7 years after the plantations or for the period which the seedlings are in danger for survival. In no case soil compression and degradation should occur.

1. INTRODUCION

Our days are undeniably characterised by the intense degradation of the environment in all levels, with direct danger in certain cases the creation of not reversible conditions. Such a case constitutes the phenomenon of desertification, an international phenomenon with special presence in the Mediterranean region and especially in Greece (Perez-Trejo, 1994). Taking into consideration at the same time the soil erosion as well, which is the most acute environmental problem in Greece, the immediate taking of measures aiming at the restoration of the endangered regions and the prevention of the desertification is vital (Dafis, 1991; Zagas *et al.,* 1991; Hatzistathis *et al.,* 1999). Greece because of the climatic, topographic and historical conditions, it has suffered in the past and is still suffering intense destruction from fires and overgrazing (Le Houeru, 1981; Tsitsoni, 1996). The continuous destruction of the vegetation by the fires, the soil compacted from the overgrazing and the intense erosion have caused advanced stages of degradation a lot of forest regions (Thirgood, 1981; Trabauld, 1987; Hatzistathis *et al.,* 1999). Many of these regions are a step before the desertification.
This study deals with the results of experiment which aimed at facing the following problems: the choice of the appropriate plant species which should be used for the restoration, the quality of plant material which comprises the decisive factor of the restorative success and the field techniques which should be used in each case.

2. METHODOLOGY

2.1. Study area

The region, which was chosen, is the Sithonia peninsula of Chalkidiki and especially the degradation ecosystems in the Porto Koufo area, which is found in the zone of evergreen broadleaves (Quercetalia ilicis) (Athanasiadis, 1978). The climate is Mediterranean with dry and hot summer, small sum of annual rainfalls (Tsitsoni, 1991) and the area has been suffered intense degradation by fires and overgrazing (Naveh, 1990). The vegetation of the area is characterised by intense feed back because of the repeated fires, having dominating species as *Cistus monspeliensis, Cistus incanus, Erica manipuliflora, Quercus coccifera* (Gkanatsas *et.al*., 1998; Hatzistathis *et al*., 1998). The soil compaction with destroyed porosity having as a result the no penetration of water in it and the creation of a surface flow, which in its turn intensifies the phenomenon of erosion and consequently the degradation of soils. The big presence of rock appearances and the striping of the soil are very characteristic (Moudrakis, 1985).

2.2. Planning and installation of experiment

The experimental planning that was followed was the technique of the Latin square and three replications took place, in three different representative places in the study area totally 1.08 ha. The planting density that was used was 2x2 metres.

/---------------- **With fencing** ----------------- / -------------- **Without fencing** -----------/
/------- 30m ----------/ ---------- 30m----------/------------30m ----------/ ----- 30m---------/
/-- 15m --/ /--15m --/

A1	B1	CONTROL WITH PROTECTION	A2	B2	CONTROL WHITOUT PROTECTION
B1	A1		B2	A2	

Figure 1. Design of installation of sample plots.

The following treatments were applied:
1. Reforestation with Aleppo pine with planting containered seedlings, with fencing to be protected from grazing (A1) and without fencing (A2) 2. Installation of shrub vegetation with planting containered seedlings of spartium, with fencing to be protected from grazing (B1) and without fencing (B2) 3. Control for follow-up of the natural development of vegetation, either with protection from grazing or without protection. Every six months result inspections and registrations followed (before the summer drought in April, 1988, 1999 and after it in November, 1998, 1999) which concerned: 1) the survival of seedlings per treatment and 2) morphological characteristics as height and diameter in the radical node. Moreover the previous measurements during the second year included also physiologic characteristics of seedlings (predawn water potential), parameter that ascribe the water stress of the plant as well as its ability of survival. The measurements took place with the Plant Moisture System of company SKYE. The measurements were materialised in 5 seedlings per handling in May, 1999 before the summer drought and in October, 1999, after the end of the summer.

In each area the elevation, the slope, the aspect and the topography were recorded.. For more complete interpretation of the soil, five (5) complete soil profiles took place and the soil samples were received from all horizons. The samples were transported to the laboratory of Silviculture, where after drying and suitable preparation were examined regarding the mechanical analysis, the estimation of the acidity (pH), the estimation of the content in the organic matter, and the estimation of the total nitrogen (N). Also the soil cohesiveness was determined in the field with manual penentrometer. Samples of withered seedlings were extracted from the field for estimation of their root system.
The statistical analysis of the results and the evaluation of the applied treatments took place.

3. Results and discussion

3.1. Soil

The soils on which the experimental plots were established are shallow up to moderate depth that is oscillated from 14 cm in theworst cases up to 47 cm in the best. The soils are characterized by high cohesiveness, due to the livestock grazing that creates problems in the installation of forest vegetation. Tanner and Mamaril (1959) reported that the grazing of animals caused an increase of penetrometer resistance from 0.32 to1.95 MPa. The values of penetrometer resistance in the surface of the soil in the study area, present a breadth 1.8-2.8 MPa, values that marginaly allow the growth of plant types (bibliographically is recorded that the roots have the biggest capacity of penetration that is smaller to 2.5 MPa) (Waisel *et al.*, 1991). The characteristic is that in-depth 20 cm the cohesiveness of C horizon, in the study area, so requires 3.3-3.5 MPa for the penetration of the roots of seedling, values that substantially do not allow the infiltration of roots. Ehlers *et al.* (1983) reported that the limiting penetrometer resistance for root growth was 3.6 Mpa in the tilled surface layer, and 4.6-5.1 MPa in the underlying soil. Dexter (1987) reported similar studies of corn, cotton and peanut roots.
By the analysis of samples of the soil profile that took place in the laboratory and the field data it was realised that there are differences in the soils of the study area. Based on the analysis the discrimination of the soils can be classified into two categories depending on the bedrock a) soils that are found on granites which are shallow up to 30 cm in depth (two profiles I,II) and b) soils on shists with depth 27-50 cm (three profiles III,IV and V). The analytical description of the soils is given in Tables1 and 2.

Table 1. Soil characteristics in granites.

Soil profi-les	Horizons	Depth (cm)	Texture Clay	Silt (%)	Sand		C %	Organic matter %	N %	C/N	pH
I	A_1	0-14	13,1	10,9	76,0	SL	1,81	3,11	0,14	12,9	6,05
II	A_1	0-3	12,5	5,9	81,6	LS	1,88	3,23	0,23	8,34	5,77
	A_3	3-9	6,0	10,3	83,7	LS	0,98	1,69	0,09	10,06	5,70
	(B)	9-18	11,8	10,4	77,8	SL	1,57	2,70	0,14	10,87	5,40

Table 2. Soil characteristics in schists.

Soil profiles	Horizons	Depth (cm)	Texture Clay (%)	Texture Silt (%)	Texture Sand (%)		C (%)	Organic matter (%)	N (%)	C/N	pH
III	$A_{1.1}$	0-4	19.3	20.1	60.6	LS	3,46	5,96	0,21	16,36	5,50
	$A_{1.2}$	4-14	20.8	16.1	63.1	LS	1,71	2,95	0,12	14,73	5,52
	B/C	14-27	20.2	21.6	58,2	LS	0,84	1,44	0,08	9,89	5,61
IV	$A_{1.1}$	0-9	22,4	20,6	57	SCL	3,09	5,32	0,16	20	6,25
	$A_{1.2}$	9-20	22,6	17,3	60,1	SCL	1,35	2,33	0,17	8,12	6,21
	(B)	20-39	22,2	19,5	58,3	SCL	0,60	1,02	0,09	6,80	6,30
	C_1	39-47	19,3	16,6	64,1	SL	0,46	0,79	0,05	9,05	6,36
V	$A_{1.1}$	0-11	16,3	19,5	64,2	SL	2,67	4,60	0,14	19,37	6,16
	$A_{1.2}$	11-22	19	14,9	66,1	SL	1,6	2,76	0,08	19,17	6,19
	(B)	22-38	22,6	17,5	59,9	SCL	1,11	1,92	0,08	14,30	6,18
	C_1	38-46	24,5	22,2	53,3	SCL	0,93	1,61	0,05	17,09	6,18

SCL: sandy-clay-loam, SL: sandy-loam, LS: loam-sandy

3.2 Survival of seedlings

By the results of Figures 2 and 3, it is realized that the losses of the first year, before the summer drought, that were due to the initial shock of transplantation, are small in the protected area. Smaller losses are observed in shists than in granites soil.

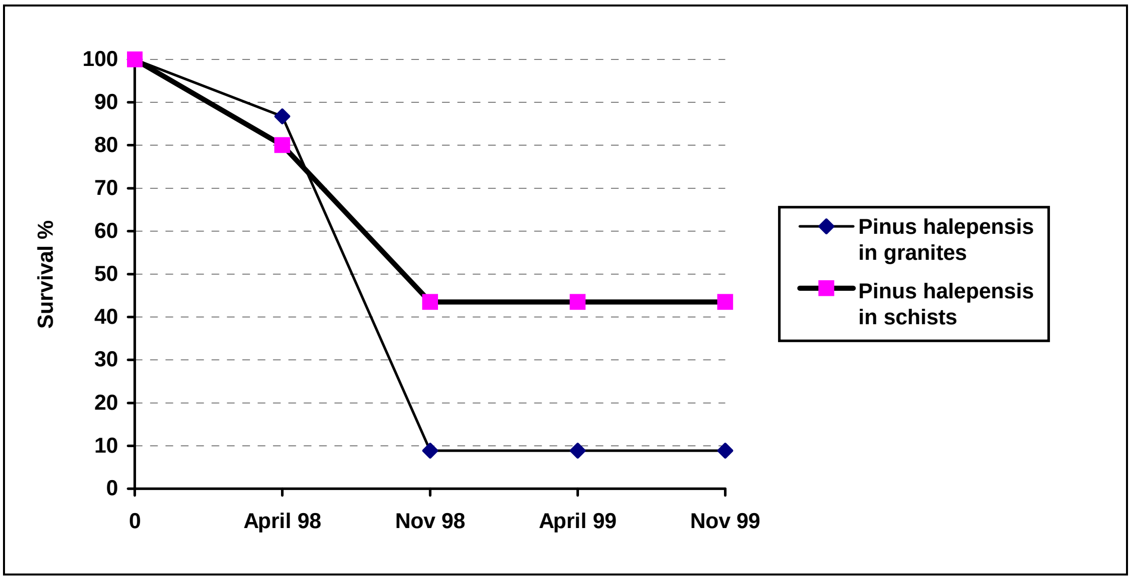

Figure 2. Survival rate of *Pinus halepensis* seedlings two years after the experiment establishment.

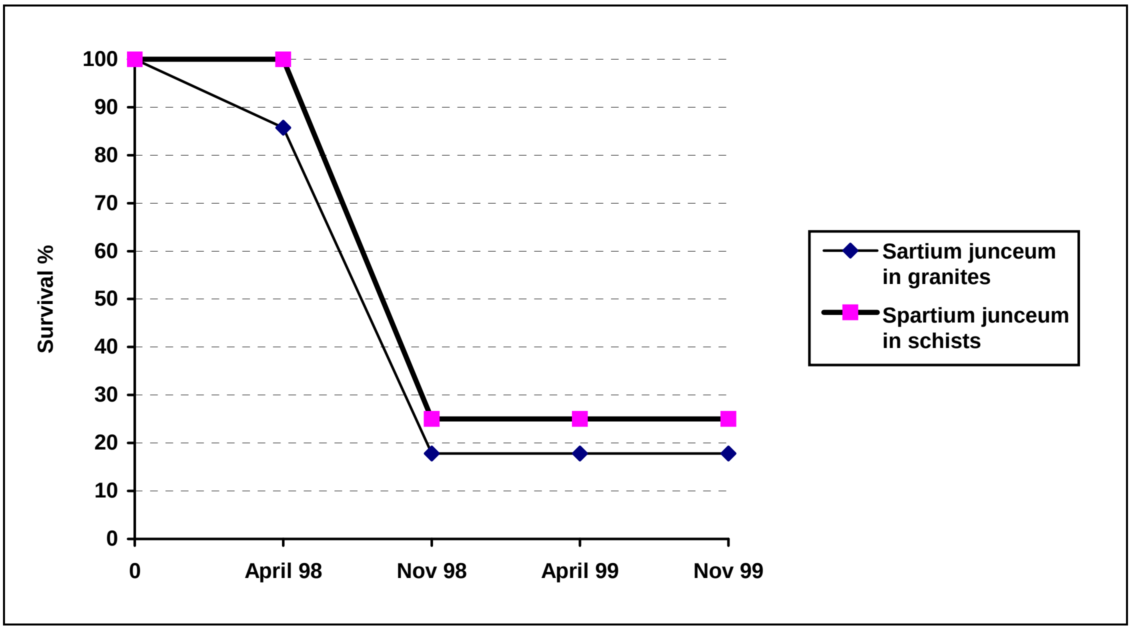

Figure 3. Survival rate of *Spartium junceum* seedlings two years after the experiment establishment.

On the contrary the losses that are due to the summer drought are very high, especially in the experimental areas of granites. Also, the survival of spartium was very low 25% in shists and 17% in granites because of perhaps the high cohesiveness of the soil, since that the spartium has very good results in loose grounds. Regarding Aleppo pine is noticed that it presented higher survival in the soils of shists 43.5% due to the bigger depth and very low on granites 8.9%. The lack of anyone treatment of seedlings after their plantations was the cause for the increased of percentages of mortality.

By the Figures 1 and 2, it is realized that the losses of the second year, before and after the summer drought were null in the two species. A fact that means that the biggest problem of the seedlings appears in the first year of their installation and especially in the summertime. If they can surpass the first difficult summertime the seedlings show that they are adapted enough and they do not face special problems of survival in the continuity.

The percentages of losses are increased in the two species at the unprotected areas, after the summer, because of the grazing and the behavior of the shepherds who are blamed for the destruction of the seedlings, so there is no hope for their survival.

3.3 Increase of seedlings

Generally the increase of seedlings in the two augmentative periods was limited for both species. A fact that is due to the very unfavorable conditions of their growth. Especially for the unprotected areas in a lot of cases reduction of the height of seedlings was noticed because of their ill treatment by the grazing. The results of augmentative figures are given in the Tables 3 and 4. These tables show that the annual increase of seedlings is very small in height and diameter two years after the plantings without any statistical differences between the treatments. The Aleppo pine as well as the spartium presented a little bit better results in the shists than in the granites.

Table 3. Growth rate of *Pinus halepensis* seedlings two years after the experiment establishment.

Soil type	Total shoot height (cm)		Root collar diameter (mm)	
	after 1st summer	after 2nd summer	after 1st summer	after 2nd summer
Granites	29,5ns	33,0ns	5,20ns	5,63ns
Schists	31,1ns	34,1ns	5,56ns	5,72ns

* values followed by the same letter are not significantly different at the 95% level of confidence (Duncan test). Ns = non significant

Table 4. Growth rate of *Spartium junceum* seedlings two years after the experiment stablishment.

Soil type	Total shoot height (cm)		Root collar diameter (mm)	
	after 1st summer	after 2nd summer	after 1st summer	after 2nd summer
Granites	24,4ns	30,0ns	3,42ns	4,37ns
Schists	26,0ns	31,2ns	3,75ns	4,82ns

* values followed by the same letter are not significantly different at the 95% level of confidence (Duncan test). Ns = non significant

3.4. Physiologic characteristics of the seedlings

The values of the water potential of species, which were used at the experimental plots are near to the values of the indigenous vegetation as is shown in Table 5. These values show that the species of the native vegetation are adapted to the conditions of lack of water developing powerful mechanisms of adaptation (closure of stomata during midday, possibility of assimilation in conditions of dim light (morning - afternoon). The taking of suitable measures for the increasing the survival of seedlings could be helped by the understanding of these mechanisms.

Table 5. Leaf predawn water potential of seedlings two years after the experiment establishment.

Species	Predawn water potential (Ψpd) in bars	
	before summer (May)	after summer (October)
Pinus halepensis	-9.60	-14.00
Spartium junceum	-7.40	-10.35
Indigenous vegetation		
Quercus coccifera	-12.40	-9,0
Cistus monspeliensis	-10.40	-7,8

4. CONCLUDING REMARCS

The evaluation of the results two years after the plantations showed the following:

1. The proposed species showed a little percentage of losses because of the initial shock of transplantation and before the effect of the summer drought. The spartium presents better results with percentage of survival 91.8% and the Aleppo pine with 83.3% followed.
2. The summer drought affected decisively the survival of the seedlings. The final percentages of survival after the drought showed 26.19% for the Aleppo pine and 21.40% for the spartium.
3. It is realized that the seedlings, which survived the first summer, managed to survive the second summer too. Hence the mortality of the seedlings takes place as a rule only in the first summer.
4. The seedlings were developed under powerfully environmental stress conditions and consequently they simply fought to survive having only a marginal increase
5. The restoration of the degraded areas with plantations appears to be difficult or impossible without the protection of the regions with fencing.
6. A differentiation of the survival of the seedlings is due to the existence of favorable microenvironments at certain places. Consequently the plantations will be accomplished at the best places.
7. The paper-pots decomposition takes place regularly during the first year. Problems of root rotation were not observed.
8. The percentage of survival of seedlings was very low and for this reason it is vital two at least waterings to take place every year.
9. The bedrock seems to have played an important role in the installation of the seedlings (growth of root system). The percentage of survival was better in shists than in granites soils.
10. The problem of low survival is probably due to the restriction of the growth of the root system. It is proved that all the seedlings that withered presented increase of only thin lateral roots to the one direction, parallel to the surface of the ground and in depth about 20 cm. The roots of the seedlings could not penetrate deeper, so that they could not find for the dry period of the summer.

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