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THE REGENERATION OF PURE *Juniperus excelsa* M. Bieb. STANDS IN PRESPA NATIONAL PARK IN GREECE

REGENERACIJA ŠUMA *Juniperus excelsa* M. Bieb. U NACIONALNOM PARKU PRESPA U GRČKOJ

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Abstract:

Juniperus excelsa M. Bieb is a species with growth plasticity that is capable of growing in harsh abiotic environments as well as in severe biotic conditions. In order to analyze the regeneration of *J. excelsa* pure stands in Prespa National Park of Greece and to determine whether regeneration in gaps or under facilitation of nurse plants dominates, ninety sample plots were established in two site types and six structural types. In each plot, all *J. excelsa* regeneration plants were graded in 2 categories. The first category represents the seedlings that have been established and grew under the facilitation of other plants, while the second category refers to seedlings that are found in canopy gaps without significant side shade. Facilitation does not dominate in the regeneration process of *J. excelsa* in Prespa National Park. On the other hand, this does not mean that regeneration in gaps predominates. Even though facilitation is not the dominant process in the regeneration of *J. excelsa* in Prespa National Park, a significant number of regeneration plants have been established under the facilitation. Site productivity seems to affect the process of facilitation. It seems that the process of grazing through trampling and animal tread determines the regeneration process of the species that can be established and grow either in light or under shade. *J. excelsa* can be a very interesting candidate species for restoration of degraded lands.

KEY WORDS: *Juniperus excelsa,* regeneration, facilitation, nurse plants, gap

Introduction
Uvod

Juniperus excelsa M. Bieb. usually appears in mountainous areas (Hall 1984; Ahmed et al. 1990; Fisher and Gardner 1995; Gardner and Fisher 1996; Ravanbakhsh et al. 2010; Stampoulidis and Milios 2010; Douaihy et al. 2011; Milios et al. 2011). Even when it is found in an elevation of few tens of meters, in Greece, the topographic relief is mountainous (personal observation). *J. excelsa* is a species of southeastern Europe that is also apparent in Crimea, Anatolia, southwest and central Asia as well as east Africa (Athanasiadis 1986; Boratynsky et al. 1992; Christensen 1997).

J. excelsa exhibits growth plasticity and can adapt and grow in diverse growth regimes (shade – light), while, in favorable conditions, it is able to increase its growth rates even at old ages (Milios et al. 2009). Moreover *J. excelsa* is capable of growing in harsh abiotic environments (shallow and stony soils, cold, hot and dry climates) as well as in severe biotic conditions like grazed sites (Hall 1984; Ahmed et al. 1989, 1990; Fisher and Gardner 1995; Gardner and Fisher

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1996; Carus 2004; Milios et al. 2007, 2011; Ozkan et al. 2010). According to Hall (1984) timber of *J. excelsa* has an economic value, while Milios et al. (2009) refer that in productive sites the species may exhibit sufficient high height growth rates.

Regarding the total area of the species expansion in many studies facilitation of nurse plants is considered as a crucial process in the *J. excelsa* regeneration (Ahmed et al. 1989, 1990; Fisher and Gardner 1995; Milios et al. 2007). On the other hand in other cases establishment in full light seems to predominate (Hall 1984; Milios et al. 2011).

In Greece *J. excelsa* appears as very small groups of trees or as scattered individual trees in rocky slopes in open forests and only in few cases creates large formations of pure and mixed stands (Milios et al. 2007). One of these areas is Prespa National Park at the northwester Greece.

The analysis of the species regeneration patterns in different regions of the planet as well as under various ecological conditions will contribute to the better understanding of its ecology. This knowledge will not only lead to a better management of *J. excelsa* formations but it may enhance the usage of the species in order to achieve various goals.

The aims of this study were: a) the regeneration analysis of *J. excelsa* pure stands in Prespa National Park of Greece and b) the determination whether regeneration in gaps or under facilitation of nurse plants dominates.

Materials and methods
Materijali i metode

The study was conducted in an area of approximately 2732 ha at elevations from 840 to 1360 m where the pure and mixed *J. excelsa* stands appear. This area is located in the western part of Prespa National Park in Greece, which lies in northern-western part of Greece close to the Albanian and F.Y.R.O.M. borders (40°50'14.91" N, 21°00'59.66" E). The soils are clay to clay silt and the substratum consists of limestones and dolomitic limestones (Pavlides 1985). The soils are rather shallow and in many cases surface appearances of parent material are observed (Pavlides 1985). In Nestorio, which is one of the closest meteorological stations (elevation of 950 m) the annual sum of precipitation averages 817 mm, and the mean annual air temperature is 10.8 °C.

In the past, the disturbances in the area were the cutting of all the trees by the army in some location of site type B, in

Juniperus excelsa formations in Prespa National Park
Sastojina *Juniperus excelsa* u Nacinalnom parku Prespa

Juniperus excelsa formation where there are some trees whose living foliage appears in the height of 50–60 cm above the ground
Sastojina *Juniperus excelsa* gdje se javljaju stabla sa krošnjama živog lista na visinama 50–60 cm iznad razine tla

1917 and during the World War II (Pavlides 1985) as well as the cutting of the Juniper branches by the local residents in order to make traps for the fish in Prespa Lakes (Catsadorakis 1995). In 2008, 430 goats, 670 sheep and 45 caws graze in the study area (data from the local veterinarian office). In the past, a lot more livestock was grazing in the area (information from elder residents).

In the pure *J. excelsa* stands there are also species such as *Quercus macedonica, Juniperus oxycedrus*, *Quercus pubescens, Pyrus amygdaliformis, Carpinus orientalis, Acer monspessulanum* and *Juniperus foetidissima* (Stampoulidis and Milios 2010).

Seedling density – Gustoća sadnica

In order to characterize a *J. excelsa* formation pure, the *J. excelsa* trees must create at least the 85–90 % of the estimated total canopy cover area. (here: estimated area that is covered by the projection of the canopy of trees – shrubs).

In the area where the pure stands of *J. excelsa* appear, two site types were distinguished. Site type A refers to the good site qualities (more or less productive sites of the area), whereas site type B refers to the medium site qualities (less productive sites) (see also Stampoulidis and Milios 2010). For the characterization of sites the soil depth, that was determined through soil profiles, was used (see Papalexandris and Milios 2010). In site type B the soil depth ranges approximately from 5 to 20–25 cm, and in site type A from 26–30 to 50 cm. The most (by far) *J. excelsa* formations are found in site type B (see also Stampoulidis and Milios 2010).

In each site type, there are sparse and dense *J. excelsa* stands and groups. In the sparse formations the estimated total canopy cover percentage (estimated total canopy cover area x 100/total area of *J. excelsa* formations) ranges from 30 to 40 %, while in the dense ones the estimated total canopy cover percentage ranges from 60 to 80 % (see also Stampoulidis and Milios 2010). In both sparse and dense stands and groups, the *J. excelsa* trees are found as scattered individuals or in small aggregations.

In addition, regardless of their total canopy cover percentage, the *J. excelsa* formations are differentiated by the height where the living foliage (LF) of trees (branches having living needles) appears. In almost all areas of site type B, all the trees are multi-stemmed and the LF of trees appears at ground level resulting in the creation of an impenetrable hemispherical or spherical crown. On the contrary, in a very small proportion of site type B areas, as well as in all areas of site type A, in a significant number of trees the height where the LF appears is 50–60 cm above the ground (see also Stampoulidis and Milios 2010).

Consequently, six structural types were distinguished: 1) sparse (STADS) and 2) dense (STADD) stands or groups in site type A where in a significant number of trees the LF appears in the height of 50–60 cm above the ground, 3) sparse (STBDS) and 4) dense (STBDD) stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground, 5) sparse (STBDSGR) and 6) dense (STBDDGR) stands or groups in site type B where the LF of trees appears at ground level.

In the summer of 2009, in each structural type 15 plots of 500 m^2 (20 m x 25 m) were established using the stratified random sampling method. In total 90 plots were established. In site type A the slopes of the areas where the plots were established range from 0 to 10 %. In site type B the slopes of the plots range from 20 to 50 %. However the dominant slopes are between 30 and 40 %.

In each plot, all *J. excelsa* regeneration plants – seedlings (trees with height up to 1.3 m) were graded in 2 categories. The first category represents the seedlings that have been established and grow under the facilitation of other plants (F plants). These are seedlings found under closed canopy or the edge of the canopy (up to 30 cm out of the projection of the canopy edge) of a single plant or a group of plants of *J. excelsa* or other species. The second category refers to the rest regeneration plants of the plot. These seedlings are considered to grow under light, in canopy gaps without significant side shade (G plants) (see Milios et al. 2007).

Moreover in each plot under a single tree or a group of *J. excelsa* trees (chosen using the simple random sampling method) the depth of the ground organic layer was measured. The ground organic layer includes the plant litter and the surface soil layer where the inorganic soil is intermingled with organic matter. In the structural types STADS, STADD, STBDS and STBDD the depth of the ground organic layer was measured under a single tree or a group of *J. excelsa* trees where the LF appears in the height of 50–60 cm above the ground. Finally in each plot the soil depth was determined through a soil profile.

Experimental design – Plan pokusa

The scheme of data collection regarding the regeneration density is considered to apply to the following experimental designs: The sample plot of 500 m^2 was considered as the experimental unit in both designs.

Design 1: It refers to *J. excelsa* stands or groups where in a significant number of trees the height of LF appears in 50–60 cm above the ground (structural types: STADS, STADD, STBDS and STBDD). The design includes two factors between and one factor within the experimental units. The between factors are: 1) site type (FST) consisting of two levels: site type A (FSTA) and site type B (FSTB), and 2*) J. excelsa* formation density (FD) consisting of two levels: sparce formations (FDS) and dense formations (FDD). The within factor is the *J. excelsa* regeneration category (R) with two levels: seedlings that have been established and growing under the facilitation of other plants (F) and seedlings that have been established and growing under light, in canopy gaps without significant side shade (G).

According to the above information, the STADD structural type is a combination of level FSTA of the factor FST and level FDD of the factor FD. The STADS is the combination of level FSTA of the factor FST and level FDS of the factor FD. The STBDD structural type is a combination of level FSTB of the factor FST and level FDD of the factor FD. Furthermore, the STBDS is the combination of level FSTB of the factor FST and level FDS of the factor FD.

Design 2: It refers to *J. excelsa* stands or groups of site type B (structural types: STBDS, STBDD, STBDSGR and STBDDGR). The design includes two factors between and one factor within the experimental units. The between factors are: 1) *J. excelsa* formation density (FD) consisting of two levels: sparce formations (FDS) and dense formations (FDD) and 2) living foliage appearance (FLF) with two levels: formations where the LF of trees appears at ground level (GR) and formations where in a significant number of trees the LF appears in the height of 50–60 cm above the ground (H). The within factor is the *J. excelsa* regeneration category (R) with two levels: seedlings that have been established and growing under the facilitation of other plants (F) and seedlings that have been established and growing under light, in canopy gaps without significant side shade (G).

According to Design 2 the STBDD structural type is a combination of level FDD of the factor FD and level H of the factor FLF. The STBDS structural type is a combination of level FDS of the factor FD and level H of the factor FLF. The STBDDGR structural type is a combination of level FDD of the factor FD and level GR of the factor FLF, while the STBDSGR structural type is a combination of level FDS of the factor FD and level GR of the factor FLF.

Data analyses – Analiza podataka

The seedling density data from the two experimental designs was analyzed using the Mann-Whitney and Wilcoxon tests (Ho 2006). The General Linear Models (GLM) were not used since the normality of distributions was not supported.

Consequently in Design 1 the interaction of the 2nd order of the factors FST, FD and R was analyzed. On the other hand, in Design 2 the interaction of the 2nd order of the factors FD, FLF and R was analyzed. In the non-parametric tests, the level of significance (p-value) was calculated with the Monte Carlo simulation method (Takeuchi et al. 2007).

The means of the depth of the ground organic layer under a single tree or a group of *J. excelsa* trees in site types: a) STADS + STADD, b) STBDS + STBDD and c) STBDSGR + STBDDGR were compared using the Duncan test (Freund and Wilson 2003).

Results
Rezultati

Only two *J. excelsa* regeneration plants of the F category were found under the canopy of other species individuals, the rest F plants grew under the facilitation of *J. excelsa* trees or groups of trees.

For both experimental designs, in all structural types except for the STBDSGR the density of the seedlings that have been established and growing under the facilitation of other plants (F) (practically under *J. excelsa* plants) do not exhibit statistically significant difference with that of the seedlings that have been established and growing under light, in canopy gaps without significant side shade (G) (Tables 1, 3). In the case of STBDSGR structural type the G seedlings have greater density than F seedlings with statistically significant difference (Table 3).

For the structural types having the same density, where in a significant number of trees the height where the living foliage appears (LF) is 50–60 cm above the ground (STADD and STBDD as well as STADS and STBDS) in site type A the F seedlings have greater density than that in site type B with statistically significant difference (Table 2). In the same structural types there is no statistically significant difference between the two site types regarding the density of G seedlings (Table 2).

On the other hand, there is no statistically significant difference between the two categories of living foliage appearance regarding the density of F and G seedlings for the

Table 1 Mean density of seedlings for the two levels of the factor, "regeneration category" for each structural type of Experimental Design 1 (interaction among the factors site type, *J. excelsa* formation density and regeneration category).

Tablica 1. Srednja gustoća sadnica za dvije razine faktora, "kategorija regeneracije" za svaki strukturni tip pokusa 1 (interakcija između faktora: tip lokacije, gustoća formiranja vrste *J. excelsa*, i kategorija regeneracije).

Structural type Strukturni tip	Regeneration category Kategorija regeneracije	Seedling density n/plot srednja gustoća sadnica broj sadnica/ploha		n
		Mean Sredina	S.D. standardna devijacija	
STADD[1] (FSTA+ FDD)	F[5]	5.47[a]	14.618	15
	G[6]	1.00[a]	1.000	15
STADS[2] (FSTA+ FDS)	F	5.53[a]	8.651	15
	G	1.40[a]	1.639	15
STBDD[3] (FSTB+ FDD)	F	4.13[a]	3.944	15
	G	2.07[a]	2.314	15
STBDS[4] (FSTB+ FDS)	F	0.80[a]	1.656	15
	G	1.73[a]	1.033	15

In each structural type, the seedling density means of the two levels of the factor regeneration category are statistically significant different at $*P<0.05$ when they share no common letter. The comparisons were made using the Wilcoxon test.

1. STADD= dense stands or groups in site type A where in a significant number of trees the living foliage (LF) appears in the height of 50–60 cm above the ground 2. STADS= sparse stands or groups in site type A where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 3. STBDD= dense stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 4. STBDS= sparse stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 5. F= seedlings that have been established and growing under the facilitation of other plants 6. G= seedlings that have been established and growing under light, in canopy gaps without significant side shade.

U svakom strukturnom tipu, gustoća sadnica znači da su dvije razine faktora kategorija regeneracije statistički značajno različite pri $* P <0,05$ kada ne dijele isto pismo. Usporedbe su provedene s pomoću Wilcoxonovog testa.

1. STADD = guste populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala živo lišće (LF) pojavljuje u visini od 50 do 60 cm iznad zemlje 2. STADS = rijetke populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala LF pojavljuje na visini od 50 do 60 cm iznad tla 3. STBDD = guste populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 4. STBDS = rijetke populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 5. F = sadnice koje su se primile i rastu uz pomaganje drugih biljaka 6. G = sadnice koje su se primile i rastu na svjetlu, u prazninama između pokrova bez značajnog bočnog hlada.

Table 2 Mean density of seedlings for the structural types of Experimental Design 1 having the same density in the two site types for each level of the factor, "regeneration category" (interaction among the factors regeneration category, *J. excelsa* formation density, site type).

Tablica 2. Srednja gustoća sadnica za strukturne tipove pokusa 1, koja ima istu gustoću na dvije lokacije za svaku razinu faktora "kategorija regeneracije" (interakcija između faktora kategorija regeneracije, gustoća formacije *J. excelsa*, tip lokacije).

Regeneration category Kategorija regeneracije	Structural type Strukturni tip	Seedling density n/plot srednja gustoća sadnica broj sadnica/ploha		n
		Mean Sredina	S.D. standardna devijacija	
F[5]	STADD[1] (FSTA+ FDD)	5.47[a]	14.618	15
	STBDD[3] (FSTB+ FDD)	4.13[b]	3.944	15
F	STADS[2] (FSTA+ FDS)	5.53[a]	8.651	15
	STBDS[4] (FSTB+ FDS)	0.80[b]	1.656	15
G[6]	STADD (FSTA+ FDD)	1.00[a]	1.000	15
	STBDD (FSTB+ FDD)	2.07[a]	2.314	15
G	STADS (FSTA+ FDS)	1.40[a]	1.639	15
	STBDS (FSTB+ FDS)	1.73[a]	1.033	15

In each of the two levels of the factor regeneration category, the seedling density means of the two structural types that have the same density are statistically significant different at $*P<0.05$ when they share no common letter. The comparisons were made using the Mann-Whitney test.

1. STADD= dense stands or groups in site type A where in a significant number of trees the living foliage (LF) appears in the height of 50–60 cm above the ground 2. STADS= sparse stands or groups in site type A where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 3. STBDD= dense stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 4. STBDS= sparse stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 5. F= seedlings that have been established and growing under the facilitation of other plants 6. G= seedlings that have been established and growing under light, in canopy gaps without significant side shade.

U svakoj od dvije razine faktora kategorije regeneracije, gustoća sadnica znači da su dva strukturna tipa s istom gustoćom statistički značajno različita pri $* P <0,05$, kada ne dijele isto pismo. Usporedbe su provedene s pomoću Mann-Whitneyjevog testa.

1. STADD = guste populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala živo lišće (LF) pojavljuje u visini od 50 do 60 cm iznad zemlje 2. STADS = rijetke populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala LF pojavljuje na visini od 50 do 60 cm iznad tla 3. STBDD = guste populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 4. STBDS = rijetke populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 5. F = sadnice koje su se primile i rastu uz pomaganje drugih biljaka 6. G = sadnice koje su se primile i rastu na svjetlu, u prazninama između pokrova bez značajnog bočnog hlada.

Table 3 Mean density of seedlings for the two levels of the factor, "regeneration category" for the STBDDGR and STBDSGR structural types[1] of Experimental Design 2 (in the frame of interaction among the factors living foliage appearance, *J. excelsa* formation density and regeneration category).

Tablica 3. Srednja gustoća sadnica za dvije razine faktora "kategorija regeneracije" za strukturne tipove [1]STBDDGR i STBDSGR pokusa 2 (u okviru interakcije između faktora: izgled živog lišćea, gustoća formacije vrste *J. excelsa* i kategorije regeneracije).

Structural type Strukturni tip	Regeneration category Kategorija regeneracije	Seedling density n/plot srednja gustoća sadnica broj sadnica/ploha		n
		Mean Sredina	S.D. standardna devijacija	
STBDDGR[2] (FDD + GR)	F[4]	2.80^a	4.693	15
	G[5]	1.33^a	1.291	15
STBDSGR[3] (FDS + GR)	F	0.33^b	0.617	15
	G	2.67^a	1.447	15

In each structural type, the seedling density means of the two levels of the factor regeneration category are statistically significant different at $^*P<0.05$ when they share no common letter. The comparisons were made using the Wilcoxon test.

1. For the STBDD (FDD + H) and STBDS (FDS + H), which are the rest two structural types of the second Experimental Design, the seedling density of F and G regeneration categories (and the corresponding comparisons) are given in Table 1. 2. STBDDGR= dense stands or groups in site type B where the living foliage (LF) of trees appears at ground level 3.STBDSGR= sparse stands or groups in site type B where the LF of trees appears at ground level 4. F= seedlings that have been established and growing under the facilitation of other plants 5. G= seedlings that have been established and growing under light, in canopy gaps without significant side shade.

U svakom strukturnom tipu gustoća sadnica znači da su dvije razine faktora kategorija regeneracije statistički značajno različite pri * P <0,05, kada ne dijele isto pismo. Usporedbe su provedene s pomoću Wilcoxonovog testa.

1. Za STBDD (FDD + H) i STBDS (FDS + H), koji su ostala dva strukturna tipa eksperimentalne izvedbe 2, gustoća sadnica kategorije regeneracije F i R (i odgovarajuće usporedbe) prikazana je u tablici 1. 2. STBDDGR = guste populacije ili skupine na lokaciji tipa B, gdje se živo lišće (LF) stabala nalazi tik uz zemlju 3.STBDSGR = rijetke populacije ili skupine na lokaciji tipa, B gdje se LF stabala nalazi tik uz zemlju 4. F = sadnice koje su se primile i rastu uz pomaganje drugih biljaka 5. G = sadnice koje su se primile i rastu na svjetlu, u prazninama između pokrova bez značajnog bočnog hlada.

structural types having the same density in site type B (STBDD and STBDDGR as well as STBDS and STBDSGR) (Table 4).

In the STADS + STADD structural types the depth of the ground organic layer under a single tree or a group of *J. excelsa* trees is the greatest, on average (means of the depth of the ground organic layer are statistically significant different with $p<0.05$), while the STBDSGR + STBDDGR structural types exhibit the lowest depth, with a statistically significant difference (Table 5).

Discussion
Rasprava

Regardless of their density, facilitation does not dominate in the *J. excelsa* regeneration process in any of the structural types. This does not mean that regeneration in gaps is the

Table 4 Mean density of seedlings for the structural types of Experimental Design 2 having the same density in the two levels of the factor "living foliage appearance", for each level of the factor, "regeneration category" (interaction among the factors regeneration category, *J. excelsa* formation density and living foliage appearance).

Tablica 4. Srednja gustoća sadnica za strukturne tipove pokusa 2, koji imaju istu gustoću u dvije razine faktora "izgled živog lišća", za svaku razinu faktora "kategorija regeneracije" (interakcija između faktora: kategorija regeneracije, gustoća formacije vrste *J. excelsa* i izgled živog lišća).

Regeneration category Kategorija regeneracije	Structural type Strukturni tip	Seedling density n/plot srednja gustoća sadnica broj sadnica/ploha		n
		Mean Sredina	S.D. standardna devijacija	
F[5]	STBDD[1] (FDD + H)	4.13^a	3.944	15
	STBDDGR[3] (FDD + GR)	2.80^a	4.693	15
F	STBDS[2] (FDS + H)	0.80^a	1.656	15
	STBDSGR[4] (FDS + GR)	0.33^a	0.617	15
G[6]	STBDD (FDD + H)	2.07^a	2.314	15
	STBDDGR (FDD + GR)	1.33^a	1.291	15
G	STBDS (FDS + H)	1.73^a	1.033	15
	STBDSGR (FDS + GR)	2.67^a	1.447	15

In each of the two levels of the factor regeneration category, the seedling density means of the two structural types that have the same density are statistically significant different at $^*P<0.05$ when they share no common letter. The comparisons were made using the Mann-Whitney test.

1. STBDD= dense stands or groups in site type B where in a significant number of trees the living foliage (LF) appears in the height of 50–60 cm above the ground 2. STBDS= sparse stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 3. STBDDGR= dense stands or groups in site type B where the LF of trees appears at ground level 4. STBDSGR= sparse stands or groups in site type B where the LF of trees appears at ground level 5. F= seedlings that have been established and growing under the facilitation of other plants 6. G= seedlings that have been established and growing under light, in canopy gaps without significant side shade.

U svakoj od dvije razine faktora kategorije regeneracije, gustoća sadnica znači da su dva strukturna tipa s istom gustoćom statistički značajno različita pri * P <0,05, kada ne dijele isto pismo. Usporedbe su provedene s pomoću Mann-Whitneyjevog testa.

1. STBDD = guste populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala živo lišće (LF) pojavljuje u visini od 50 do 60 cm iznad tla 2. STBDS = rijetke populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 3. STBDDGR = guste populacije ili skupine na lokaciji tipa B, gdje se LF stabala nalazi tik uz zemlju 4. STBDSGR = rijetke populacije ili skupine na lokaciji tipa, B gdje se LF stabala nalazi tik uz zemlju 5. F = sadnice koje su se primile i rastu uz pomaganje drugih biljaka 6. G = sadnice koje su se primile i rastu na svjetlu, u prazninama između pokrova bez značajnog bočnog hlada.

dominant form of regeneration (Tables 1, 3). Only in the STBDSGR, which is a sparse structural type, the *J. excelsa* seedlings that have been established and growing under light, in canopy gaps without significant side shade (G) have greater density than that of the seedlings that have been established and growing under the facilitation of *J. excelsa* plants (F) ($p<0.05$) (Table 3).

On the contrary, in the rest sparse structural types (STADS and STBDS) there is no difference in the density of seedlings between the G and F category even thought the areas without canopy cover of trees and shrubs is about 60 to 70 %

of the total area. So, in Prespa National Park the low portion of open areas is not the factor that does not allow the domination of seedlings that have been established and growing in canopy gaps (G). In Cyprus, according to Milios et al. (2011) it is possible that in some areas of *J. excelsa* formations seedlings growing in open areas do not dominate as a result of a low portion of gaps (open areas) that is available for their establishment.

In the areas where facilitation is the crucial factor determining *J. excelsa* regeneration facilitation is related to protection against grazing as is observed in the central part of the Nestos valley in Greece (Milios et al. 2007) and possibly in the Balouchistan of Pakistan (Ahmed et al. 1989, 1990) and to improvement of harsh climatic conditions by partial shade as probably happened in the valley of Hayl Juwary in Oman (Fisher and Gardner 1995). In Africa, Hall (1984) mentions that in areas where precipitation is lower than 850 mm the regeneration of the species is closely related to the mother plants. Moreover, Milios et al. (2007) refer that plant litter under the nurse plants (that belong to the same species) is another factor that together with protection against grazing create a facilitation mechanism for the *J. excelsa* regeneration in the Nestos valley in Greece.

In areas where there are not stressful factors *J. excelsa* regeneration is established in open places as observed in Africa, after a disturbance like fire, in locations where precipitation is of between 1000–1200 mm (Hall 1984). In Cyprus in the *J. excelsa* formations, where there is no grazing, even though the soils are shallow and rocky the regeneration in gaps is the dominant form of regeneration if there are enough open areas. Even in areas where there are not adequate free from shade areas the facilitation does not dominate in the regeneration process (Milios et al. 2011).

In the present study grazing is the decisive factor which determines the regeneration process of *J. excelsa*. Even though grazed seedlings were not found trampling probably destroys regeneration plants. The heavily grazed broadleaved species in the nearby mixed species stands possibly explain the absence of grazing marks in *J. excelsa* seedlings, since the goats, sheep and cattle prefer the broadleaves. According to Ahmed et al. (1989) *J. excelsa* seedlings and smaller juveniles can be damaged or killed by trampling or animal tread. On the other hand Milios et al. (2007) found grazed *J. excelsa* seedlings in the central part of Nestos valley.

It seems that the process of grazing through trampling and animal tread reduces the seedling density in gaps preventing the domination of regeneration plants growing in full light even in two of the three structural types where the areas without canopy cover of trees and shrubs is about 60 to 70 % of the total area. On the other hand if the number of grazing animals were a lot more probably facilitation of nurse plants through the protection of seedlings from trampling and tread would have been the dominant regeneration process. Herbivory affects population dynamics of plants (Gomez 2005), furthermore grazing affects negatively plant growth (Julien et al. 2006; McEvoy et al. 2006).

Table 5 Depth of the ground organic layer under a single tree or a group of *J. excelsa* trees in structural types: a) STADS + STADD, b) STBDS + STBDD and c) STBDSGR + STBDDGR.

Tablica 5. Dubina organskog sloja ispod jednog stabla ili skupine stabala *J. excelsa* u strukturnim tipovima: a) STADS + STADD, b) STBDS + STBDD i c) STBDSGR + STBDDGR.

Trees in the structural types Stabla u strukturnim stablima	Depth of the ground organic layer (cm) Dubina organskog sloja tla (cm)		n
	Mean Sredina	S.D. standardna devijacija	
STADS[2] + STADD[1]	3.90[a]	1.185	30
STBDS[4] + STBDD[3]	3.23[b]	0.971	30
STBDSGR[6] + STBDDGR[5]	1.60[c]	0.712	30

The means are statistically significant different at *P<0.05 when they share no common letter. The comparisons were made using the Duncan test.

1. STADD= dense stands or groups in site type A where in a significant number of trees the living foliage (LF) appears in the height of 50–60 cm above the ground 2. STADS= sparse stands or groups in site type A where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 3. STBDD= dense stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 4. STBDS= sparse stands or groups in site type B where in a significant number of trees the LF appears in the height of 50–60 cm above the ground 5. STBDDGR= dense stands or groups in site type B where the LF of trees appears at ground level 6. STBDSGR= sparse stands or groups in site type B where the LF of trees appears at ground level.

Znači statistički značajno različita pri * P <0,05, kada ne dijele isto pismo. Usporedbe su provedene s pomoću Duncan jevog testa.

1. STADD = guste populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala živo lišće (LF) pojavljuje u visini od 50 do 60 cm iznad zemlje 2. STADS = rijetke populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala LF pojavljuje na visini od 50 do 60 cm iznad tla 3. STBDD = guste populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 4. STBDS = rijetke populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla 5. STBDDGR = guste populacije ili skupine na lokaciji tipa B, gdje se LF stabala nalazi tik uz zemlju 6. STBDSGR = rijetke populacije ili skupine na lokaciji tipa B, gdje se LF stabala nalazi tik uz zemlju.

Even though facilitation is not the dominant process in the regeneration of *J. excelsa* in Prespa National Park, a significant number of regeneration plants have been established under the facilitation. Site productivity seems to affect the process of facilitation, while the living foliage appearance does not influence it. In site type A, the density of F seedlings in dense *J. excelsa* formations is greater ($p<0.05$) than that of dense formations of site type B (where in a significant number of trees the height where the living foliage appears is 50–60 cm above the ground) (Table 2). In the case of the corresponding sparse formations of the two site types, the same pattern is observed (Table 2). On the other hand, in site type B, a difference between the densities of F seedlings in areas where in a significant number of trees the height where the living foliage appears is 50–60 cm above the ground and in areas where the LF of trees appears at ground level is not observed ($p>0.05$) either in sparse and dense formations (Table 4). However, as it is expected, in all the structural types mentioned above there is no difference between the two site types and the two categories of the living foliage appearance, regarding the density of G seedlings ($p>0.05$) (Table 2, 4).

The depth of the ground organic layer under a single tree or a group of *J. excelsa* trees is not the crucial factor that led to the establishment of a greater number of seedlings under facilitation (F) in (more or less) productive sites (site type A) compared to that of less productive sites (site type B) (Table 5). In site type B, there is a greater depth of ground organic layer under single trees or groups of *J. excelsa* trees where the LF appears in 50–60 cm above the ground compared to that under single trees or groups of *J. excelsa* trees where the LF appears at ground level. This is not associated with a difference between densities of F seedlings ($p>0.05$) in the corresponding structural types (STBDD and STBDDGR as well as STBDS and STBDSGR) where these two categories (regarding living foliage appearance) of single trees or groups are found (Table 4).

The establishment of a greater number of F seedlings in site type A compared to that of site type B is probably the result of greater amount of available growing space (see Oliver and Larson 1996) that exist under and near nurse plants in site type A. This is referred mainly to higher water availability (as a result of a deeper soil) (see Papalexandris and Milios 2010). This greater amount of available growth space gave the F plants the ability to confront better the competition of nurse plants. According to Papalexandris and Milios (2010) the higher soil water content of productive sites (as a result of greater soil depth), compared to that of medium productivity sites probably permit the establishment and survival of beech seedlings in low elevation beech stands in the central part of the Evros region in northeastern Greece. Furthermore Milios and Papalexandris (2008) for the same stands mention that the higher soil water content probably permit the survival of beech seedlings under heavy shade. According to Pugnaire and Lugue (2001) the importance of facilitation, among different plant species, increases in more stressful environments (regarding abiotic conditions) while, in the same time, there was an increase in belowground competition. Even when positive interactions (facilitation) among plants predominate, competition for water may exist (Maestre et al. 2003).

Juniperus excelsa formations in Prespa National Park exhibit lower density of *J. excelsa* seedlings compared to that of the mixed formation of the species in the central part of Nestos valley in Greece (see Milios et al. 2007). On the other hand in some site types in Cyprus *J. excelsa* groups and small stands have greater density of seedlings than the formations of the species is the present study (see Milios et al. 2011).

The results of this research support the conclusions of previous studies regarding the growth behaviour of the species that is characterized as one that can be established and grow either in light or under shade (Milios et al. 2007, 2009, 2011) since seedlings growing in diverse growth conditions (full light, shade) were found.

Taking into account the characteristics of *J. excelsa*, it can be a very interesting candidate species for restoration of degraded lands.

Moreover, if we consider that, in Cyprus, in harsh environmental conditions, facilitation influences positively the successful establishment of *Pinus brutia* (Petrou and Milios 2012) which is a light demanding, pioneer species that can survive in severe environments (Quezel 2000; Boydak 2004), then in the context of climate change in many areas the regeneration of many species will be problematic as a result o harsh climatic conditions. New species that can adapt in the new ecological condition must be introduced. *Juniperus excelsa* can be one of these species.

Conclusions
Zaključci

Facilitation does not dominate in the regeneration process of *J. excelsa* in Prespa National Park. On the other hand, this does not mean that regeneration in gaps predominates, since only in one (of the three) sparse structural types, the *J. excelsa* seedlings in gaps are the dominant form of regeneration. It seems that the process of grazing through trampling and animal tread determines the regeneration process of the species that can be established and grow either in light or under shade. *Juniperus excelsa* can be a very interesting candidate species for restoration of degraded lands.

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Sažetak:

Kontekst: *Juniperus excelsa* M. Bieb je vrsta s *plastičnosti* rasta sposobna za rast u teškim abiotskim uvjetima, kao i u teškim biotskim uvjetima (Hall 1984.; Ahmed et al. 1989., 1990., Fisher i Gardner 1995.; Gardner i Fisher 1996.; Carus 2004.; Milios sur. 2007., 2009., 2011.; Ozkan i sur. 2010.).

Cilj: Cilj ovog rada bio je analizirati regeneraciju jednoličnih populacija *J. excelsa* u nacionalnom parku Prespa u Grčkoj i utvrđivanje je li dominantna regeneracija na čistinama ili uz pomoć biljaka zaštitnica.

Metoda: Promatrano područje podijeljeno je u devedeset parcela od 500 m^2 (20 m x 25 m), u šest strukturnih tipova, koji se nalaze u dva tipa lokacije, s pomoću stratificirane metode slučajnog uzorka. Za karakterizaciju lokacija koristila se dubina tla, koja je određena kroz profil tla (jedan u svakoj parceli) (vidi Papalexandris i Milios 2010.). Lokacija tipa A je lokacija dobre kvalitete (uglavnom produktivni dijelovi područja), dok je lokacija tipa B lokacija srednje kvalitete (manje produktivni dijelovi) (vidi također Stampoulidis i Milios 2010.). Šest strukturnih vrsta jednolikih populacija vrste *J. excelsa* u nacionalnom parku Prespa su: 1) rijetke (STADS) i 2) guste (STADD) populacije ili skupine na lokaciji tipa A, gdje se u značajnom broju stabala pojavljuje živo lišće (LF) u visini od 50 do 60 cm iznad zemlje, 3) rijetke (STBDS) i 4) guste (STBDD) populacije ili skupine na lokaciji tipa B, gdje se u značajnom broju stabala LF pojavljuje u visini od 50 do 60 cm iznad tla, 5) rijetke (STBDSGR) i 6) guste (STBDDGR) populacije ili skupine na lokaciji tipa B, gdje se LF stabala pojavljuje tik uz zemlju. U svakoj parceli, sve regeneracijske biljke J. excelsa podijeljene su u dvije kategorije. Prva kategorija predstavlja sadnice koje su se primile i rasle uz pomoć drugih biljaka (F), dok se druga kategorija odnosi na sadnice koje se nalaze u prazninama između raslinja bez značajnog bočnog hlada (G).

Rezultati i rasprava: Samo dvije regeneracijske biljke J. excelsa kategorije F pronađene su pod raslinjem jedinki drugih vrsta, a ostatak F biljaka rastao je uz pomoć stabala ili skupina stabala *J. excelsa*. Pomaganje ne dominira u procesu regeneracije *J. excelsa* u nacionalnom parku Prespa. S druge strane, to ne znači da je regeneracija u prazninama dominantna (Tablice 1 i 3). Iako pomaganje nije dominantan proces u regeneraciji vrste J. excelsa u nacionalnom parku Prespa, značajan broj regeneracijskih biljaka izrasao je uz pomaganje (Tablice 1 i 3). Produktivnost lokacije vjerojatno utječe na proces pomaganja. Primanje većeg broja F sadnica na lokaciji tipa A u usporedbi s lokacijom tipa B (Tablica 2) je vjerojatno rezultat veće količine raspoloživog prostora za rast (vidi Oliver i Larson 1996.) koji se nalazi u blizini i ispod biljaka pomagačica na lokaciji tipa A. To je uglavnom zbog veće dostupnosti vode (kao rezultat dubljeg tla) (vidi Papalexandris i Milios 2010.). Ta veća količina dostupnog prostora rasta daje F biljkama sposobnost da se bolje natječu s biljkama pomagačicama. U 2008. 430 koza, 670 ovaca i 45 krava pase na proučavanom području (podaci lokalnog veterinara). U prošlosti, puno više stoke paslo je na tom području (podaci od starijih stanovnika). U ovom istraživanju ispaša je odlučujući čimbenik koji određuje regeneracijski proces vrste *J. excelsa*, koja se može primiti i rasti kako na svjetlu tako i u hladu. Iako nisu pronađene popasene sadnice, regeneracijske biljke vjerojatno uništava gaženje. Intenzivna ispaša listača u obližnjim mješovitim populacijama eventualno objašnjava odsutnost tragova ispaše na sadnicama vrste *J. excelsa*, budući da koze, ovce i goveda preferiraju listače. Čini se da gaženje smanjuje gustoću sadnica u prazninama, što sprječava dominaciju regeneracijskih biljaka koje rastu na punom svjetlu, čak i na dva od tri strukturnih tipa, gdje su područja bez pokrova lišća drveća, a grmlje je oko 60 do 70 % ukupnog područja. S druge strane, ako bi se broj životinja koje pasu znatno povećao, dominantan proces regeneracije vjerojatno bi bila zaštita sadnica od gaženja koju pruža pomaganje biljaka zaštitnica. Vrste *J. excelsa* mogu biti vrlo zanimljivi kandidati za obnovu degradiranog zemljišta.

KLJUČNE RIJEČI*: Juniperus excelsa,* regeneracija, pomaganje, biljke zaštitnice, čistina