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Regeneration Analysis of the *Juniperus excelsa* Mixed Stands in Prespa National Park of Greece as a Base for the Assessment of the Appropriate Silvicultural Treatment for the Conservation of the Species

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ABSTRACT

Analysis of the regeneration of mixed stands of *Juniperus excelsa* (Greek juniper) in Prespa National Park revealed two distinct structural types: a) stands with small gaps, and b) stands without gaps. Fifteen 500-square-meter sample plots were established in each structural type. All plant species were counted in each plot, and Greek juniper plants were classified into two groups based on their regeneration status. Plants that have been established and grow under the facilitation of other plants fall into the first group, while those that have been established and grow in light, in canopy gaps, belong to the second. Regarding the regeneration of Greek juniper in the Greek juniper mixed stands with small gaps, facilitation is not the primary mechanism at work. There are less Greek juniper regeneration plants in the gap-free structural type, compared with the small-gap type. Greek juniper regeneration plant density will decrease if gaps close. Finally, in both structural types, the other species' regeneration plants exhibit higher density than those of Greek juniper. Creating gaps around Greek juniper trees by extensive intervention is one of the most successful ways for the forest practice to protect the Greek juniper mixed stands.

Keywords: gaps; facilitation; Greek juniper; Prespa National Park; silvicultural intervention

INTRODUCTION

Juniperus excelsa M. Bieb. (Greek juniper) is a species that can germinate and grow in direct sunlight as well as establish and survive in shade for decades (Milios et al. 2007, Milios et al. 2009). It can survive and grow under various disturbance and competition regimes, while it can exhibit the highest height growth at a wide range of ages and it can have significant increases in growth of ring width, even at an old age (Milios et al. 2009). Moreover, Milios et al. (2009) refer that Greek juniper can exhibit high rates of height increment in productive sites. Greek juniper can be planted in degraded areas in the context of restoration programs (Stampoulidis et al. 2013), since it can grow and usually is found in areas with harsh and severe abiotic conditions, as well as in grazed, disturbed and degraded sites (Hall 1984, Ahmed et al. 1989, 1990, Fisher and Gardner 1995, Gardner and Fisher 1996, Carus 2004, Milios et al. 2007, 2009, 2011, Ozkan et al. 2010, Stampoulidis et al. 2013). According to Stampoulidis et al. (2013), in the future, Greek juniper could be introduced in areas in which the regeneration of native species will be difficult, due to unfavorable climatic conditions, which are a result of climate change.

Southeastern Balkans, Crimea, Anatolia, western Asia, and Arabic peninsula are all part of the species' range (Douaihy et al.2013, Tavankar 2015, Korakis 2015, Mazur et al. 2021, Yücedağ et al. 2021).

The mountains of Macedonia and Thrace, as well as several Greek islands, are habitat to this species in Greece (Milios et al. 2007, Stampoulidis et al. 2013, Korakis 2015).

Greek juniper is protected by the Greek law and its forests belong to a habitat type that is comprised into the European Habitat Directive 92/43 and characterized as a priority habitat type (Korakis 2015). It is found as a species in degraded scrublands, as solitary trees, in small groups mostly on rocky slopes, and only very rarely in larger formations of pure or mixed stands (Milios et al. 2007). Prespa National Park, located in the northwest of Greece, is the primary region where Greek juniper creates massive formations (Stampoulidis et al. 2013). Restoration activities are required for the conservation of the formations of the species in the Prespa National Park (Kakouros and Fotiadis 2014).

In the Prespa National Park there are pure and mixed Greek juniper stands. In the pure stands Stampoulidis and Milios (2010) distinguished two site types: the first type represents good sites qualities (productive sites) and the other type represents medium sites qualities (less productive sites). In both site types there are dense and sparse pure groups and stands of the species. In pure Greek juniper stands, two tree forms, regarding their foliage, have been observed. In the first form, the living foliage starts from the ground level, while in the second form the living foliage appears from a height of 50–60 cm above the ground level (Stampoulidis and Milios 2010). In Greek juniper forests of the Prespa National Park, the forest service does not apply silvicultural treatments (Kakouros and Fotiadis 2014). However, silvicultural treatments have to be applied for the long-term conservation of the species in the area.

Apart from Prespa National Park, another area where Greek juniper creates formations is in the middle portion of Nestos Valley in northeastern Greece (Milios et al. 2007). Stampoulidis (2010) pointed out that the maximum height of Greek juniper trees is higher in the Prespa National Park, compared to that of the formation of the species in the middle portion of Nestos Valley, while in Prespa National Park the density of Greek juniper trees (h>1.30 m) is lower than that of the mixed formations of the species in the middle portion of Nestos Valley.

Analysis of the ecosystems of the target species is necessary for the creation of suitable silvicultural treatments aimed at the conservation of tree species that are under threat or significant for any reason. Stand structure assessments and regeneration analyses are two crucial parts of this analysis (Milios 2021, Milios et al. 2021).

The goal of this research is to use findings from a regeneration analysis of Greek juniper mixed stands in Prespa National Park, Greece, to determine the best silvicultural approach for the long-term survival of the species.

MATERIALS AND METHODS

Study Area

The study was conducted in the western part of the Prespa National Park in northwestern Greece (40°49'12.88"N, 21°2'31.98"E), covering an area of about 2,732 ha and ranging in elevation from about 840 to about 1,360 meters. There are both pure and mixed stands of Greek juniper in this region.

Greek juniper may be seen growing in groups or as solitary trees in mixed stands. This study's sample plots were located in an area dominated by *Quercus macedonica* DC. or *Quercus pubescens* Willd., with *J. excelsa*, *Carpinus orientalis* Mill., and *Acer monspessulanum* L. serving as co-dominant species in the overstory. Furthermore, *Juniperus oxycedrus* L. species occurs mostly in a shrubby form in mixed stands.

The soils are clay to clay-silts, while the substratum consists of limestones and dolomitic limestones (Pavlides 1985). At least one soil profile was taken in each established plot to measure soil depth in Greek juniper mixed stands. The soil depth is between 25 and 40 centimeters deep.

The average annual rainfall is 817 mm, and the average temperature is 10.8°C, according to data from the Nestorio meteorological station (which is adjacent to the region).

Field Measurements

There is little variation in site productivity across plots due to the small variation in soil depth found in the established plots. However, the percentage of the stand area covered by the tree canopy projection (max=100%) was not constant. Two distinct structural types were identified according to the estimated canopy cover percentage of a stand (estimated area covered by the tree canopy projection of a stand x 100/area of a stand):

a) Canopy cover percentages in MSSG (Mixed Stands with Small Gaps) ranging from 65% to 75% (Figure 1).

b) Canopy cover percentages in MSWG (Mixed Stands Without Gaps) ranging from 95% to 100% (Figure 2).

The density of Greek juniper trees is 135 per hectare in the MSSG structural type and the total number of trees of all species (Greek juniper included) is 441 per hectare, whereas the corresponding values in the MSWG structural type are 144 per hectare and 664 per hectare (a multi-stemmed tree was counted as one tree) (Stampoulidis 2010). In MSSG structural type the mean height is 6.17 m with standard deviation of 2.372 m for Greek juniper, and 4.62 m with standard deviation of 1.783 m for the other species. In MSWG structural type the mean height is 6.95 m with standard deviation of 2.314 m for Greek juniper, and 6.11 m with standard deviation of 2.015 m for the other species (Stampoulidis 2010).

Thirty identical 500-square-meter sample plots (20 m × 25 m) were set at random in the summer of 2009. Fifteen sample plots were established in MSSG and fifteen sample plots in MSWG. The established plots exhibited the canopy cover percentage range of their structural type. The slope varied from 10% to 30% across all plots with various exposures across all plots. Each plot was surveyed for all regeneration plants and tallied for seedlings (plants up to 1.3 m in height), and Greek juniper regeneration plants were classified into two types. Greek juniper regeneration, which has been established and grows under the facilitation of other plants, is the first type. Regeneration found under closed canopy or at 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 Greek juniper or other species, falls into this type. The second type represents the regeneration that has been established and grows under light, in small gaps (Stampoulidis et al. 2013).

Statistical Analysis

The non-parametric Mann-Whitney and Wilcoxon tests were used to assess the density data from the regeneration process. Since the assumption of normality of data distributions was not met, GLM analysis was not performed on the data. SPSS was used for all statistical analyses (IBM 2021).

RESULTS

When comparing the number of Greek juniper regeneration plants exposed to facilitation vs the number of plants exposed to light in gaps of the MSSG structural type, there is no statistically significant difference (Table 1). Regeneration plants are more numerous ($p<0.05$) in the MSSG structural type than in the MSWG structural type (Table 2). In addition, other species exhibit more regeneration plants ($p<0.05$) than Greek juniper in both structural types of mixed stands (Table 2).

The number of regeneration plants per hectare in the two Greek juniper mixed stand structural types are shown in Figure 3. No Greek juniper regeneration plants could be seen growing in the light in the MSWG structural type. The following taxa are represented by the regenerating plants of other species found in the two structural types:

MSSG: *Quercus pubescens, Quercus macedonica, Carpinus orientalis, Fraxinus ornus* L., *Cornus mas* L., *Acer monspessulanum* and *Juniperus oxycedrus*.

MSWG: *Quercus pubescens, Acer monspessulanum, Quercus macedonica, Carpinus orientalis, Juniperus oxycedrus, Quercus cerris* L. and *Cornus mas*.

Figure 1. MSSG (Mixed Stands with Small Gaps). In the foreground of the photograph, a Greek juniper regeneration plant can be seen. The rest of the trees in the photograph are other tree species.

Figure 2. MSWG (Mixed Stands Without Gaps). On the left side of the photograph a part of trunk of a Greek juniper tree can be seen, while in the background on the right side of the photograph a Greek juniper tree can be faintly seen. The rest of the trees in the photograph are other tree species that grow in mixed stands.

Table 1. Density *of Juniperus excelsa* regeneration plants in the two structural types of *J. excelsa* mixed stands: MSSG (Mixed Stands with Small Gaps) and MSWG (Mixed Stands Without Gaps).

Structural type	Number of *J. excelsa* regeneration plants in light in small gaps				Number of *J. excelsa* regeneration plants under facilitation				Number of sample plots
	Mean	SD	Max	Min	Mean	SD	Max	Min	
MSSG	0.80a	0.676	2	0	1.07a	1.624	5	0	15
MSWG	0	0	0	0	0.73	1.100	4	0	15

In MSSG structural type, the means in a line are statistically significant different at p <0.05 when they share no common letter. The comparison was made using the Wilcoxon test, SD=Standard Deviation

Table 2. Density of regeneration plants in the two structural types of *J. excelsa* mixed stands: MSSG (Mixed Stands with Small Gaps) and MSWG (Mixed Stands Without Gaps).

Structural type	Total number of *J. excelsa* regeneration plants				Total number of other species regeneration plants				Number of sample plots
	Mean	SD	Max	Min	Mean	SD	Max	Min	
MSSG	1.87a**b**	1.767	6	0	64.80**a**	20.557	107	31	15
MSWG	0.73b**b**	1.100	4	0	72.53**a**	38.643	147	18	15

Juniperus excelsa means in the column are statistically significant different at p <0.05 when they share no common letter in normal print. The comparison of the total number of *J. excelsa* regeneration plants between the two structural types was made using the Mann-Whitney test.
Means in a line are statistically significant different at p <0.05 when they share no common letter in bold print. The comparisons between *J. excelsa* and other species' regeneration plants in both structural types were made using the Wilcoxon test, SD=Standard Deviation.

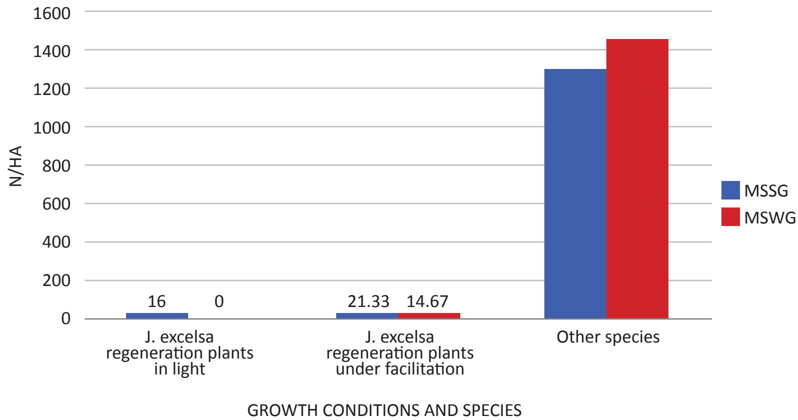

Figure 3. Density per hectare of *J. excelsa* (in light and under facilitation) and other species regeneration plants in the two structural types of mixed stands: MSSG (Mixed Stands with Small Gaps) and MSWG (Mixed Stands Without Gaps).

DISCUSSION

Based on the results of this study, Greek juniper can be established in both light (in small gaps) and shade (under canopy), the same as the literature refers (Milios et al. 2007, 2009, 2011, Stampoulidis et al. 2013). It is not surprising that Greek juniper regeneration plants could not be located in light in the MSWG structural type, since there was no place for them to grow and develop in gaps while receiving full light.

No significant difference was found between the number of plants established and growing under facilitation and those established and growing in full light ($p>0.05$), suggesting that facilitation is not the major mechanism in the regeneration of Greek juniper in mixed stands with small gaps (MSSG). To a large extent, facilitation may affect the success of plant establishment (Badano et al. 2016, O'Brien et al. 2019, Collins et al. 2019, Lucero et al. 2019, Petrou and Milios 2020, Duarte et al. 2021). When discussing the importance of nursing plants in the establishment of Greek juniper plants, Milios et al. (2007) note that in the middle portion of Nestos Valley in Greece, almost all of the regeneration plants of the species were discovered under the facilitation of nurse plants. There are regeneration plants of the species that were established under facilitation in Cyprus, although this process is not the dominant in the regeneration of the species (Milios et al. 2011). Furthermore, Stampoulidis et al. (2013) in pure Greek juniper stands in Prespa National Park discovered that facilitation does not dominate as a process in the regeneration of Greek juniper; however, it is important as a process, since a sizable proportion of regeneration plants were established and grew under facilitation. So, in restoration programs tree seedlings can be established under the facilitation of a group of trees or individual trees (Milios et al. 2007, 2009, 2011, Stampoulidis et al. 2013).

The fact that the structural type without gaps (MSWG) shows a lower ($p<0.05$) number of Greek juniper regeneration plants than that with small gaps (MSSG), clearly points out that if the gaps close, the density of Greek juniper plants regeneration will decrease. It is worth noting that in MSWG, there were only 14.67, Greek juniper regeneration plants per hectare (Figure 3). On the other hand, in both structural types, the regeneration plants of the other species show higher density ($p<0.05$) than those of Greek juniper (Table 2) and exhibit a very high number of plants (Figure 3).

Regeneration of broadleaf species is being intensively grazed in the study region. Grazing is therefore one of the primary disturbance sources (Stampoulidis et al. 2013). Vegetation composition in mixed stands will shift, and it is likely that Greek juniper individuals may become rare if grazing is not intensive (or ceases) and does not prevent the entire dominance of broadleaf species. Greek juniper is a site insensitive species that is supplanted by more site sensitive species at better sites, when disturbances cease (Milios et al. 2007, Milios et al. 2011). Reducing human disturbance (mostly grazing), and the establishment of other species, are two key factors threatening the survival of *Juniperus thurifera* L. in deep-soil regions of the Pyrenees and the Alps, as stated by Gauquelin et al. (1999).

Effective steps should be taken by the forest practice to protect the Greek juniper mixed stands in Prespa National Park. The establishment of Greek juniper regeneration plants will be promoted by creating gaps around Greek juniper trees by extensive interventions and then controlling the spouts of other species, as well as the regeneration of competing species in the gaps. As a result, Greek juniper plants will be established without facing competition from other species, leading to a greater presence of this species in the mixed stands.

Removing individuals of potentially competitive species will help the Greek juniper regeneration plants in the future. For the stands in central part of the Nestos Valley in Greece and for the stands of the species in Cyprus, Milios et al. (2007 and 2011) recommend the similar technique of releasing Greek juniper plants from the competition of other species.

CONCLUSIONS

There are less Greek juniper regeneration plants in the gap-free structural type, compared with the small-gap type. Greek juniper regeneration plant density will decrease if gaps close. In both structural types, the other species' regeneration plants exhibit higher density than those of Greek juniper. Creating gaps around Greek juniper trees by extensive intervention is one of the most successful ways for the forest practice to protect the Greek juniper mixed stands. Removing individuals of potentially competitive species will help the Greek juniper regeneration plants in the future.

Author Contributions

AS and KK conceived and designed the research, AS carried out the field measurements, AS, KK, EP and PP processed the data and performed the statistical analysis, AS, KK, EP and PP wrote the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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