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Ecology and conservation status of *Taxus baccata* population in NE Chalkidiki, northern Greece

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Abstract: *Taxus baccata* L. is a rare species threatened with extinction in Greece, as in other parts of Europe. This paper deals with the ecological status of the species in the area of NE Chalkidiki northern Greece, where the species appears in one of the greatest populations of the country. Site, stand and yew population characteristics were studied in the area that species occupies. Eleven sample plots were marked, and on each plot, the height and diameter at breast height (DBH) were measured for all yew trees, as well as for all the individuals of the rest tree species, with diameter at breast height greater than 4 cm. Tree vitality of all trees was also estimated according to IUFRO classification. Yew radial growth was studied using tree-ring analysis. Tree natural regeneration was investigated within subplots of different dimensions and according to two height classes. Results showed that yew population occurs in stands dominated by beech, presenting a mean density of 301 trees per hectare, with a total population of 430 trees with DBH above 4 cm. It forms the secondary stand, and dominates in the stand understorey, accompanied with *Fagus sylvatica* and *Ilex aquifolium*, while it appears rarely in the overstorey. Yew tree vitality was found to be quite high, and significantly higher than that of beech. Radial growth of the sampled trees follows a slow and constant annual increment gradually decreasing by tree age. Yew natural regeneration was found to be relatively low, 1341.8 individuals (seedlings and saplings up to 1 m) per hectare. Management and *in situ* conservation of the species in the area should focus on species protection measures, and on specific silvicultural treatments for creating favourable conditions for species growth.

Additional key words: stand structure, forest regeneration, radial growth

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Introduction

Taxus baccata L. (European yew) is a rare and endangered plant species in many European countries (Iszkulo 2001; Iszkulo et al. 2005; Piovesan et al. 2009; Ruprecht et al. 2010). Its habitats ("Mediterranean *Taxus baccata* woods 9580" and "Apennine beech forest with *Taxus* and *Ilex* 9210") are listed as priority habitats in the European Habitat directive (92/43/EEC) (EEC 22/07/1992). It is one of the most ancient forest species in Europe with origin of the pre-Miocene age, before two million years (Ellenberg 1988; Thomas & Polwart 2003). In the Middle Ages, yew was considered as "green gold" because its timber was used for manufacturing the most formidable bows, while recently it was characterized as "miracle" medicine tree, when biologists discovered that it contains the taxol, an extraordinarily effective anticancer toxin (Bissery et al. 1991; Gordaliza 2007).

During the past 5000 years, yew disappeared locally or was isolated in smaller populations (Tittensor

1980; Pridnya 1984; Lewandowski et al. 1995; Svenning and Magård 1999). This disappearance was mainly attributed to anthropic factors rather than climate change or reduced ecological fitness (Thomas and Polwart 2003; Piovesan et al. 2009). Habitat fragmentation, a common result of human activities, negatively impacts yew pollination, since the formation of viable seeds (yew is a dioeceous species) requires co-existence of both sexes (Piovesan et al. 2009). Land use changes may also contribute to the shrinkage of yew habitat, through logging of old-growth stands in combination with grazing and burning. Such activities have contributed to the transformation of forest landscape, and affected vegetation dynamics, especially of shade-tolerant and late-successional species such as yew (Busing et al. 1995; Piovesan et al. 2009). Excessive throwing of European yew trees constitutes another important factor, particularly in continental Europe, England and Ireland, where yew comprises one of the species more influenced by human interventions (Svenning & Magård 1999; Garcia et al. 2000; Vacik et al. 2001). For other regions, yew reduction was attributed to the pasturage of seed cones and plants from the animals, especially to the intense deer grazing. Other reported causes are: competition for light with other species such as beech, unfavourable soil conditions especially soil water limitation, changes in stand microclimate, and fungal diseases (Król 1978; Pridnya 1984; Lewandowski et al. 1995). In southern Europe, yew decline was also attributed to the climate change (Anzalone et.al. 1997).

European yew is a native species in Greece, which never occurs in big populations, and belongs to group of rare and endangered species (Voliotis 1986). According to Kassioumis et al. (2004) in a query research, yew appears in 173 forest sites along Greece, usually in populations less than 50 individuals. Big yew populations appear mainly in confined regions of Central and Northern Greece, particularly along the mountains of Pindus, and mountainous Chalkidiki. Despite the great ecological importance of the species, data on species population ecology and conservation status are completely missing. Yew ecology for the southern limit of its distribution often relies on studies performed in more northern areas, geographically and biologically distant; however, Piovesan et al. (2009) gives a detailed report for yew population ecology in Central Apennines in Italy, one of the southern limits of yew in Europe. To maintain such a rare and endangered species, specific conservation measures should be taken, included *in situ* silvicultural treatments and conservation activities (Dovciak 2002; Ruprecht et al. 2010) based on species ecological status.

The aim of this study was to estimate the ecology and the conservation status of the population of *Taxus baccata* in the mountain area of NE Chalkidiki, where the species appears as one of the biggest populations in Greece. The area belongs to the European ecological network Natura 2000, as a Site of Community Interest (Commission of European Communities 2006), coded GR1270005. The specific aim of the study was to determine the ecological conditions where the species appears, and to estimate the species population characteristics, including stand structure, tree vitality, species radial growth pattern, and natural regeneration.

Materials and Methods

Study area

The studied forest is located on Mount Stratoniko (40°33' N and 23°47' E), in the NE Chalkidiki, northern Greece, and it belongs to the public forests of Arnaia District. According to the archives of the local Forest Service, yew appears in groups or scattered trees, in an area of 265.2 ha. Elevation ranges from 350 to 900 m, with a slope of 10–99%, and exposition N–NE–NW–E–WE. The main type of bedrock is gneiss-mica schist, usually characterized by a thick humus layer. Soils are characterized as clay-sand-loam, deep to moderately deep, and locally shallow, with adequate soil moisture and fertility. The climate is a transient between continental and real Mediterranean (Kotini–Zampaka 1983), and is classified as intense medium–Mediterranean type (Tselepidakis and Theoharatos 1989). It comprises the characteristic traits of the Mediterranean climate, with dry summertime and humid winter, with a medium annual temperature of 12.6°C, annual precipitation 569 mm and average annual air relative humidity 77%.

Yew population appears in forests dominated by *Fagus sylvatica*, and scattered individuals or patches of *Castanea sativa* and *Quercus frainetto*. The core population appears in East, Northeastern and North slopes of medium to strong inclination, in areas with a relevant constant range of altitude, ranging between 350–650 m a.s.l. However, the total area where the species appears either in groups or in scattered individuals is wider, with more variable characteristics (e.g. in Northwest sites, altitude up to 900 m). Other woody species appearing in the tree storeys are: *Ilex auifolium*, *Quercus dalechampii*, *Ostrya carpinifolia*, *Tilia tomentosa*, *Sorbus torminalis*, *Acer pseudoplatanus*, *Acer hyrcanum*. In the understorey, the following species dominate: *Galium odoratum*, *Hedera helix*, *Ruscus aculeatus*, *Ruscus hypoglossum*, *Cyclamen hederifolium*, *Polypodium vulagre*, *Cardamine bulbifera*, *Daphne laureola*, *Asplenium trichomanes*, *Mycelis muralis*, *Helleborus cyclyphyllus*, *Rubus caesius*, *Pteridium aquilinum*, *Clematis vitalba*, *Veronica officinalis*, *Fragaria vesca*, *Viola hirta*, *Lathyrus inermis*.

The forests of the area are under the management of the Public Forest Service of Arnaia. Their management though, does not include any special treatments for yew, as it is considered that its appearance in understorey, patches and scattered individuals, does not request any specific management measure. Thus, in stands where the species occurs, the management objectives concern only the dominant tree species *F. sylvatica*.

Experimental design and data collection

Yew population data was collected along the area the species appears, in summer 2010. Eleven sample plots, sized 25×20 m (500 m^2) were randomly selected, and their location was put in the map, using a GPS. Data concerning stand age and site quality for each plot were taken from the archives of the local Forest Service. In each plot we recorded coordination, altitude, exposure, inclination, and we estimated the overstorey canopy cover (visually assessed by two experienced persons). Tree height (with Haga altimeter) and diameter at breast height (DBH) were measured for: i) all living trees of all tree species, with breast diameter over than 4 cm, and ii) all yew individuals with DBH less than 4 cm, and height over 1.0 m. Tree vitality was also estimated for all trees, according to IUFRO classification as follows: 10 = trees of vigorous growth (vital), 20 = trees of normal growth (normal), 30 = trees of declining growth (Tsitsoni and Karagiannakidou 2000; Thanasis et al. 2007). Each tree was classified in the tree storey belonging, as follows: upperstorey, trees with height over 2/3 of the mean dominant height (average height of 100 dominant trees per hectare (Dafis 1990), middlestorey, trees with height 1/3–2/3 of the mean dominant height, and understorey, trees lower than 1/3 of the mean dominant height. Stand basal area was calculated per species and per tree storey.

For the estimation of yew radial growth, six stem disk samples were taken from the ground base of six randomly selected trees of different size. Tree age and radial growth were estimated in the laboratory by measuring tree annual rings in a stereoscope in accuracy of 0.01 mm. Samples were measured twice along different paths from the centremost ring to the outermost. In order to analyse periods of tree suppression and release for each tree, we compared the average tree-ring width over a 10-year period with the average tree ring width the 10 previous years (Lorimer 1985; Dahir and Lorimer 1996; Groven et al. 2002; Ganatsas and Thanasis 2010). A growth release was de?ned as 100% or greater increases (than the previous 10 years) in radial growth rate for 10 years following 10 years of slow growth. Based on the data analysis we estimated the growth behaviour of the species.

Natural regeneration (individuals with a total height < 1.0 m) of all tree species was measured within three (3) selected subplots, located in diagonal provision across each plot. In each subplot, all tree seedlings and saplings were measured according to two height classes (Iszkulo and Boratynski 2004): less than 30 cm (seedlings), and 30–100 cm (saplings), by means of two subplots with different dimensions (1×1m and 3×3m, respectively) (Dhar et al. 2006). In the smaller subplots we measured the density and height (in cm) of all seedlings and in the bigger subplots the density and height (in cm) of all saplings.

Within each plot, tree morphological characteristics were analyzed for each tree species separately. Basal area, stem density, and tree vitality were also estimated for each species. For tree natural regeneration, the stem density per species was calculated, and the mean and standard error of mean of individuals' height were computed. The studied variables were statistically analyzed by means of analysis of variance (ANOVA). The homogeneity of variances was tested by Levene's test. Correlation analysis was performed in order to explore any relation between yew natural regeneration and stand characteristics. All data analysis was carried out using SPSS V. 17.0 statistical program; tests for significance were conducted at $P = 0.05$.

Results

Yew population characteristics

According to the data analysis, *Taxus baccata* appears in stands dominated by *Fagus sylvatica,* which were characterized as two-storey stands (Figs 1, 2). The dominant storey was constituted by beech trees, and the secondary stand was composed by a mixture of yew and beech trees, accompanied by *Ilex aquifolium*. The total tree density of yews (with DBH over 4 cm) was found to be 90.8 trees per hectare, consisting of 24.1% of the total tree density (Table 1). However, a quite great number of individuals with diameter lower of 4 cm, and with height over 1 m was additionally observed in the understorey (210.2 individuals per hectare). Yew individuals were usually growing beneath beech trees, dominating in the understorey with 285 individuals per hectare, participating in the stand middlestorey with 16 individuals per hectare (percentage 22.5% of this story), while they were rare in the overstorey.

The tree diameter and height distribution diagrams (Figs 1, 2) show that yew appears in the lower and medium classes of diameter and height, up to 28 cm in diameter, and 16 m in height, while only few trees appear in the higher diameter and height classes. Therefore, the number of bigger yew trees (over 52 cm DBH) was very small (3.6 trees per hectare), and no trees of yew were found to exceed the height of 16.5 m. Average DBH and height of the yew trees were found to be 16.7 cm and 5.8 m, respectively (Table 1), while if considered together with the yew indi-

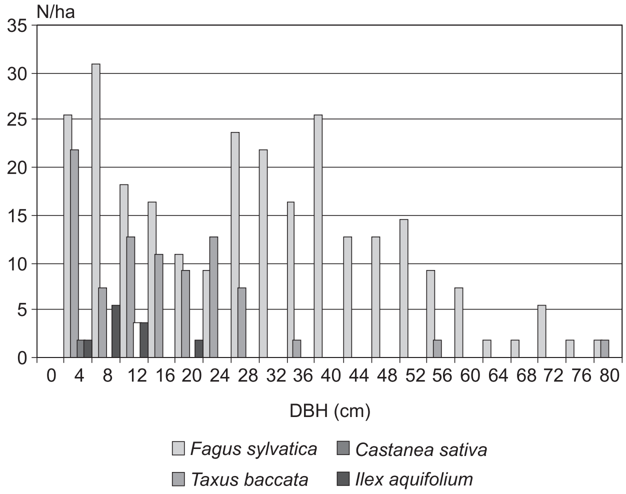

Fig. 1. Diameter distribution of the trees (with DBH over 4 cm) in the studied forest in NE Chalkidiki, northern Greece

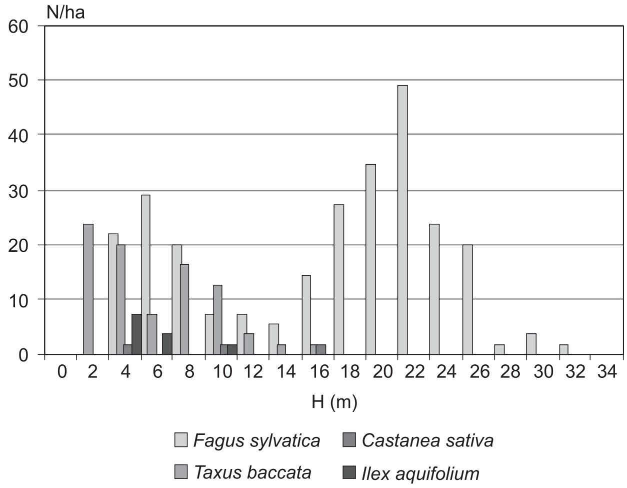

Fig. 2. Height distribution of the trees (with DBH over 4 cm) in the studied forest in NE Chalkidiki, northern Greece

viduals with DBH less than 4 cm and height over 1.0 m, the average DBH and height became 5.9 cm and 2.5 m, respectively (Table 1).

Yew trees exhibited a medium vitality, with a mean value of 17.5, having great differences between the stories. Trees belonging to middlestorey depicted high values of vitality (average 12.2), with a very good status and growth, while trees of the understorey showed medium values. Great differences can be mentioned between *T. baccata* and *F. sylvatica* trees in the middlestorey, where yew significantly excels beech trees in vitality. In the understorey, these differences were reduced, but still yews had significant higher vitality than *F. sylvatica*, and *Castanea sativa* trees, while there were no differences with *I. aquifolium* (Table 1).

Pattern of yew radial growth

The age of the sampled *T. baccata* trees ranged between 24 and 62 years, and the dimensions between 1.35–1.80 m in height, and 2.0–4.5 cm in base (ground) diameter. The radial growth of the sampled trees follows a slow and constant annual increment, gradually decreasing by the tree age (Fig. 3). The mean annual radial increment was found to be 0.36 mm,

Table 1. Morphological characteristics of all trees in the stands where *Taxus baccata* appears, in NE Chalkidiki, northern Greece. Values are mean and standard error of mean (in parenthesis). Means of tree vitality followed by different letters within a story are significantly different ($P \le 0.05$)

Tree storey	Species	Diameter DBH (cm)	Height H (m)	Tree vitality	Basal area (m²/ha)	Density N/ha
Upperstorey	*F.s.*	42.9 (1.5)	22.5 (0.3)	15.6	21.99	138
Middlestorey	*F.s.*	25.8 (2.3)	15.5 (0.5)	22.7a	3.52	55
	T.b.	32.3 (7.0)	11.4 (0.7)	12.2b	1.85	16
Middlestorey total		27.3 (2.4)	14.6 (0.5)	20.3	5.37	71
Understorey	*F.s.*	8.1 (0.6)	5.8 (0.2)	26.6a	0.48	74
	T.b.	13.1 (0.5)	4.5 (0.2)	17.5b	0.63	74.8
	I.a.	10.0 (1.9)	5.0 (0.7)	22.9ab	0.12	12.7
	C.s.	8.2 (3.7)	7.0 (2.0)	30.0a	0.02	5.4
Understorey total		10.9 (0.3)	5.4 (0.2)	20.5	1.35	166.9
Total per species	*F.s.*	29.7 (15.0)	16.4 (0.6)	20.1	26.00	267.4
	T.b.	16.7 (0.8)	5.8 (0.3)	17.2	2.48	90.8
	I.a.	10.0 (1.9)	5.0 (0.7)	22.9	0.12	12.7
	C.s.	8.2 (3.7)	7.0 (2.0)	30.0	0.02	5.4
All tree species with breast diameter over than 4 cm		25.7 (1.2)	13.5 (0.6)	19.7	28.71	376.3
Yew individuals with breast diameter less than 4 cm, and height over 1.0 m	*T.b.*	2.4 (0.3)	1.4 (0.2)	20.4	0.65	210.2

F.s. = Fagus sylvatica, T.b.= Taxus baccata, I.a.= Ilex aquifolium, C.s.= Castanea sativa.

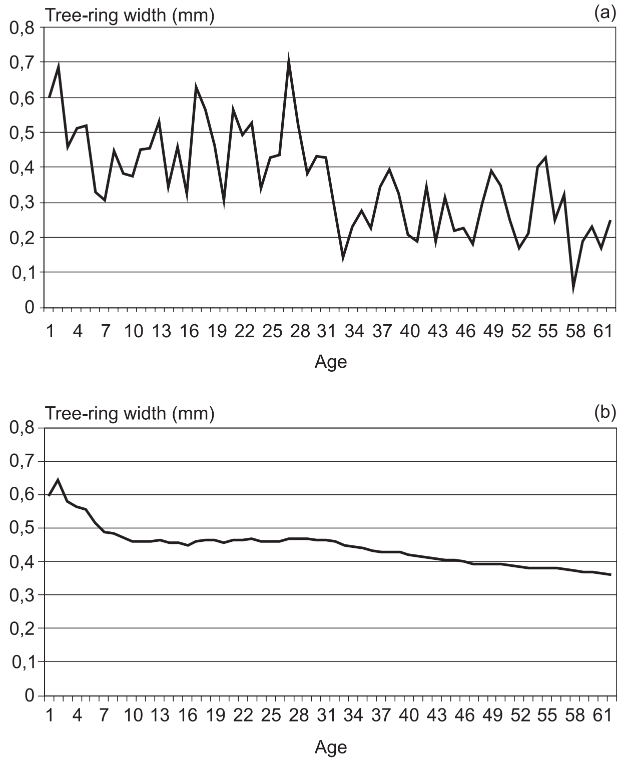

Fig. 3. Radial growth of the sampled trees of *Taxus baccata*; (a) mean current annual radial increment, (b) mean annual radial increment. Values are mean of the six sampled trees

ranging between 0.17 mm and 0.70 mm (Table 2). The annual increment was significantly higher during the first three decades of the yew age. However, it seems that two periods can be distinguished in yew radial growth, i.e. before and after the 32nd year of tree life, when yew radial growth was significantly decreased. All the studied trees were found to have grown without any suppression or release period according to Groven et al. (2002) and Lorimer (1985) criteria.

Forest natural regeneration

The total regeneration density of all tree species (seedlings and saplings lower than 1.0 m) was found to be 6128.0 individuals per hectare (Table 3), and it was highly variable among plots. *F. sylvatica* dominates in the new tree generation with a total density of 3468.0 individuals per hectare, followed by *T. baccata* (1341.8 individuals) and *I. aquifolium* (880.5 individuals). *T. baccata* appears in both height classes of natural regeneration, presenting higher density in the lower class (1106.1 seedlings per hectare), than in the higher class (235.7 saplings per hectare). It is worth pointing out that no one-year old seedlings of yew were found in any plots. The average height of all young yew individuals was found to be 32.4 cm, ranging from 15 to 100 cm. However, no parameter of yew natural regeneration was found to be correlating with any overstorey characteristics, such as basal area, canopy cover and total tree density (data not shown).

Table 2. Current annual radial increment of the sampled yew trees. Means followed by different letters are significantly different (P ≤ 0.05)

Tree age years	Current annual radial increment		Range (min–max) mm
	Mean mm	Standard error of mean	
1–10	0.46 a	0.08	0.37–0.68
11–20	0.45 a	0.06	0.30–0.62
21–30	0.48 a	0.06	0.34–0.70
31–40	0.28 b	0.04	0.14–0.43
41–50	0.26 b	0.05	0.18–0.39
51–60	0.25 b	0.06	0.17–0.43
>60	0.21*	–	0.17–0.25
Average	0.36	0.04	0.17–0.70

*There was only one tree aged over 60 years (62 years old).

Table 3. Tree natural regeneration in the stands where *Taxus baccata* appears. Values are mean and standard error of mean (in parenthesis)

Type of individuals	Height class	Species	Height (cm)	N/ha
Seedlings	0–30 cm	*F.s.*	22.2 (1.1)	2727.3
		T.b.	17.4 (1.9)	1106.1
		I.a.	17.1 (2.8)	712.2
		Other species	25.0 (5.1)	303.0
		Mean	19.8 (1.0)	4848.6 (sum)
Saplings	30–100 cm	*F.s.*	57.3 (4.4)	740.7
		T.b.	60.3 (6.6)	235.7
		I.a.	60.8 (7.8)	168.3
		Other species	56.6 (9.6)	134.7
		Mean	58.2 (3.5)	1279.4 (sum)
Total		*F.s.*	29.0 (6.6)	3468.0
		T.b.	32.4 (5.7)	1341.8
		I.a.	30.3 (7.7)	880.5
		Other species	35.7 (9.8)	437.7
		Mean	30.8 (6.0)	6128.0 (sum)

F.s. = Fagus sylvatica, T.b.= Taxus baccata, I.a.= Ilex aquifolium, C.s.= Castanea sativa.

Discussion

The studied yew population in NE Chalkidiki appears in stands dominated by *F. sylvatica* where it forms the secondary stand, and dominates in the stand understorey, accompanied with *F. sylvatica* and *I. aquifolium*. The stand structure analysis showed that there was a significant presence of *T. baccata* in the tree middlestorey, probably due to the very low growth of the species and the relevant low height that the species reaches at the mature stage. The population density was 301 individuals (90.8 of them being above 4 cm DBH) per hectare, including many mature trees. The total yew population in the area is estimated to be 430 trees with DBH above 4 cm. The species appears in relatively constant site conditions in Northeastern, East and North slopes, in relatively wet sites, along and close to small local streams, with medium to strong slope inclination. According to Sanz et al. (2009), distance to the nearest stream is by far the most significant variable explaining yew presence, while additionally, yew stands concentrated not only in the close vicinity of streams, but also in north pacing slopes. The population is characterized by a small geographical extension, but in a density and structural complexity, similar to that found in another southern European limit in the Central Apennines, central Italy (Piovesan et al. 2009). These population characteristics conclude that it should be considered as an important yew population in Europe (Hageneder 2007), consisted of a quite high number of individuals, closed to the minimum amount of 500 individuals that is currently considered necessary to safeguard population genetic variability (USDA Forest Service 1992; Piovesan 2009). Taking into consideration that yew populations are usually characterized by high intrapopulation diversity (Lewandowski et al. 1995), the studied population should be considered as an important genetic pool, and thus, it should be subjected to special management. As it was previously mentioned, the studied area belongs to the European ecological network Natura 2000 as a Site of Community Interest coded GR1270005.

Vitality of yew trees was found to be quite high, and significantly higher than that of beech trees, especially in the middlestorey. This fact contributes to the conclusion that, the beech forest in the studied area, as well as in other Mediterranean areas (Piovesan et al. 2009), provides favourable conditions for yew growth, possibly in part because of niche portioning between deciduous overstorey (beech) and the evergreen understorey (yew) (Perry 1994; Piovesan et al. 2009). On the contrary, in central Europe, yew loses the competition with beech and fir, and 30% thinning is necessary (Dhar et al. 2008; Iszkulo et al. 2012).

The radial growth (during the period of 60 years) of the sampled trees follows a slow and constant annual increment, gradually decreasing by the tree age. The average value (0.36 mm per year) recorded in this study is lower than that reported from Iszkulo et al. (2012), and Cedro and Iszkulo (2011) for natural populations in central Europe, and, from Pigott (1995), Yadav and Singh (2002) and Moir (2004) for big mature Yew trees. However, we have to consider that this low value concerns measurements at ground level (base diameter instead of DBH), made on naturally regenerating trees, grown under the dominant stand, and being in their first stage of their life. Thus, the recorded value agrees with the average annual increment reported by Moir (2004) for the first decades of a yew tree. Moir (2004) also identified that the radial growth rate of yew can increase once a mature stage of growth has been achieved. It is worth mentioning that the studied trees were found to have grown with no any suppression or release period according to Groven et al. (2002) and Lorimer (1985) criteria, a fact which confirms (even though the low number – six trees) the aforementioned favourable conditions that beech forest secures for yew development in the area.

Species natural regeneration was relative low compared to the higher density of *F. sylvatica* seedlings and saplings; this means that the future stands may also dominated by *F. sylvatica*. Similarly, low regeneration of yew population was observed by Piovesan et al. (2009), in Central Apennines, in Italy, another southern limit of species' ecological distribution, where the species appears also in stands dominated by *F. sylvatica*, and with the presence of *I. aquifolium* in the understory, with no evidence of antagonism between yew and beech. As slow-growth and late successional-species, presents shade-tolerant ecophysiological characteristics (according to Thomas (2010), *T. baccata* is the most shade tolerant tree in Europe), yew seems able to secure species participation in the future stands in the area, especially in understorey and middlestorey, accompanied by *I. aquifolium* that presents similar characteristics, but it appears in lower densities. However, low yew regeneration was not apparently correlated with low yew population survival, since seedling density was highly variable on relatively short time scales (Kwit et al. 2004; Dhar et al. 2007).

Yew seedling and sapling density and height were found not to be correlating with any overstorey characteristics, such as basal area, total tree density and canopy cover. This is probably due to the fact that, since all individuals were older that one year (and most of them some decades, as the tree-ring analysis showed), the present stand status does not represent the conditions where the yew individuals were established. The lack of one-year-old seedlings may be connected with periodic abundant cones production.

To protect such a rare and endangered species, with limited geographical distribution, and small populations, appropriate conservation measures should be planned, including silvicultural treatments for *in situ* species conservation (Ruprecht et al. 2010). Austria, for example, has established a gene conservation network to achieve species conservation in the country (Vacik et al. 2001; Dhar et al. 2006). Conservation actions are mostly concerned to secure species regeneration, mainly due to the observation of nonviable young seedlings in many regions (Lewandowski et al. 1995; Hulme 1996; Rikhari et al. 1998; Garcia et al. 2000; Rajewski et al. 2000; Piovesan et al. 2009). Thus, the proposed silvicultural treatments for management and *in situ* conservation of yew in the region should focus on the creation of more favourable lighting conditions for young yew seedlings (Iszkulo and Boratynski 2004; Iszkulo and Boratynski 2006). Even though yew seedlings can grow in <0.5–5% full sunlight, growth is better with increasing light (Thomas 2010); thus, an increasing light level in the understorey would increase growth of yew saplings (Iszkuło et al. 2007). Additional measures should be taken for yew protection from illegal logging and damages during harvest operations.

Finally, based on the findings of this study, and taking into consideration the current practices worldwide, the studied yew population should be included within a species gene conservation network (Vacik et al. 2001; Dhar et al. 2006), that needs to be established in the country (or in a European scale), in order to achieve species conservation. Forest management plans of the area should set specific objectives for *in situ* conservation of the species, through the appropriate silvicultural treatments mentioned above, specified at stand level.

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