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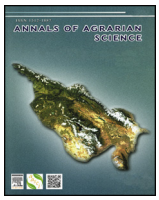

Patterns of distribution and survival of European yew (*Taxus baccata* L.) in an alpine tree line ecotone in the Greater Caucasus (Georgia)

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ABSTRACT

Four disjunction sites with European yew (*T. baccata*) were included in this study (Fig. 1). All of them are represented in the western part of the Greater Caucasus Range (GCR). Considerable interest was directed towards two sites in the alpine tree line ecotone. Another two sites included low or mid-elevation locations.

The present paper is the first attempt towards data analysis on yew elevation variability across the Greater Caucasus, including treeline ecotone. An effort has been made to reveal survival strategy of yew under pessimal conditions. The sharp geomorphology of high mountainous limestone habitat; harsh climatic conditions long-term impact of severe disturbances due to temperature extremes, solar radiation, cold winds, and other topo climatic conditions; related to both - individual and community stands of yew were considered. All these fluctuating abiotic disorders affect the anatomy, physiology and behavioral peculiarities of relict yew; in particular the vegetative propagation ability of krummholz stand of yew. Our aim here was to strengthen the environmental awareness among the local people through this study, vis-a-vis enlighten the incredible natural sites of the GCR, which contain remarkable endemic and relict flora.

Introduction

Species of genus *Taxus* L. (Taxaceae) occur throughout temperate zone of the Northern Hemisphere. Most botanists believe that genus encompasses seven closely related species [1]. Genus *Taxus* is a relict conifer. It appeared during the transition between the Cretaceous and the Tertiary, 66 million years ago [2]. Taxaceae radiated from the southwest China. In the Tertiary period Asian species complex diverged within various geographic clades including European yew lineage [3].

European or English yew is a relict of moderate tertiary climatic countries [1].

According to the paleontological findings, the plant is accepted as the oldest tree genus in Europe. The oldest fossil record dates to the Miocene (about 23 mya) [4]. Its latitudinal distribution encloses 63°N-30°N [5]. It is native to most of Europe, northern Africa (the Atlas Mountains), Asia Minor, the Caucasus and northern Iran [6,7].

In temperate Eurasia changes in the abiotic factors of the Neogene have profoundly affected the regional species distribution. For example, the mid-Miocene-Pliocene global climate oscillation and further complications in the Alpine-Himalayan orogenic belt, have served as the reason of advancing aridity. The climate eventually became unsuitable for the growth of *T. baccata*. This event has led to disjunction in the yew populations and has shaped in general its modern-day latitudinal and altitudinal distribution trend. The additional fragmentations in the range of yew have occurred due to further deteriorations in the climate during the Quaternary multiple glacial periods as well as anthropogenic factors (various human disturbances) in the Holocene [8].

Within the range yew's dispersal ability is limited by low temperatures in the north and by long drought in the south. It has a very wide soil tolerance but is vulnerable to waterlogging [1,6].

Altitudinal distribution increases from north to south with moisture demand. Currently, similar to other species of *Taxus*, European yew is highly shade tolerant, but can withstand full exposure to the sun [1,9]. In mountainous areas yew prefers north-western or north-eastern shade slopes, close to maritime-coastal climates, where it occurs under canopy of deciduous or mixed forests [1,10].

During climate warming within the Pleistocene/Holocene boundary, despite its poor dispersal ability, species of *Taxus* have followed a speedy distribution in northwest Europe and simultaneously in the high mountainous altitudes [11].

As the Holocene started with rapid climate warming, the yew spread to the southern fringes of Europe and Asia Minor. During the Last Glacial Maximum (about 25 thousand years ago), a bottleneck for thermophilous dendroflora, yew continued to live in refugial areas of the Amanus and Taurus Mts of southern Turkey. During the later climate warming *T. baccata* began to migrate from southern Turkey and

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probably between 9000–7000 BCE crossed Anatolia and reached the Caucasus (the Black Sea shores and the Caucasus Mts) [12]. In the present interglacial period, *Taxus* was more abundant in the first half of the Holocene, and, therefore, must have played more important role in the hardwood and softwood forest communities [10].

Today, one of the most important reasons in the decline of *T. baccata* is human impact (widespread deforestation, habitat fragmentation, etc.). 'Such activities have transformed the forest landscape and affected vegetation dynamics, especially of shade-tolerant and late-successional species like yew' [13].

This tree species is under threat, and has become locally extinct or reduced to individual trees or small populations over the past 4000 years in many parts of its range. This trend is continuing [1,14]. Hence, in the majority of countries, *T. baccata* is included in the Red Data Books and is accepted as a problem in nature conservation [5].

Within the temperate forests, yew is found usually either as solitary trees or scattered at most in small groups. Dense, pure woodlands consisting of *T. baccata* can be found rarely, in refugial sites, under mild maritime climate [1].

In the Caucasus, European yew is clear example of its location in woodland communities and, at the same time, it is obviously manifested in its spatial patterns of distribution through different sequence types of altitudinal vegetation belts, significantly in the GCR.

During this study only elevation distribution pattern has been taken into account. The aim of the present study was to improve our understanding on the range of distribution limit of *T. baccata* by its maximum elevation, i.e. in the treeline ecotone of the Greater Caucasus, to reveal a pathway related to survival ability of yew in harsh ecological environment.

Material and methods

In order to enlighten the altitudinal expansion of European yew (Table 1), attention was focused on the range of relict tree in southern Caucasus, significantly in Georgia. In this region, in the GCR yew sequentially occurs almost at all elevation types of vegetation from lowlands and foothills up to treeline zone (2200 m a.s.l.) of the Greater Caucasus. Data was used from: (1) literature sources and (2) from latest personal observations (2014–2016).

Results and discussions

Among four mountain systems of the Caucasus Isthmus – the Greater Caucasus, Lesser Caucasus, Talysh Mountains and Javakheti-Armenian Uplands (part of the Armenian Highland) – yew populations exist in the first three systems. Although, in all altitudinal zonations, including treeline ecotone, yew is sporadically represented only in the GCR.

The Greater Caucasus, one of the greatest ranges in western Eurasia is presented as climatic barrier between Eastern Europe and West Asia, stretching latitudinally for over 1000 km [15]. Southern macroslope of the range consists of majority of characteristic landscapes of the Caucasus Isthmus [16]. Yew tolerates a wide range of soils, but most notably it prefers calcareous soils with a high lime content. Limestone massifs of the GCR are of the Jurassic and Cretaceous origin and with their powerfully thick deposits of limestone are remarkable by active karstic processes [17,18]. Western part of the southern slopes of the GCR, under the influence of the moderating activity of the Black Sea, are remarkable with its warm, humid climate at the lower elevations. However, the latter changes to cool, humid climate towards the mid-elevations and to a moderately cold and extremely humid climate at the highest altitudinal zone should be taken into consideration [16].

Calcareous substrate harbours a high biodiversity. Plant species richness peaks on calcareous habitats [19–22]. Patterns of high level of neo- and paleoendemism on species and genera levels ('calcareous riddle') in calcicolous flora of the GCR has always been of interest for the Caucasian botanists [23–25]. The same holds true for the phytogeography of calcicolous alpine species [26].

Available data of the sites, as it mentioned already, was used in this study from four disjunction areas of Transcaucasia (the GCR) with considerable attention to two subalpine treeline ecotones. Another two low or comparatively lower altitudinal vegetation sites have been well studied previously by several botanists and foresters.

Below are identified two sites where yew forms either old-growth monodominant forest formation (Taxetum) (Fig. 1.4., Batsara; Fig. 4., Batsara) or is successfully associated (co-occurring) with evergreen shrub/tree, Colchic box-tree (*Buxus colchicum*) or some deciduous trees in canopy (e.g., *Fagus orientalis,* also *Carpinus betulus, Tilia dasystyla* subsp. *caucasica*) (Fig. 1.1., Sochi). Two other sites are found in treeline ecotone (Fig. 1.2., Okhhachkue; 1.3., Khvamli).

There are 130 known yew stands in the Western Caucasus (one of the highest recorded data in the North Hemisphere) [12], of which Sochi yew stand in southwestern Caucasus encompasses 301 ha, and Khosta yew-box grove envelopes 190 ha, ranging from 40 to 520 m a.s.l [27–30] (Fig. 1.1.). Until today two sites have been protected due to above mentioned moderate, oceanic climate. Sochi-Khosta yew and yew-box-tree stands are considered to have remained relatively unchanged since the mid-Tertiary (about 30 mya). Magnificant giant yew reaches a height of 30 m and is 1 m in girth, and height of Colchic box-tree goes up to 18 m and diameter is up to 50 cm. This forest is under protection of UNESCO as an object of the World Heritage [5,28].

Another, mixed – Oriental beech forest with yew (Fageta-taxceto) is found in the East Georgia (Kakheti district), as already mentioned, it occurs in the Batsara River Gorge (the Alazani River's left tributary). In

Table 1
The altitudinal range of *Taxus baccata* in different countries of temperate Eurasia.

Countries/Regions	Elevations	Authors
South Slovakia	660–1000 m a.s.l.	Thomas & Polwart, 2003
Alps	1100–1400 m a.s.l.	,,——————————“
Iran	1400 m a.s.l.	,,——————————“
Turkey	1400–1900 m a.s.l.	,,——————————“
Pyrenees	1400–1650 m a.s.l.	,,——————————“
Southern Spain	1600–1900 m a.s.l.	,,——————————“
Carpathians	1660 m a.s.l.	,,——————————“
Sardinia	1700 m a.s.l.	,,——————————“
Macedonia	1800 m a.s.l.	,,——————————“
Central Greece	1950 m a.s.l.	,,——————————“
Northern Africa	2000–2500 m a.s.l.	,,——————————“
The Greater Caucasus Range (GCR)	1900 m a.s.l.	Tvauri, 2006
GCR	2000 m a.s.l.	Sukhachev, 1934
GCR	2050 m a.s.l.	Thomas & Polwart, 2003
GCR (Okhachkue, W. Georgia)	2200 m a.s.l.	Gegechkori, 2015
GCR (Khvamli, W. Georgia)	1950 m a.s.l.	,,——————————“, 2016