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ORIGINAL ARTICLE

The dendroecological potential of shrubs in north Iranian semi-deserts

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ABSTRACT

In deserts and semi-deserts such as in the Irano-Turanian region in northern Iran, forest vegetation is scarce but shrubs are dominant. For this floristic province, placed in a biodiversity hotspot with a cold and dry climate, we provide the first climate-growth study on shrubs. From stems of three wide-spread shrubs (*Astragalus*, *Rhamnus* and *Ephedra* species) annual rings were identified and their widths measured.

On average, around 40-year long annual-ring series per stem were obtained, cross-dated and related to meteorological variables. *Astragalus* and *Rhamnus* reflected a clear regional climate signal in their ring widths whereas *Ephedra* showed an only weak association with climate variables. While above-average air humidity in combination with low temperatures in spring and summer favored shrub growth, precipitation had surprisingly only a weak effect on growth. From the abundance of fog events in this area, we concluded that the extreme moisture dependency of the shrubs before and throughout the growing season may have been relieved by the uptake of fog drip through the foliage.

As projected by climate models, the deficit in humidity will intensify and temperature will continue to rise in this region. So, the ability of the Irano-Turanian endemic shrubs to infiltrate into neighboring regions could become limited and their current distribution range may be confined to higher elevations which provide a moister and cooler environment.

1. Introduction

Phytogeographically, large parts of Iran are characterized by floristic elements of the Irano-Turanian steppe (Akhani et al., 2013), with features such as scarcity of forest vegetation, dominance of chamaephytes (mainly dwarf shrubs), occurrence of specific taxonomic groups, including the "giant" genus *Astragalus* (Fabaceae), high species richness and endemism, and a very high potential of its floristic elements to penetrate into neighboring regions (Djamali et al., 2012). The climate in the Irano-Turanian region is characterized by low amounts of precipitation and a long dry summer season (Sagheb Talebi et al., 2014). In mountain ecoregions a dry and cold climate predominates (Heshmati, 2012), and the vegetation consists mainly of xerophyte plants with plenty of shrublands (Zohary, 1973). Despite its role as refugia for xerophytic species, this region is up to now still poorly studied (Manafzadeh et al., 2014).

Shrubs play a vital role in maintaining an ecological balance in arid regions like the Irano-Turanian steppe (FAO, 1989). They protect the soil against wind erosion (Garcia-Moya and McKell, 1970), serve as nitrogen reservoir through the storage of nitrogen in roots, stems, and leaves (Jalali et al., 2012), protect the plants underneath (Jafarian et al., 2013), and may even act as nurse plants for the seedlings of trees like oak (Callaway and D'Antonio, 1991). Desertification in the Irano-Turanian region and rise of dust storm frequency in the west of Iran (Amanollahi et al., 2015) are worrisome ecological issues, which are partly related to the extinction of shrublands in Iran as well as in countries west of Iran (Zeinali and Asghari, 2016). At the same time maintenance and expansion of these shrublands through plantation have been proposed as a possible solution for these issues (Amiraslani and Dragovich, 2011; Zeinali and Asghari, 2016). Moreover, as in recent decades, the weather has become warmer and drier in the northwest parts of Iran (Sagheb Talebi et al., 2014), a possible shrub retreat needs more attention. Although techniques like remote sensing have been applied to monitor the shrublands in Iran, no direct observation of shrub growth and its responses to changing climate has yet been made in the region. Hence, for the first time, we investigated the potential of shrub species growing in the highlands of the Irano-Turanian region for dendroecology. We also aimed to determine which climate factors control radial growth during different periods of the year. Knowledge about the growth patterns in shrubs and about the environmental factors affecting these patterns are essential to understand the mechanisms underlying a shrub expansion or retreat

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(Blok et al., 2011), to achieve a comprehensive view of ecosystems at a regional scale (Srur and Villalba, 2009) and of the conservation of plant communities (Gazol and Camarero, 2012; Génova et al., 2013).

Although annual ring widths and wood density, as well as stable isotopes or xylem anatomical features in woody plants in temperate and cold regions have largely been used as a source of information on past environmental changes (Seo et al., 2013), the focus of these studies was on large trees whereas the application of dendroecological analysis on shrub species is a relatively recent advance of the last three decades (Woodcock and Bradley, 1994; Gers et al., 2001; Schweingruber and Dietz, 2001; Bär et al., 2006; Liang and Eckstein, 2009; Srur and Villalba, 2009; Weijers et al., 2010; Blok et al., 2011; Gazol and Camarero, 2012; Liang et al., 2012; Myers-Smith et al., 2015b). Shrubs may present a unique possibility to extend the present tree-ring networks beyond latitudinal and altitudinal tree lines (Liang et al., 2012; Lu and Liang, 2013). Moreover, for understanding long-term interactions between plants and their environments in harsh and treeless regions (e.g., in steppes, deserts and mountains in the Irano-Turanian region), shrubs and dwarf shrubs are the best or even the only option (Zimowski et al., 2014). Most shrub dendrochronological studies focused on alpine, boreal and arctic shrubs (Lu and Liang, 2013; Myers-Smith et al., 2015b; Young et al., 2016) with temperature as a common growth-limiting factor. Recently, dendrochronological methods have received more attention to study ecology of shrublands in hot-summer Mediterranean climate with drought stress (Gazol and Camarero, 2012; Zimowski et al., 2014; Oddi and Ghermandi, 2015). However, xerophyte shrubs in arid and semi-arid regions in the Middle-East have not been studied yet. Studies on vegetation-climate relations in Iran using annual growth rings are mainly confined to trees in the Hyrcanian forests with subtropical climate on the mountain chain along the southern Caspian Sea coast. These forests have undergone intense deforestation as a result of over-harvesting or socio-economic issues in the last decades. The vast area of pure scrublands especially in the very dry basin or semi-arid high mountain ranges of the Irano-Turanian region, on the other hand, are less or undisturbed ecosystems, threatened chiefly by climate change rather than human pressure. Shrubs in these unique environments present a unique opportunity to study the ecology of the area, and in combination with similar studies in nearby locations, provide a solid baseline datasets from which to study vegetation dynamics and succession across the region.

Based on the environmental characteristics of the region, we hypothesize that (1) variations in the annual ring widths of shrubs are influenced by the regional climate, (2) the response of shrubs to climate, manifested in their radial growth, may be species-specific, and (3) precipitation is the main limiting factor for growth in the shrublands studied. These hypotheses were tested by applying conventional dendrochronological methods on three co-dominant shrub species, i.e. *Astragalus brachycalyx*, *Rhamnus pallasii*, and *Ephedra procera*. These species are widespread in the Middle East and Western Asia.

2. Material and methods

2.1. Study area

In the winter of 2013 shrubs of *A. brachycalyx* Fisch. (17 individuals), *R. pallasii* (16) and *E. procera* C.A.Mey. (21) (hereafter the genus names will be used only) were collected on the Asgar Abad village meadow (47°43′ E and 37°54′ N, 1870 m a.s.l.), approximately 15 km east from Sarab city in the northwest of Iran (Fig. 1). The study area is located in a mountainous part of the Irano-Turanian ecological zone between Sarab and the Caspian Sea coast. The climate is cold and dry with 243 mm of total annual precipitation and a mean annual temperature of 8.6 °C (1987–2013) (Fig. 2). Although the minimum temperature is below 0 °C on around 150 days/year, the summers are pleasantly warm with the mean July temperature of 20.1 °C. The dominant climate patterns that influence the region are Black Sea and Mediterranean westerlies. Typically, a northwesterly flow reduces precipitation and lowers temperatures (Alijani, 2002). The number of days with precipitation (rainfall ≥1 mm, snow or sleet) in winter, spring and summer, respectively, are about 14, 7, and 1 mm. Rainfall occurs from early fall to late spring and reaches its maximum in winter. A considerable number of fog events (probably upslope fogs) occur in the area, especially in the highlands. Moreover, a north wind blows throughout the year which is cold in winter and cool and moist in summer. This wind is called “fog wind” in the local language and could be another source of fog events on the ridges. The monthly climatic data (total precipitation, average temperature and average relative air humidity) were obtained from 1987 to 2013 from the Sarab meteorological station which is located less than 13 km away from the study site at 1682 m a.s.l. Over the last decade, this station typically records the lowest precipitation compared to other stations in the region (Pooralihosein and Massah Bavani, 2014).

2.2. Sample preparation

All three species are found growing together at the sampling site and in the region but the frequency of individuals varies from place to place. In general, *Rhamnus* grows mostly as a multi-branched, 1.5 m high shrub. This species grows on dry stony slopes in northeast Turkey, Georgia, Armenia, Azerbaijan, and northwest Iran. *Astragalus* and *Ephedra* have fewer branches. Whereas *Astragalus* rarely gets taller than 50 cm, *Ephedra* can reach 1 m of height (Fig. 3). *Astragalus* is commonly found on rocky mountain slopes in western Asia, from western Iran and northern Iraq to East Turkey (Zarre-Mobarakeh, 2000). This species prefers dry soil and can grow in nutritionally poor soils. *Ephedra* is widespread in highlands of Caucasus and extending eastwards to Pakistan; growing in rocky arid areas. According to Myers-Smith et al. (2011), almost all species of *Astragalus* in the study region can be categorized as dwarf shrubs (0.1–0.4 m), most of the *Rhamnus* individuals are tall, multi-stemmed shrubs (1–1.5 m), while *Ephedra* is seen almost equally in both forms of tall and dwarf shrubs. However, for the sake of simplicity, we only use the term “shrub” throughout the paper. These three dominant shrub species are deciduous, show clearly visible annual growth rings and stable populations (Gazol and Camarero, 2012) and, moreover, they are the least preferred by grazing animals. Other shrub species, mainly *Peganum harmala*, *Pteropyrum olivieri* and *Rosa canina* were also present (Emami-Nasab and Oladi, 2014). They have distinct rings but we did not study *Pteropyrum* and *Rosa* since *Pteropyrum* has irregular rings and *Rosa* individuals are short-lived and more grazed upon other shrubs. However, studies on *P. harmala* are underway.

The main or the thickest stem of each shrub was cut from 1 to 2 cm above the ground. Shrubs with an upright and straight main stem were preferred to avoid reaction wood. In the laboratory, 5–10 consecutive disks with a thickness of about 3 cm were cut along each stem with distances of 1 cm between each other to detect missing or discontinuous annual rings, as suggested by Kolishchuk (1990) and later applied in Bär et al. (2006), Gazol and Camarero (2012), Myers-Smith et al. (2015b), and many other shrub studies. To increase the visibility of wood anatomical features and trace the probable variation of the ring width around the circumference of the stems, the disk surfaces of *Rhamnus* and *Ephedra* were finely sanded. Since such polishing was not satisfactory for *Astragalus*, its disk surfaces were cut using a sharp blade. The resulting smoothed surfaces were then scanned at 4800 dpi resolution using a conventional scanner (HP C4100). The images obtained from the scanning of the whole disk gave us a broad view on growth irregularities, i.e. eccentricity and non-uniform cambial activity (Myers-Smith et al., 2015b), hence helping us to choose the best radius for sectioning. Afterwards, pith-to-bark sections (approximately 1.5 cm wide) were taken from each disk using a chisel, and of these sections, cross-sections (< 10 μm thick) were cut with a sliding microtome (GSL-1, WSL) and stained with safranin (safranin 0.5%