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Dendrochronological potential of *Ephedra equisetina* from Zaravshan Mountains (Tajikistan) in climate change studies

KEY WORDS:
dendrochronology, climate change, shrubs, *Ephedra*, Zaravshan Mountains, Tajikistan.

ABSTRACT.

Samples from Mongolian *Ephedra* (*Ephedra equisetina* Bunge) was collected in the Zaravshan Mountains (the Fann Mountains), Tajikistan. The wood of *Ephedra* is ring-porous with well-defined growth rings. Annual ring widths were measured, individual series were first cross-dated and then averaged as a standard chronology. Correlations were calculated between the standard ring-width chronology and monthly climate data recorded in the weather station Iskanderkul. Dendroclimatological analysis showed that July temperature is the growth limiting factor of this species. Our study has shown high dendrochronological potential of *Ephedra*.

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Introduction

Traditionally dendrochronological research has been limited to the forests areas. In recent years, interest has increased in dendrochronological studies of shrubs and dwarf shrubs species. Despite some difficulties (e.g. sample preparation, cross-dating, limited age) this method has successfully been applied to shrubs in various parts of the world (e.g. Woodcook and Bradley 1994, Schmidt et al. 2006, Zalatan and Gajewski 2006, Au and Tardif 2007, Bär et al. 2007, Xiao et al., 2007, Sass-Klaassen et al. 2008, Owczarek 2009, Owczarek et al. 2013). Most of the studies are related to arctic or subarctic shrub species. Although *Ephedra* does produce growth rings, which in most cases are of roughly annual frequency, the genus has never been used for dendrochronological research (Earle 2013). The aims of this study are: (1) to investigate dendrochronological potential of *Ephedra* from the western Pamir-Alay and determine the actual age of shrubs, (2) to evaluate possibility of accurate cross-dating, and (3) to analyze growth response to the extreme environment.

Material and Methods

Fig 1. *Location of the study area (red rectangle) and existing tree-ring chronologies (green triangles) in Central Asia.*

Study area and climate

The study area is located in the Fann Mountains, which are part of the western Pamir-Alay Mountain system, located in Tajikistan's Sughd Province within the Zaravshan Range, to the north of Gissar Range (Fig. 1).

The main predominant characteristics for Tajikistan's climate are: aridity, abundance of heat and significant interannual variability. The climate of the Fann Mountains is a dry continental one further accentuated by the screening effect of the surrounding high ridges from the moist westerly and north-westerly winds (Lydolph 1977, Makhmadaliev et al. 2008). The annual precipitation recorded in the study area (Iskanderkul station) is 275 mm, mean precipitation is highest in April (55.8 mm). Mean annual temperature is 6.5°C. Mean monthly temperature varies from -5.4 °C in January to 18.0°C in July (Fig. 2).

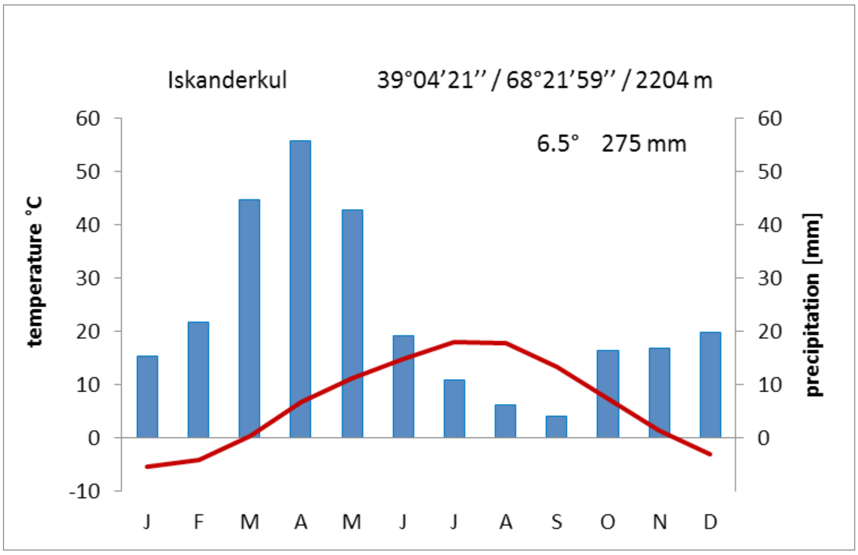


Fig 2. *Climate diagram of the Iskanderkul climate station. Mean precipitation and temperature are indicated by a blue and red line, respectively. Data are averaged over the period AD 1930–1997.*

Fig 3. Mid-mountain xerophytic light forest ecosystems (Ferula kuhistanica, Rosa Ecae, R. Fedtschenkoana, R. Ovczinnikovii, Berberis heteropoda, Ephedra equisetina).

Shrub sampling and chronology development

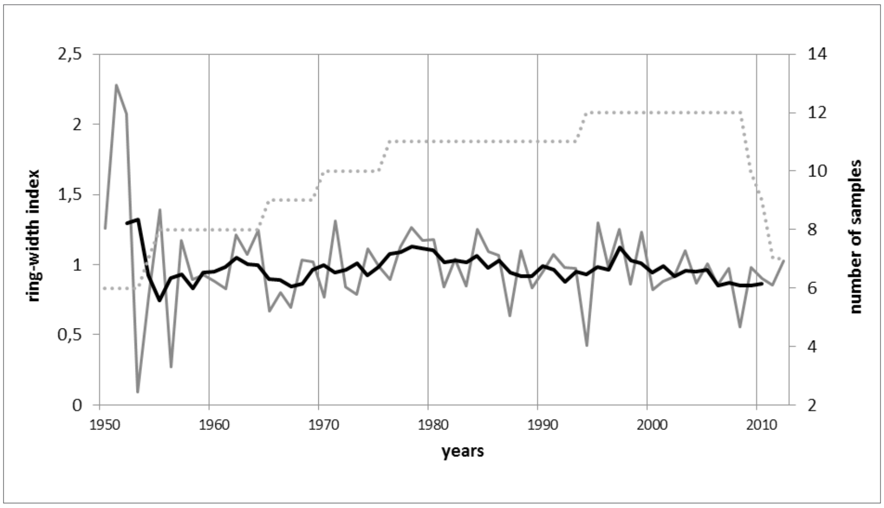
The sampling site was located at the elevation of 2200-2250 m a.s.l.. Twenty stem discs of the Mongolian *Ephedra (Ephedra equisetina* Bunge) (Fig. 3) were collected using a hand saw. It was not possible to take increment cores due to small-diameter of steams (>5 cm). An extensive sample collection was not made in order to minimalize detrimental impacts on the ecosystem. To minimize non-climatic effects on tree growth, only shrubs without injury and disease were taken. The samples were processed according to the standard dendrochronological procedures (Cook and Kairiukstis 1990). The discs were dried and sanded with progressively finer grit sand paper. Growth ring widths were measured to the nearest 0.01 mm using a LINTAB measuring system and TSAPW in software (Rinn 2010). The crossdated tree-ring sequences were quality checked by the COFECHA program (Holmes 1983). To remove non-climatic trends from the raw ring width we used the program ARSTAN for detrending (Cook and Holmes 1999). The ring-width chronology was developed by fitting a negative exponential function to preserve low-frequency variability and maximize the climate signal.

Dendroclimatological analysis

For the dendroclimatological analysis we used station records of Iskanderkul (2204 m a.s.l.), which were obtained from National Snow and Ice Data Center, Central Asia Temperature and Precipitation Database (Williams and Konovalov 2008), through their web site: http://nsidc.org/data/g02174.html. The station data includes monthly precipitation and monthly mean temperature, monthly mean maximum temperature, and monthly mean minimum temperature. Bootstrapping correlations were calculated between the standard chronology and monthly climate data using DENDROCLIM2002 (Biondi and Waikul 2004). All statistical procedures were evaluated at obvious level with $p < 0.01$.

Results and discussion

Fig 4. Residual ring-width chronology of Mongolian Ephedra from the Zaravshan Mountains. The ring-width indices and their 5-year moving average, and the sample depth are indicated



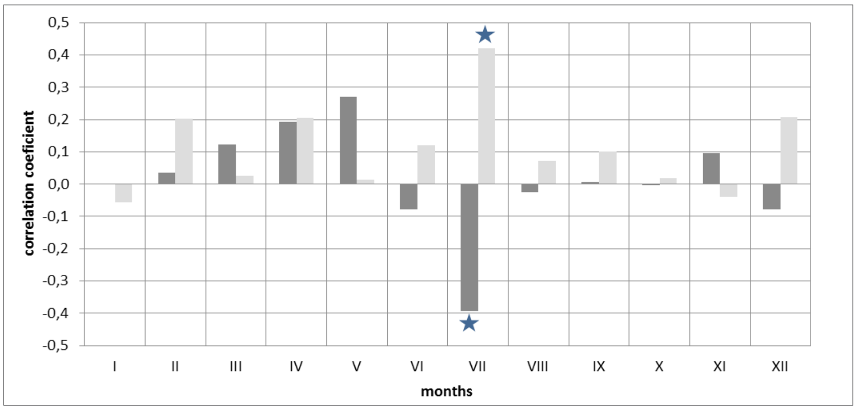
Wood and Chronology characteristics

The wood of Mongolian *Ephedra* is ring-porous with vessels present only in first portion of each growth ring, lacking resin ducts, with wide multiseriate rays (Carlquist 1992, Fu et al. 1999). Ring boundaries were clearly visible. Age of the examined specimens ranged from 15 to 63 years. Mean ring width varied from 2 mm to 12 mm. Apart from the wider innermost rings distinct age trend was not visible. No comparative analyses can be done as this species has never been analyzed by means of dendrochronology. However, the mean growth rate of *Ephedra* from Tajikistan is similar to the growth of rododendron species from the Tibet (0.36 mm per year) (Liang and Eckstein 2009), and much wider then subarctic and arctic dwarf shrubs (0.01 mm – 0.1 mm per year) (Au and Tardif 2007, Owczarek 2009, Owczarek et al. 2013).

Mean correlation between the shrubs represents the strength of the common signal among the series. The mean correlation of analyzed ring widths series is 0.43. Mean sensitivity (MS) and standard deviation (SD), which are believed to indicate greater climatic influence on growth (Cook and Kairiukstis 1990), is also quite high (MS=0.35, SD=0.55). The constructed chronology span the years 1950-2012 (Fig 4).

Favorable growth conditions occurred in the years: 1962, 1971, 1978, 1984, 1995, 2007. Negative years can be distinguished in the chronology in the years: 1953, 1956, 1965, 1987, 1994, 2008. This results correspond with data obtained for shrubs from the Tibetan Plateau (e.g. Liang and Eckstein 2009).

Fig 5. Correlation of the ring-width chronology of Ephedra equisetina with climatic variables (dark bars for precipitation and light bars for temperature). The significant (P = 0.01) months are indicated by an asterisk.



Climate-growth relationship

The Mongolian *Ephedra* ring width variability is positively correlated with temperature (mean, maximum and minimum) in July of the current year, all recorded at Iskanderkul (Fig. 5). It has been reported that the monthly mean minimum temperatures in July of the current year are the dominant and unifying growth limiting factors for timberline coniferous tree species from the Tibetan Plateau (Zheng et al. 2008, Liang et al. 2008, 2009). Also, Siberian larch from East Kazakhstan was found to be sensitive to the June–August seasonal average of maximum temperature (Chen et al. 2012). Moisture availability is not problematic for *Ephedra* in the study area. Apart from opposite correlation with July precipitation, no significant relationships between tree growth and precipitation were found. Fig. 6 presents course of growth rings index and climate variable. However, opposite climatic response was calculated for the dwarf shrub Wilson juniper (Juniperus pingii var. wilsonii) from central Tibetan Plateau (moisture turned out to be growth limiting for Wilson juniper) (Liang et al. 2012).

Conclusions

Our study has proved the high dendrochronological potential of *Ephedra equisetina*, shrub species common in analyzed part of the Zaravshan Mountains, Tajikistan. The preliminary investigations indicated its well-defined growth rings, reliable cross-dating between different individuals, and distinct climatic signals reflected by the ring width variability. This new to the dendrochronology species, offers new research directions to investigate the climate and environmental changes, in the regions where analysis of annual rings of trees cannot be applied. However, for the long-term climate reconstruction, it deserves further study to collect *Ephedra* older individuals or its relict material. The obtained research results provide grounds for the further investigation on the potential of other shrub species in the areas beyond survival limits of trees.

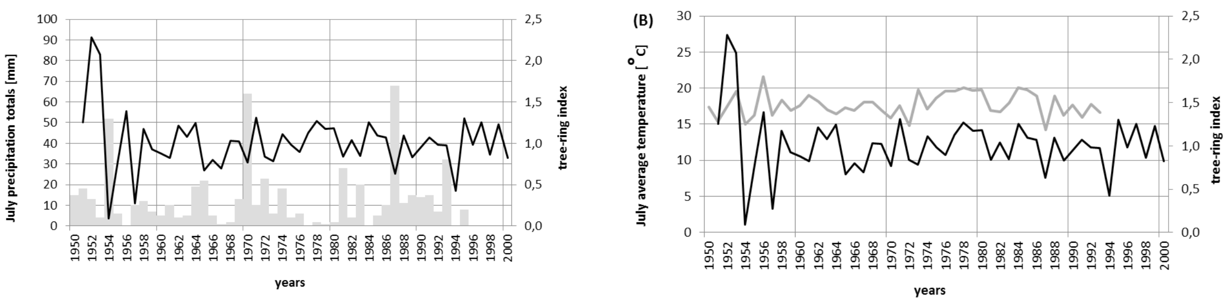


Fig 6. Ephedra equisetina ring-width chronology compared with July climate variables: (A) precipitation, (B) temperature.

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