

Comparison of the influence of climate on tree-ring growth on different spruce species growing in different environmental conditions

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Introduction

Spruce is one of the most common and widely distributed tree species in the world. Norway spruce, Schrenk's spruce, Himalayan spruce and Siberian spruce belong to the same group of spruces (Bykov 1985). However they are located in different geographical and altitudinal regions of the world. One of the countries where Schrenk spruce found the best growing conditions is Kyrgyzstan, Schrenk spruce occupies almost all of eight forest districts. However, its stands are very fragmented and grow at different elevations, where climate factors create diversified growing conditions (Grisa and all 2008, Orlov 1989 Gan 1970,). One forest district where spruce finds favourable growing conditions is III-Fergano Chatkal (Sary-Chelek and Kang Kol Biosphere Reserve). Norway spruce is a widely distributed species in Eurasia, but in Poland, Norway spruce only occurs in theoretical range the northern and southern parts of the country.

The objective of this study was to compare two species of spruce (Schrenk spruce, Norway spruce) which grow in two different environmental conditions (Kyrgyzstan, Poland) and to study difference in their growth strategies under different pluvial conditions.

Material and methods

The study was conducted in Poland and Kyrgyzstan including three study sites, respectively. In Kyrgyzstan, the Sary-Chelek Biosphere Reserve and Kang Kol Reserve (Fig. 1) are situated on the southern slopes of Chatkal massif in the western mountain ranges of the Tien-Shan. In Poland, study sites are located in south Poland (Karpaty mountains, Tatra National Park), study places are located in Kościeliska valley and in north-east Poland in Lidzbark and Zaporowo Forest Districts (Fig 2).

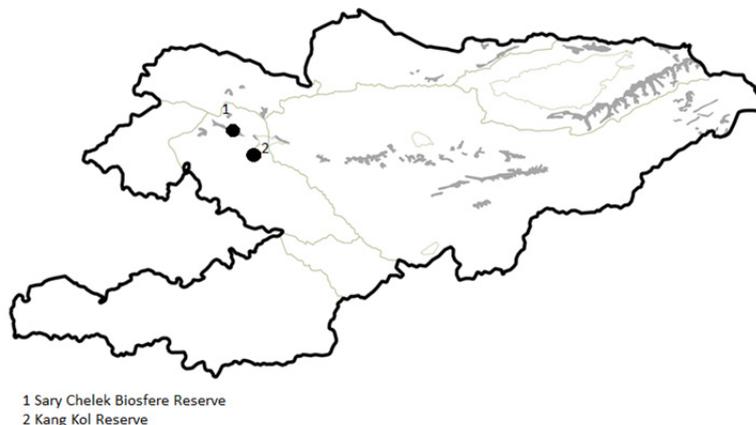


Figure 1: Map of Kyrgyzstan with 1-Sary-Chelek Biosphere Reserve, 2-Kang-Kol Reserve

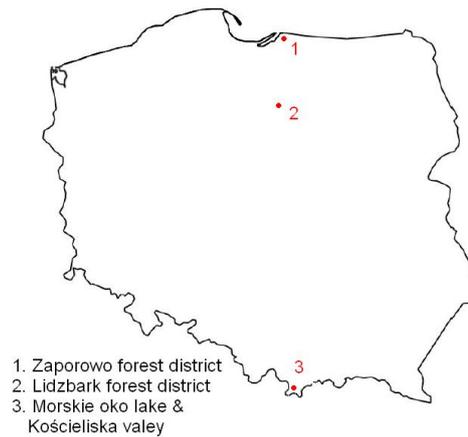


Figure 2: Map of Poland: 1-Zaporowo forest district, 2- Lidzbark forest district, 3-Morskie Oko lake and Koscieliska valley

Increment cores (one per tree) were sampled from dominant and co-dominant trees. In Kyrgyzstan and in the Tatra mountains perpendicularly to the slope to minimize the effects of slope inclination on tree-ring width. In each plot 15-20 trees were sampled, located in the area.

Tree-ring widths were measured using the Coorecorder 7.3 software, and verified using CDdendro 7.3 (www.cybis.se). After COFECHA analyses, samples with low cross-correlation results were eliminated from further analyses (Holmes 1983). As a result the real chronologies (real tree rings width) have been compiled. For these chronologies, basic statistical measures of ring widths were calculated like arithmetic mean, median values, standard deviation, and mean sensitivity (Tab. 1).

Tab. 1. Characteristic of spruce's residual chronologies.

Study region	Characteristic of residual chronologies							
	Study site	Elevation a.s.l	Data of collection data	Mean	Median	Standard deviation	Mean sensitivity	Chronology length
East Part of Tian-Shan Kyrgyzstan	Kang-Kol	2000 m a.s.l.	2011	1,041	0,969	0,412	0,174	1870-2011
	Sary-Chelek	1400 m a.s.l.	2010	1,010	0,965	0,309	0,179	1830-2009
South Poland	Koscieliska	1100 m a.s.l.	2011	0,979	0,969	0,150	0,106	1889-2012
	Morskie Oko	1400 m a.s.l.	2011	0,940	0,985	0,228	0,163	1904-2012
North – West Poland	Lidzbark	161 m a.s.l.	2012	0,968	0,982	0,181	0,146	1937-2013
	Zaporowo	137 m a.s.l.	2012	0,969	0,948	0,229	0,154	1953-2012

The ARSTAN software was used (Cook and Holmes 1986; Cook and Kairiukstis 1990) to develop residual chronologies by applying negative exponential curves or straight lines as detrending functions (double detrending with two different lines seems to be one of the best methods of detrending) . The standard chronologies were used for comparison of the radial increments of spruce in the analysed area (Tab 2). The residual chronologies were used to assess growth-climate (only precipitation) relationship with a linear Pearson's correlation (Pearson 1995). The significance of the observed relationships was recognized at $p=0.05$ level.

Tab. 2. Comparison of coincidence (*p* value) of chronologies thick growth of trees by *t*-test.)

	Morskie Oko 1400	Koscieliska 1100	Sary-Chelek 1400	Kang-Kol 2000	Zaporowo 137	Kostkowo 161
Morskie Oko 1400	x					
Koscieliska 1100	0,050409	x				
Sary-Chelek 1400	0,025010*	0,240481	x			
Kang-Kol 2000	0,192485	0,821410	0,294054	x		
Zaporowo 137	0,534331	0,334828	0,169566	0,579537	x	
Kostkowo 161	0,388375	0,331279	0,137033	0,599627	0,901366	x

- Lack of coincidence of chronologies at 0,05 significance level

Data for the analysis covered both the year of the tree-ring formation and the previous year (a total of 24 months), as well as an average representing each climatic season. Climatic conditions in the Sary-Chelek Reserve were characterized by the total precipitation obtained from the meteorological station situated in the center of the Sary-Chelek village, elevation 1100 m a. s. l., (precipitation for period 1969-2009, 40 years). In the Tatra mountains meteorological data was taken for 100 years (2009-1900) and comes from CruTs (Climat Research Unit) data base (<http://badc.nerc.ac.uk/data/cru/>) (Mitchell i in. 2004). Climate data used in north – east Poland comes from Kostkowo forest station (period 1988-2011) – Lidzbark Forest District Region.

Results

The longest chronology, reaching back to 1830 AD (179 years) was created from the spruce site located at 1400 m a.s.l. in Sary-Chelek Biosphere Reserve in Kyrgyzstan (Tab. 1).

The mean tree ring width shows similarity (tree rings width) among the spruce sampling sites, reaching from Kyrgyzstan 1,041 mm Kang-Kol Reserve, 1,010 mm, Sary-Chelek Biosphere Reserve, to South Poland, Koscieliska valley 0,979 mm, and Morskie Oko valley 0,940 mm and North- West Poland, Lidzbark Forest District 0,968 mm mm, Zaporowo Forest District 0,969 mm. However, differences in standard deviation were observed: Highest standard deviations occurred in the Kang-Kol Reserve and Sary-Chelek Reserve in Kyrgyzstan, the lowest standard deviation was observed in south Poland in Koscieliska valley (Tab.1).

Monthly precipitation data showed mostly positive association with tree ring growth at the Kyrgyzstan (Fig.1) sites. Positive correlations were found with winter, spring, summer and autumn precipitation prior to the year of ring formation at the 2000 m a.s.l in Kang-Kol Reserve. In the Sary-Chelek Biosphere Reserve at elevation 1400 m a.s.l., positive correlations were found with summer, autumn and winter precipitation prior to the year of ring formation (July, August, September, October, November and December) (Fig. 3). The North-West Poland site showed different growth reaction with precipitation. Significantly positive correlations were found at Zaporowo district between January precipitation in the prior year of ring formation and January, August in the year of ring formation (Fig. 4). At Lidzbark site, positive correlation was found only in August in the year of tree-ring formation. Negative correlations were observed between June precipitation of the prior year of tree-ring formation at Zaporowo, and with July and December at Kostkowo district, in current year on tree rigs formation and in September at Zaporowo District. In the south Polish sites, no significant correlations of tree growth with precipitation were found (Fig. 5).

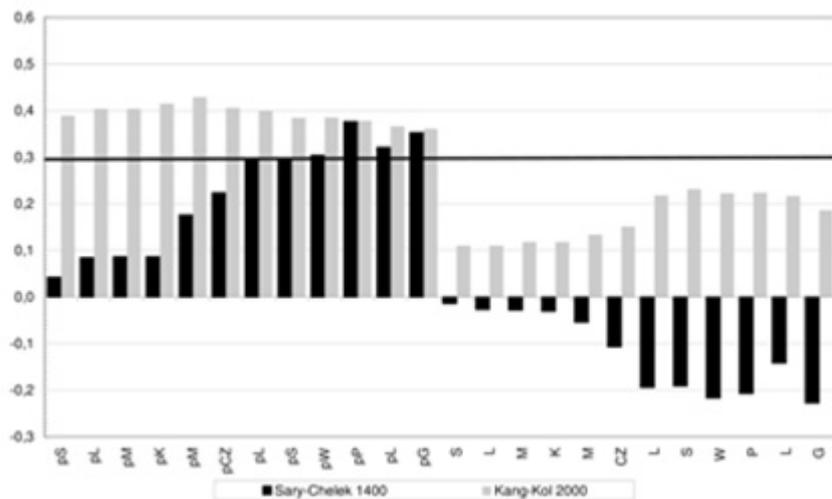


Fig. 3. Correlation between *Picea schrenkiana* residual chronologies and precipitation in the Sary-Chelek Biosphere Reserve and Kang-Kol Reserve. Horizontal lines indicate correlations at $p < 0.05$.

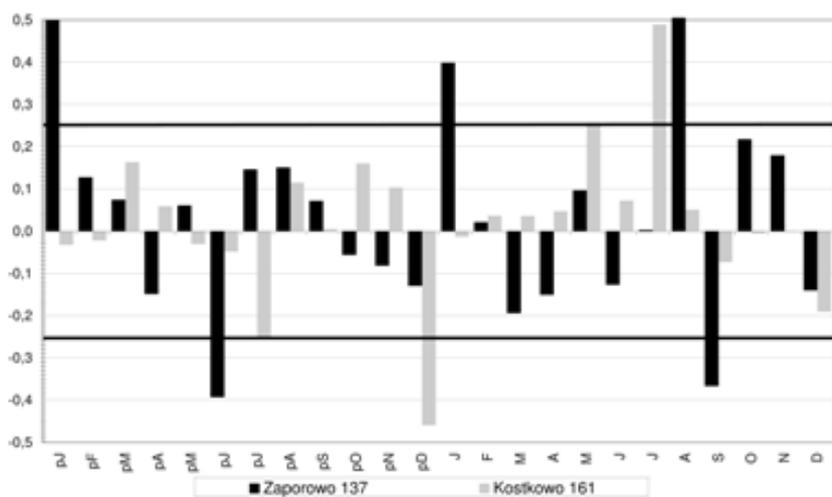


Fig. 4. Correlation between tree-ring width of *Picea abies* and mean monthly precipitation in Lidzbark and Zaporowo forest districts. Horizontal lines indicate correlations significant at $p < 0.05$.

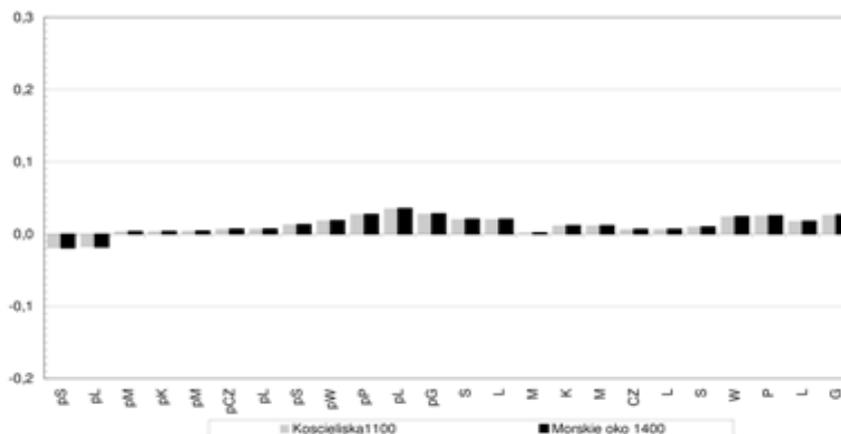


Fig. 5. Correlation between tree rings width of *Picea abies* trees and mean monthly precipitation in Morskie Oko lake and Koscieliska valley. Horizontal lines indicate correlations significant at $p < 0.05$.

Conclusions

- The research stands from Kyrgyzstan characterized the biggest tree-ring width value, the longest chronology are also from Kyrgyzstan (Tab. 2). The Pearson correlation with tree rings and precipitation is the biggest also in Kyrgyzstan (Fig. 1).
- Characteristic of standard chronologies from all study areas are similar without chronologies between Morskie Oko 1400 & Sary-Chelek 1400 all (Tab.2)
- At study sites from Kyrgyzstan and Mazury District (Kostkowo and Zaporowo), correlation between precipitation and tree-ring width were observed (Fig 2, Fig 4), whereas at sites from the Tatra Mountains (Fig. 3) no correlation between tree-rings width and precipitation were found. This could be normal accepted on 1100 m a.s.l, but not significant reaction on 1400 m a.s.l could be created by regional conditions.

Acknowledgements

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