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SHORT COMMUNICATION

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Ecological and genetic aspects of distribution of the marginal populations of Swiss stone pine (*Pinus cembra* L.) in Ukrainian Carpathians

Vasyl Mohytych[1] ✉, *Marcin Klisz*[1], *Roman Yatsyk*[2], *Yuriy Hayda*[3], *Mariana Sishchuk*[2]

[1] Forest Research Institute, Department of Silviculture and Genetics of Forest Trees, Braci Leśnej 3, Sękocin Stary, 05-090 Raszyn, Poland, phone: +48 227150476, e-mail: V.Mohytych@ibles.waw.pl

[2] Ukrainian Mountain Forestry Research Institute named after P.S. Pasternak, Mykhaila Hrushevskoho 31, 760018 Ivano-Frankivsk, Ukraine

[3] Ternopil National Economic University, Lvivska 11, 46400 Ternopil, Ukraine

Abstract

Current distributions of Swiss stone pine mostly cover the mountain regions of Europe (Alps and Carpathians). Easternmost distribution of this species is located in western Ukraine. Due to environmental fragmentation in Eastern Carpathians and competition with Norway spruce and other species, marginal populations of Swiss stone pine create isolated island, where other species are not able to cope with harsh conditions. Still, *Pinus cembra* L. play an important role for soil-formation and soil-protection in high elevations. The evidence of recent reduction in the area of Swiss stone pine raises the question whether the introduction of this species at lower altitudes can be successful? According to the studies conducted on reciprocal transplant experiments, Swiss stone pine population from higher elevation are able to profit in low elevation sites. Thus, parallelly with gene conservation activity, the possibilities of assisted migration should be recognized for this species.

Key words

Swiss stone pine, Eastern Carpathian mountains, habitats fragmentation, gene conservation, marginal population

Distribution and characteristics of natural populations

Swiss stone pine (*Pinus cembra* L.), a post-glacial relict and valuable forest-forming tree species, in Ukrainian Carpathians reaches the north-eastern border of the species' range (Fig. 1; Huber et al. 2017). Occupying debris fields, it plays an important soil-forming, soil-protecting and water-regulating function (Smahliuk 1972; Sirenko 2008a). Until now, in the Carpathian natural forest stands, this species has been protected mainly in the inaccessible forest stands in Gorgany mountain (occasionally – Chornohora) range on high rocky slopes at altitudes of 1100–1500 m a.s.l. (over 80% – 1250–1450 m a.s.l.) in moist coniferous mixed forests, where it forms stands with Norway spruce or mountain pine (*Pinus mugo* Turra). The species is distributed in the Gorgany Nature Reserve, in the Carpathian National

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Natural Park, in botanic reserves of national importance 'Kedrynskyi', 'Tavpishyrskyi', 'Yaikivskyi', as well as landscape forest reserve of national importance 'Bradulskyi' and 'Grofa' (Didukh 2009; Los et al. 2014).

The climatic conditions of the area with Swiss stone pine stands is characterized by the average annual temperatures of -1.2°C to +5.9°C (July: +9.1 to +16.2°C, January: -12.2 to -5.1°C), annual precipitation from 1762 to 2051 mm and average relative humidity 77%. The upper limit of species distribution depends mostly on air temperature, wind, snow, humidity, and soil temperature. Swiss scots pine stands are predominantly (26%) located on the south-western slopes, due to their greater moisture content. The majority of natural stands (67%) are distributed on steep slopes (25–35°). The vast majority of species-specific habitats are dated to peat-podzolic soils, much less on brown mountain forest soils (Sirenko et al. 2014). Such mountain soils are characterized by early stages of soil formation, with high stone content and a mosaic pattern in soil structure development in the upper horizons (Krynytskyy et al. 2009). The largest share of stands with this species belongs to the coniferous mixed forests (76%) with Norway spruce, silver fir and silver birch (Sirenko et al. 2014). Coniferous mixed forests with dominating Swiss scots pine and Norway spruce are characterised by differing crown closure, with the density in the overstorey being far less than the lower canopies (Krynytskyy et al. 2009).

In the conditions of debris fields of Gorgany mountain range, *Pinus cembra* grows slowly reaching at the age of 200–300 years 17 ± 2 m height and the 40 ± 10 cm DBH, with stem volume ranging from 0.5 to 2.2 m^3. The average annual increment in diameter is 1.5 mm and the average annual volume increase is only 0.004 m^3. However, the highest annual volume, ranging from 0.005 to 0.01 m^3, was observed at the age of over 150 years (Chernevyy et al. 2011).

Habitats fragmentation and consequences for genetic variation

According to Sirenko (2005), in 1972, the Swiss stone pine stands occupied an area of 6,313.5 ha in Ivano-Frankivsk and Zakarpattia administrative regions. However, data reported in forest management inventory for 1997 and 1999 confirm reduction in the area of such stands to 4,194.6 ha. Consequently, over 25 years, the area of Swiss stone pine stands declined by 2,118.9 ha (34%).

Stands in the western Chornohora formed by Norway spruce with an admixture of Swiss stone pine moved up by 80 m a.s.l. on the average between 1933 and 2001 (Sitko and Troll 2008). Long term observation on Gorgany Nature Reserve (1200–1500 m a.s.l.) with Swiss stone pine stands revealed declining trend in share of this species. In the upper part of the nature reserve, the share of this species gradually decreased, while at the lower part, it almost disappeared (Smolensky et al. 2007). Thus, on fertile sites, Swiss stone pine is replace by Norway spruce and European beech. Due to the observed declining trend in the distribution of Swiss stone pine in Ukrainian Carpathians, continuous distribution of this species may transform to isolated island.

In consequence, isolated populations of Swiss Stone pine may face inbreeding depression, which may negatively affect seed quality (Politov et al. 2008). In view of the above, conservation of the Carpathian populations of Swiss stone pine is gaining importance. Marginal populations of Swiss Stone pine comprise private haplotypes and may represent a particular legacy of the species' evolutionary history (Krutovskii et al. 1995; Höhn et al. 2009).

The Carpathian populations were found to have higher gene diversity than the Alpine ones. The reduction in the area of Carpathian pine forests in Holocene, caused by the global climatic changes and the anthropogenic impact, is hazardous for the gene pool of this species. The maintenance of genetic uniqueness of Carpathian populations, and individual stands in particular, requires special attention for the protection of Swiss stone pine in the Eastern Carpathians (Belokon et al. 2005).

Carpathian populations of Swiss stone pine revealed higher levels of expected heterozygosity and differentiation in comparison with Alpine ones, caused by the fragmentation of their distribution in the region. The level of genetic variation confirmed by microsatellite markers was higher than it was earlier estimated by allozyme loci. Thus, the among-population differences in allele composition and frequencies could be applied for elaborating gene resources conservation strategy for this species (Mudrik et al. 2008). So far, in the Ukrainian Carpathians, four genetic reserves covering 632 ha were established and 19 plus trees of *Pinus cembra* were selected (Yatsyk 1996).

Studies of mycorrhiza, flowering phenology and growth

Studies on Swiss stone pine ecology in experimental conditions, so far focused on mycorrhizal fungi, flowering phenology as well as growth performance. According to Sirenko (2008b), in natural conditions, Swiss stone pine create four different mycorrhizas specific for this species. In turn, the experiment with soil inoculation with mycorrhizal fungi revealed significant increase in the number of seedlings in relation to the soil without mycorrhiza. Hence, mycorrhizal fungi specific for Swiss stone pine appear to be important conditions for seedlings' performance.

The phenology of Swiss stone pine generative organs development was studied in Vysokohirnyi Alpine Arboretum (VA, 1200–1300 m a.s.l., Ivano-Frankivsk administrative region; Fig. 1). Four years of phenological observation allowed to determine the length of all the phases from bud burst to seed maturation. According to Sishchuk and Yatsyk (2013), the whole period of seed formation lasted 96 days.

The intraspecific variability in growth performance of Carpathian populations of Swiss stone pine were tested on two genetic trials located in Vysokohirnyi Alpine Arboretum and Dibrova Arboretum (DA, 300 m a.s.l; Fig. 1). However, three Swiss stone pine populations (among other pine species) were included in these experiments (Tab. 1), only Ust-Chorna (USC) was planted on both trials. After 37 years of growth, the USC population, achieved significantly higher values of mean height growth and DBH on DA (lower trial) compared to VA (upper trial). Moreover, among three Carpathian populations tested on DA trial, Solotvyno (SOL) reached the highest mean DBH. Thus, based on such limited results, it can be concluded that most likely, growth conditions related to elevation may significantly affect growth performance of Swiss stone pine populations in Carpathians.

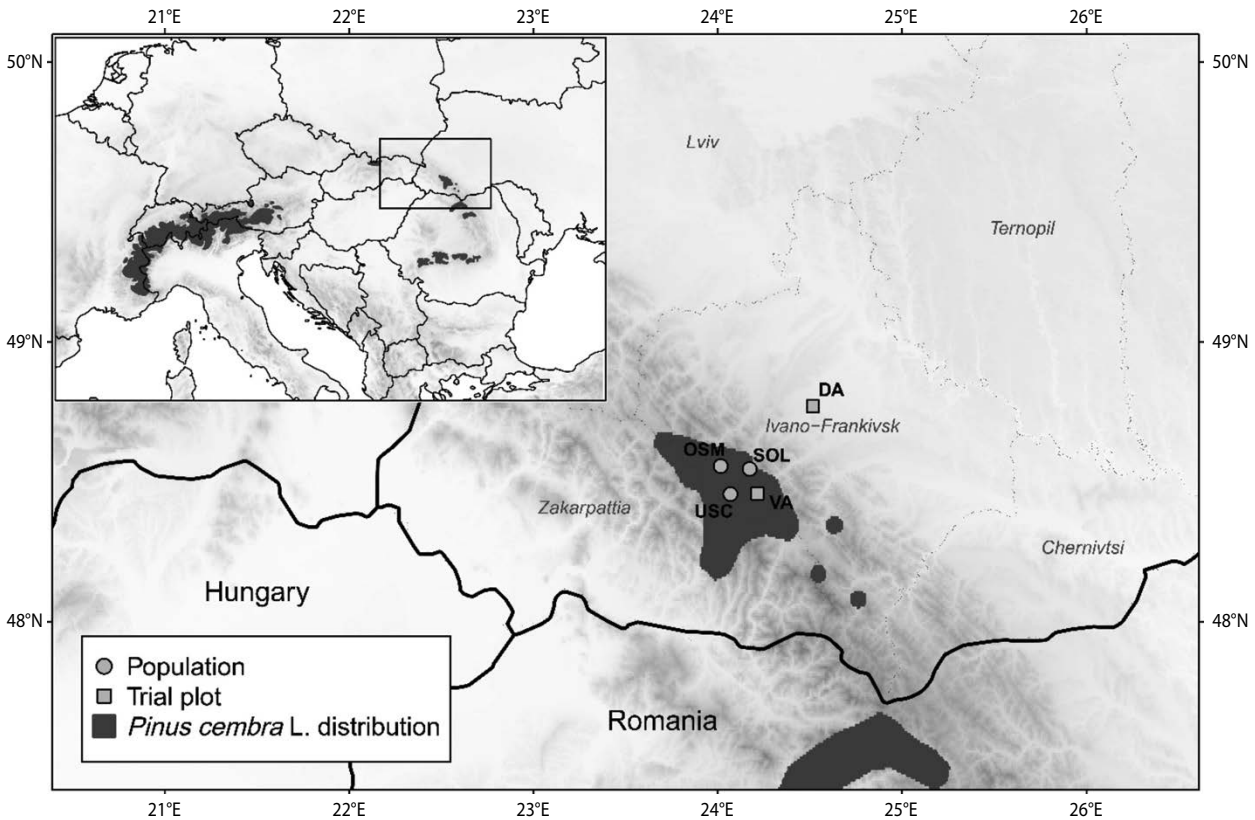

Figure 1. Natural distribution of Swiss stone pine in western Ukraine and distribution range in Europe (upper left map: in grey) according to http://www.euforgen.org/. Experimental sites: VA — Vysokohirnyi Alpine Arboretum, DA – Dibrova Arboretum. Natural populations: USC – Ust-Chorna, OSM – Osmoloda, SOL – Solotvyno

Table 1. Biometric characteristics of Swiss stone pine provenances on provenance trials Vysokohirnyi Alpine Arboretum and Dibrova Arboretum

Administrative region	Population	Age	Number of trees	Height [m]	DBH [cm]
Vysokohirnyi Alpine Arboretum (VA)					
Zakarpattia	Ust-Chorna (USC)	37	354	8.2 ± 0.11	18.1 ± 0.5
Dibrova Arboretum (DA)					
Zakarpattia	Ust-Chorna (USC)	38	87	11.5 ± 0.1	22.1 ± 0.6
Ivano-Frankivsk	Osmoloda (OSM)	42	62	11.1 ± 0.2	20.9 ± 0.7
Ivano-Frankivsk	Solotvyno (SOL)	43	79	11.5 ± 0.1	25.5 ± 0.9

Conclusions

Marginal populations of Swiss stone pine with its distribution mainly limited to Eastern Carpathians create isolated islands in Chornohora and Gorgany mountain range. Due to the fragmentation of their distribution high among population, genetic variation is observed. Distinct genetic structure of Ukrainian populations in relation to the Alpine and southern-Carpathian indicates the validity of developing conservation strategies for Ukrainian stone pine gene resources. There are evidence that high altitude populations have high capabilities to adapt in the conditions of the lower elevation indicating the possibility of their introduction in the foothills of Eastern Carpathians. However, to define the criteria for the introduction of this species, it is crucial to determine the ecological requirements and the climatic margin of its distribution.

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