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Inna Tsaryk[1], Yakiv P. Didukh[3], Lidia Tasenkevich[4], Barbara Waldon[5], Adam Boratyński[2]

Pinus mugo Turra (Pinaceae) in the Ukrainian Carpathians

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Abstract: *Pinus mugo* occurs only in the highest mountain chains of the Ukrainian East Carpathians. The largest part of the species area covers the Chornokhora ridge and the highest ridges of the Gorgany. In the other mountains of Ukraine it does not form thicket on so large terrains. Vertically, most of localities are placed at an elevation between 1400 and 1900 m, with maximum at 2010 m in the Chornokhora and with minimum about 700–800 m. The latter stands were reported from the peat bogs, however, the most of them have been destroyed and do not exist now. The dwarf mountain pine forms the community of *Pinetum mugo*, formed exclusively on the substrata not containing calcium dioxide. The species is connected with northern exposures. The area of distribution of *Pinus mugo* has been strongly reduced during centuries and association *Pinetum mugo* transformed into pastures.

Additional key words: Chorology, plant geography, mountains, plant-exposure interaction, plant elevation interaction

Adressess: [1]National Academy of Sciences of Ukraine, Institute of Ekology of the Carpathians, Kozelnytska 4, 79026 Lviv, Ukraine, e-mail: itsaryk@yahoo.com; tsaryk@mail.lviv.ua
[2]Polish Academy of Sciences, Institute of Dendrology, Parkowa 5, 62-035 Kórnik, Poland, e-mail: borata@man.poznan.pl
[3]National Academy of Sciences of Ukraine, M. G. Kholodny Institute of Botany, Tereschenkivska 2, 01601 Kyiv, Ukranie, e-mail: didukh@botan.kiev.ua
[4]State Musem of Natural History, Teatralna 18, 290008 Lviv, Ukraine, e-mail: tasen@mail.lviv.ua
[5]Institute of Biology and Environment Protection, University of Bydgoszcz, Al. Ossolińskich 12, 85-064 Bydgoszcz

Introduction

Pinus mugo is an extremely variable taxon, recently considered as complex species *Pinus mugo* complex (Christensen 1987a; 1987b; Christensen and Dar 1997). The taxonomical rank of taxa included into the complex has been an object of many studies on the morphometric, chemotaxonomic and genetic levels (Marcet 1967; Szweykowski 1969; Staszkiewicz and Tyszkiewicz 1969; 1972; Szweykowski and Bobowicz 1983; Krzakowa et al. 1984; Bobowicz 1990; Filppula et al. 1992; Staszkiewicz 1993; 1994; Lauranson-Broyer et al. 1997; Prus-Głowacki et al. 1998; Lewandowski et al. 2000; 2002; Boratyńska and Bobowicz 2000; 2001; Boratyńska and Pashkevich 2001; Boratyńska et al. 2003; 2005). It was found, that typical, pure dwarf pine occurs in the eastern part of the complex range (Christensen 1987a; b; Lewandowski et al. 2000; 2002; Boratyńska and Bobowicz 2000; 2001; Boratyńska and Pashkevich 2001), in the East and South Carpathians.

The comparative morphological and genetic studies on *Pinus mugo sensu stricto* (=*P. mugo* subsp. *mugo sesnu* Christensen (Christensen 1987a; b) from the Ukrainian Carpathians, demonstrated as a rule some distinctness of all other populations of the taxon (Staszkiewicz and Tyszkiewicz 1976; Lewandowski et al. 2000; 2002; Boratyńska and Bobowicz 2000; 2001; Boratyńska et al. 2004). For this reason the distribution of Ukrainian populations of typical *P. mugo* should be recognized and some of the most typical ones should be protected.

The intermediate forms between *Pinus mugo* subsp. *mugo* and *P. mugo* subsp. *uncinata*, recognized as *P. mugo* nothosubsp. *rotundata* (*sensu* Christensen 1987a), were also reported as extremely rare in the Ukrainian Carpathians (Windakiewicz 1873; Trampler 1937).

Taxa included into *Pinus mugo* complex (*sensu* Christensen 1987a) occur in the high mountains of Central and South Europe, from Pyrenees on the West to the East Carpathians on the East and from the Sudety Mts and Carpathians on the North to the Abruzzian Apennines and Rodopy Mts on the South. *P. mugo* subsp. *mugo*, the typical mountain dwarf pine, is characteristic for the eastern part of the *P. mugo* complex range and covers area from the Alps to the Carpathians and Rodopy Mts.

The altitudinal maximum of the typical *P. mugo* was reported from about 2700 m in the Abruzzian Apennines and Rila Mts (Meusel et al. 1965). It occurs first of all in the subalpine zone, where it forms the shrubby communities at the and above upper forest line. The *Pinetum mugo* associations are typical for the subalpine vegetation belt of the highest mountain massifs (Deyl 1940; Pawłowski and Walas 1949; Beldie 1967, Chopik 1976; Malinovsky 1980; Chifu and Mititeu 1992; Doniţa and Coldea 1992; Sanda et al. 1992; Jirásek 1996; Matuszkiewicz 2001, Chytrý and Tichý 2003; Poldini et al. 2004). Because of not continuous range of the most of mountain chains, the range of *P. mugo* is divided into several dozen of islands, more or less isolated each other. The association of *Pinetum mugo* covers largest areas in the highest mountain massifs, as in Tatra in the West Carpathians. The populations of *P. mugo* in the lower and not extended mountains exist as a relict ones at the summit parts of the mountains, and such localities are or can be endangered by expansion of trees colonizing the lower parts of *Pinetum mugo* vegetation belt as a result of global warming (Dirnbock et al. 2003; Dullinger et al. 2003, 2004).

The dwarf mountain pine plant association was only fragmentary studied in the Ukrainian Carpathians (Sulma 1929; Trampler 1937; Deyl 1940; Pawłowski 1948; Pawłowski and Walas 1949; Chubaty 1965; Malinovsky 1980; Malinovsky and Kricsfalusy 2000).

The main goal of the present study was to summarize and verify the geographic distribution and describe the occurrence conditions of *Pinus mugo* on the Ukrainian territory, based on the authors field investigations, literature and herbaria. The characteristics of phytocoenotic role of *P. mugo* in the plant associations and evaluation of threat in particular mountains of Ukraine are the supplementary aims. Because of general character of the map of species range in the Carpathians (Meusel et al. 1965; Jalas and Suominen 1973), the first step was to compile more detailed map of its distribution there.

Another aim was to verify occurrence data of the individuals resembling *Pinus mugo* subsp. *uncinata* and/or individuals intermediate between *P. mugo* subs. *mugo* and subsp. *uncinata* on the Ukrainian territory. The latter taxon was reported as *Pinus uncinata* from peat bogs at vicinity of Dolina (Windakiewicz 1873) and from peat bog on the Kikhola mount (Trampler 1937). It was also reported from the territory of Pogórze Przemyskie in Poland close to the Ukrainian frontier (Schramm 1925).

Material and methods

The geographical distribution of the species in the whole Carpathians was prepared on the basis of literature data (mainly Zapałowicz 1889; 1906; Pawłowski 1948; Beldie 1952; Pawłowski 1956) and maps of distribution of the species in particular countries (Chubaty 1965; Jasičova 1966; Gostyńska-Jakuszewska 1976).

The data for the study in the Ukrainian Carpathians came from literature (Rehman 1873; Windakiewicz 1873; Weigl 1888; Wołoszczak 1888; 1892a; b; 1893; Zapałowicz 1889; 1906; Wierdak 1927; 1930; Lublinerówna 1928; Sulma 1929; Środoń 1936; 1948; Trampler 1937; Pawłowski 1937; 1948; Kontny 1938; Deyl 1940; Komendar 1955; 1960; 1966; Chubaty 1965; Chopik 1976; Malinovsky 1980; Malinovsky and Kricsfalusy 2000), herbaria (KOR[1], KRA, KRAM, KW, KWU, KWHA, LW, LWS, PR, PRC and UU) and maps of species distribution in particular mountain ridges (Sulma 1929; Trampler 1937; Chubaty 1965). Most of the data were verified in the field during 1997–2004. The map of distribution and distribution on the altitudinal profile of the Ukrainian Carpathians were constructed on the data[2] mentioned above.

The influence of exposition on the species distribution was analysed. The data were gathered from the published phytosociologic relieves (Sulma 1929;

[1] Acronyms of herbaria follow Holmgren et al. (1990), and Vasser (1995) for Ukraine.

[2] The full list of data geographically arranged available at Institute of Dendrology, Kórnik.

Trampler 1937; Deyl 1940; Pawłowski and Walas 1949; Chubaty 1965; Malinowsky and Kritsfalushy 2000) and from authors' field observations.

The phytocoenothic role of *P. mugo* was described on the basis of published earlier relieves from the Ukrainian Carpathians (Sulma 1929; Trampler 1937; Pawłowski 1937; 1948; Deyl 1940; Pawłowski and Walas 1949; Malinovsky and Kritsfalushy 2000). Syntaxonomical position of communities and character of taxa follow Jirásek (1996).

Results

Distribution

Carpathians in general

Distribution area of *Pinus mugo* in the Carpathians is discontinuous. In the West Carpathians the main part of the species range covers the Tatras, which are the largest center of its occurrence in the whole Carpathians. Not so abundant localities are dispersed in the highest mountains surrounding the Tatras (Fig. 1). The dwarf mountain pine thicket belt in the

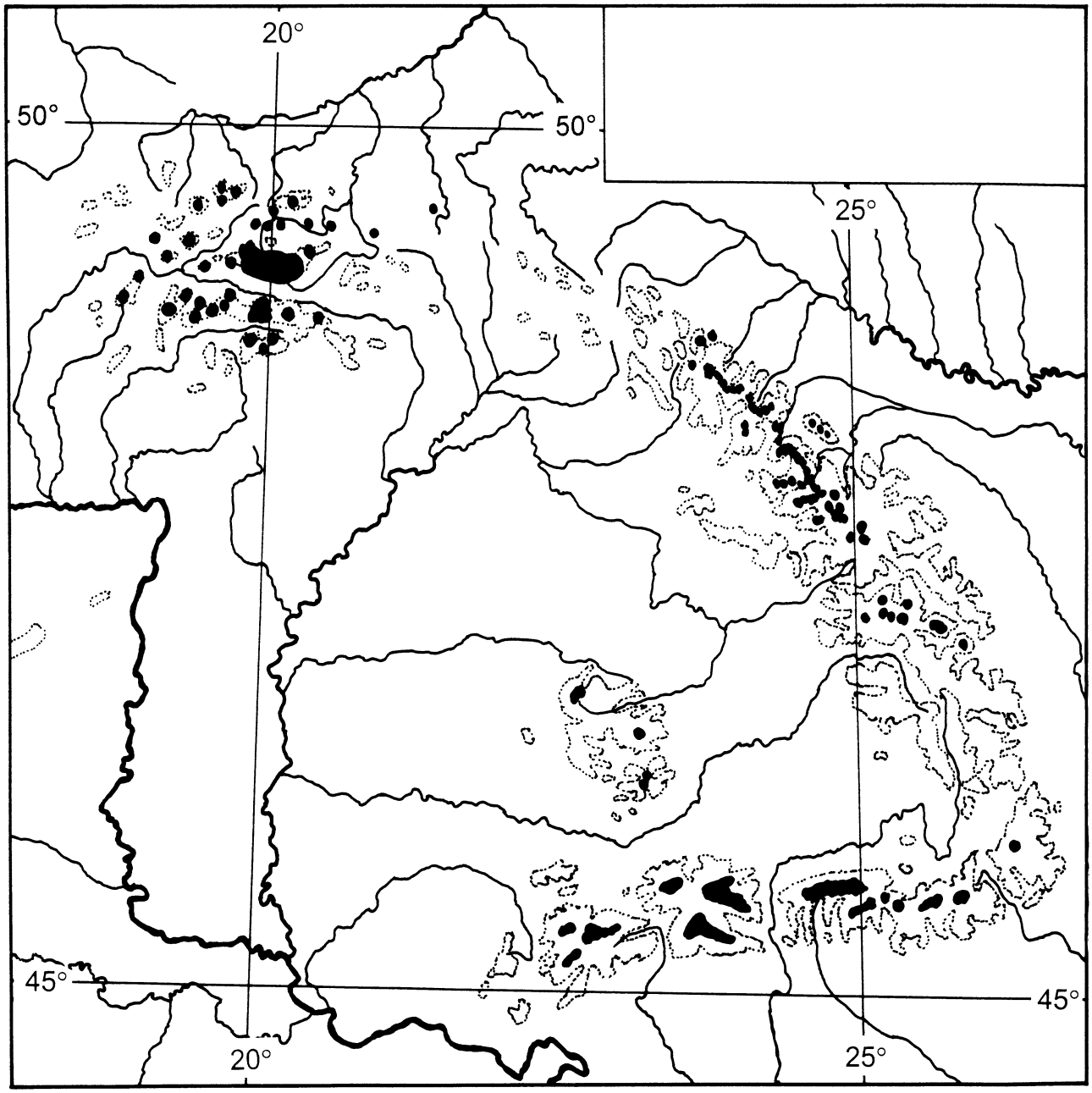

Fig. 1. Distribution of *Pinus mugo* in the Carpathians (after Beldie 1952, Chubaty 1965, Jsičova 1966, Gostyńska-Jakuszewska 1976 and authors' field data)

Tatras ranges between altitudes of 1500 and 1800 m, with the most elevated locality at 2140 m and the lowest one at about 600 m.

The second Carpathian center of *Pinus mugo* occurrence spreads out the East Carpathians in Ukraine and Romania. The localities of the species are dispersed and cover the most elevated mountain ranges, which are isolated from each other. The greatest areas covered with the species community are reported from the Chornokhora and Rodna Mts. Other localities are not so abundant. *P. mugo* attains their altitudinal climatic limit at the most elevated mountains only, while the lowest at about 700 m at the northern and 800–900 m at the southern slopes, mostly on the peat bogs.

The third region of *Pinus mugo* occurrence overlaps the South Carpathians in Romania. The localities of the species are reported from the most elevated mountain ridges, with the largest areas covered with mountain dwarf pine stands in the Făgăraş, Bucegi, Retezat and Parâng, predominantly between altitudes of 1600 and 2000 m and mostly on the Northern slopes. The maximally elevated localities were reported from the altitude of 2300 in the Bucegi and Făgăraş, the lowest ones from about 1200–1300 m.

The fourth region of *Pinus mugo* occurrence close to the Carpathians covers the most elevated mounts of the Bihor and Apuşeni mountains in Transilvania. The localities in the last region are dispersed and not abundant. The lowest ones are at 1200 and the most elevated at 1830 m.

Ukrainian Carpathians

Pinus mugo in the Ukrainian East Carpathians is represented only by typical subspecies – *P. mugo* subsp. *mugo* (sensu Christensen 1987a). We did not confirm the occurrence of *Pinus* ×*rotundata* Link in the Ukraine.

Southeastern and central parts of Ukrainian Carpathians overlap the northern part of the East-Carpathian range of *Pinus mugo* (Fig. 1). The species covers highest mountains, from the Chyvchyny on the South East to the mount Kuk in the Borzhava range and Kanch in the West Gorgany on the North West (Fig. 2). Only single, isolated localities of the dwarf mountain pine were reported from Bukovyna and Khryniava massifs.

Pinus mugo covers the largest area in the Chornokhora and central and eastern parts of the Gorgany ranges. The continuous thicket of dwarf mountain

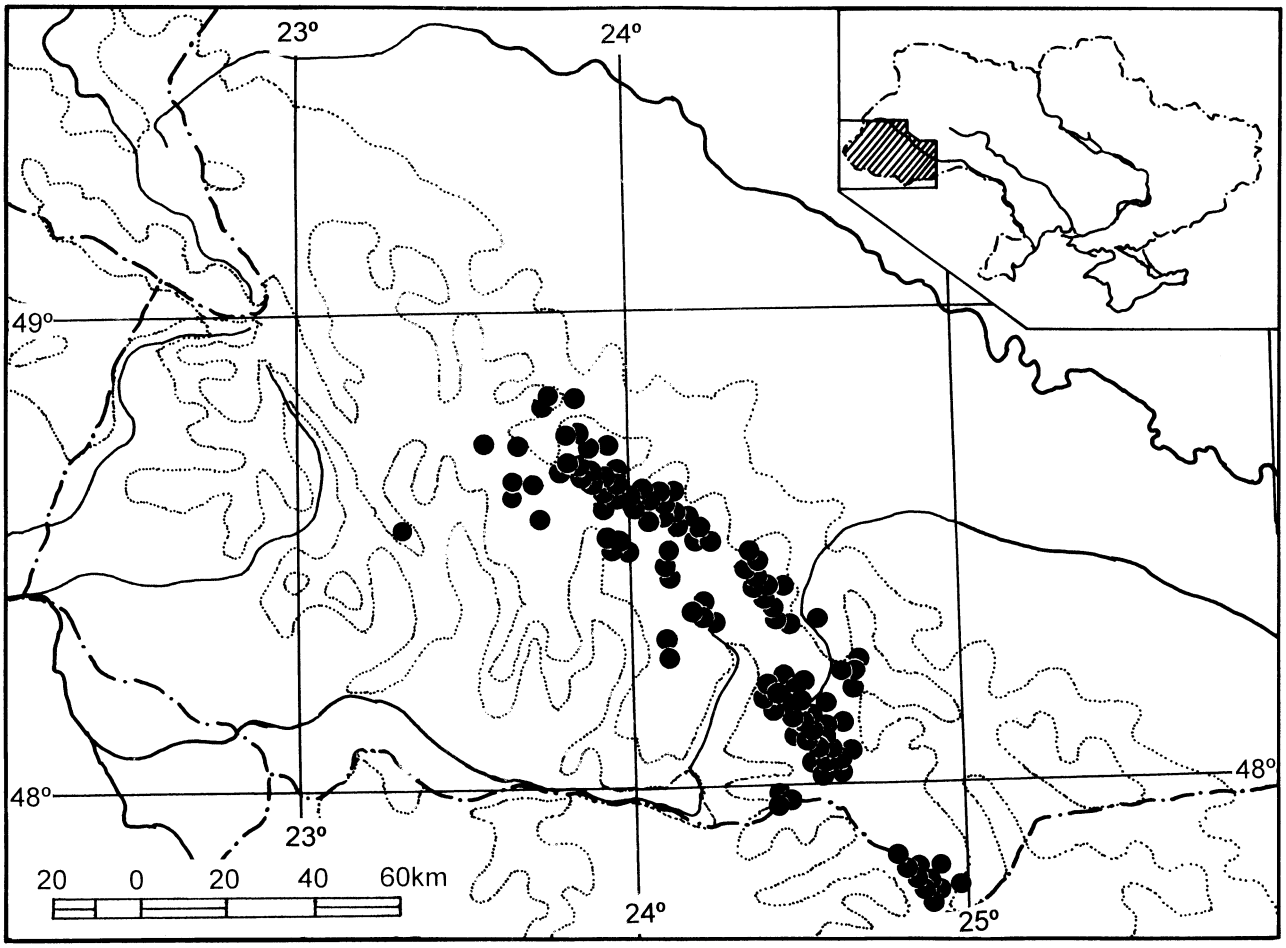

Fig. 2. Distribution of *Pinus mugo* in the Ukrainian East Carpathians

pine cover predominantly the northern (including north-eastern and north-western) slopes of the Chornokhora, at altitudes between 1400 and 1800 m, with the lowest localities at about 1100 m and with single individuals at 1980 m. The species occurs significantly more rare on the southern (including south-eastern, south-western and western) slopes. The more or less dense thickets are spread out between 1400 and 1760 m with the lowest ones at 1340 m and the highest at 2010 m on Pip Ivan slopes (Fig. 3).

P. mugo range is divided into islands outside the Chornokhora, with conglomerations of localities in the regions of the most elevated mountains, mostly within the central part of the Gorgany and in the southern part of the Chyvchyny mountains (Fig. 2). The most numerous populations of the dwarf mountain pine are known from the mountains surrounding the Limnytsia river basin in the Gorgany, such as Popadia, Bushtul, Syvula and Ihrovyshche (Fig. 2). More to the West and to the East from these massifs the species populations become less numerous and cover smaller areas. The most of the species populations in the Gorgany are formed on the northern slopes. The dense thickets of *P. mugo* are spread-out between 1300 and 1740 m on the northern slopes with the most elevated individuals at the altitude of about 1830 m and the lowest reported from 720 m, from the peat bogs in stream valleys. The southern slopes of the Gorgany have poorly developed communities of dwarf mountain pine, mostly between altitudes of 1250 and 1400 m, with maximum at 1830 m and minimum at 930 m in the stream valleys. The total area covered by *P. mugo* on the southern slopes of Gorgany Nature Reserve is only 4.5 ha, while on the northern ones it comes to 327 ha (Olekhiv and Shpichak, unpublished data of Forest Plan).

The dwarf mountain pine potentially can grow up to the summits of the mounts in the Gorgany and frequently it goes to. The course of low limit of *P. mugo* is predominantly determined by local competition between the species and *Picea abies*. In several places at low limit of dwarf mountain pine range the transitory zones are formed, where the association of *Pinetum mugo* and forests of *Picea abies* penetrate each other, depending on the local micro-site conditions. The slopes covered with stones are frequent sites of the dwarf mountain pine inside the upper forests belt, formed with Norway spruce in the East Carpathians, and particularly in the Gorgany mountains.

The lowest localities of *Pinus mugo* are generally located in the stream valleys on the northern slopes, where the cold air flows down during inversions of temperatures. The abrupt slopes are also a frequent reason of depression of the low limit course. Several localities were reported deep below the low limit of the species range, mostly on the peat bogs, as on Mshana peat bog in the Limnica valley at altitude of about 800 m. Generally, the species locations at the lower mountain vegetation zone are connected with specific ecological conditions. Some of them are connected with the peat bogs, other with the rocks and abruptions. Most of them, however, disappeared during the last decades, as mentioned above locality in the Limnica valley and at the Moloda stream valley.

The most restricted is distribution of *Pinus mugo* in the Bukovyna and Khryniava mountains. The highest mountains do not cross the upper tree line there and the occurrence of dwarf mountain pine in these

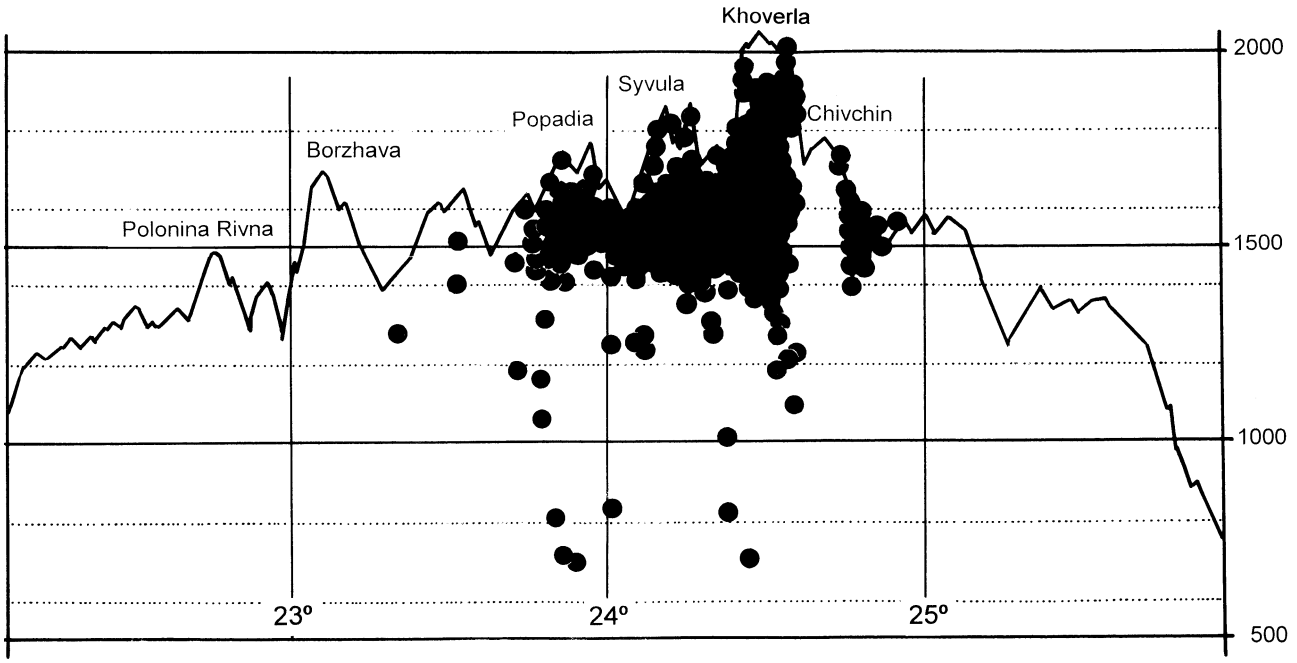

Fig. 3. Vertical distribution of *Pinus mugo* on the profile of the Ukrainian East Carpathians

mountains is connected with specific micro-site conditions, as rocks or stony slopes near the summits. The localities can have a relict character.

The occurrence of *Pinus mugo* in the Ukrainian East Carpathians, even inside the main altitudinal area of the species range, depends from the exposure of the localities. The localities exposed to the North predominate in all mountain massifs (Fig. 4). The great numbers of the highest and lowest localities have also been found on the slopes exposed to the North (Fig. 4), however the most elevated one in Ukraine is on the southern slope of Pip Ivan in the Chornokhora.

Phytocoenotic role

Pinus mugo forms a thicket community, known as *Pinetum mugo* plant association from the *Pinion mughi* Pawłowski, Sokołowski et Wallisch 1928 alliance. The association is characteristic one for the subalpine zone of the Ukrainian Carpathians. It covers large areas on the acid rocks avoiding the limestones and calcium containing substrata. *P. mugo* is the most characteristic plant of that community. Depending on local conditions, several variants of the dwarf mountain pine thicket were recognized, with *Athyrium distentifolium*, *Rumex alpestris* subsp. *carpaticus*, *Calamagrostis villosa*, *Cetraria islandica* and *Sphagnum girgensohnii* as dominating plants. The very characteristic for Ukrainian Carpathians are the last two types, which develop on the Northern slopes.

Other subalpine taxa from *Betulo-Adenostyletea* and *Vaccinio-Piceetea* classes enter communities of *Pinetum mugo*, but without high constancy. The East Carpathian dwarf mountain pine thicket association is rather poorly floristically differentiated. The highest degrees of occurrence constancy and cover have only *P. mugo* and *Vaccinium myrtillus*. The other frequent species, as *Calamagrostis villosa*, *Pogonatum alpinum*, *Athyrium distentifolium*, *Rumex alpestris* subsp. *carpaticus*, *Dryopteris dilata*, *Hylocomium splendens*, and also *Homogyne alpina* and *Vaccinium vitis-idaea* occur in single individuals and have the considerably small cover coefficient. Only *Sphagnum girgensohnii*, *S. intermedium* and *Cetraria islandica* cover locally large areas.

Protection

The role of *Pinus mugo* was reduced due to pasturing during centuries and also due to production of pine oil from the needles of the species in the first decades of the 20th century. Potentially the species can cover much larger area than it really does today. It is difficult to determine strictly the primary area settled with *Pinetum mugo* communities. Probably, areas utilized as mountain subalpine pasturelands are in great instance the potential sites of *Pinus mugo* associations. The subalpine pastures of the Chornokhora cover more than 60–70% of such sites, which indicate the scale of reduction of *Pinus mugo*, and it is much more extensive in other mountain chains, except of the Gorgany. The latter mountains present poor site conditions and have not been utilized so extensively as pastures.

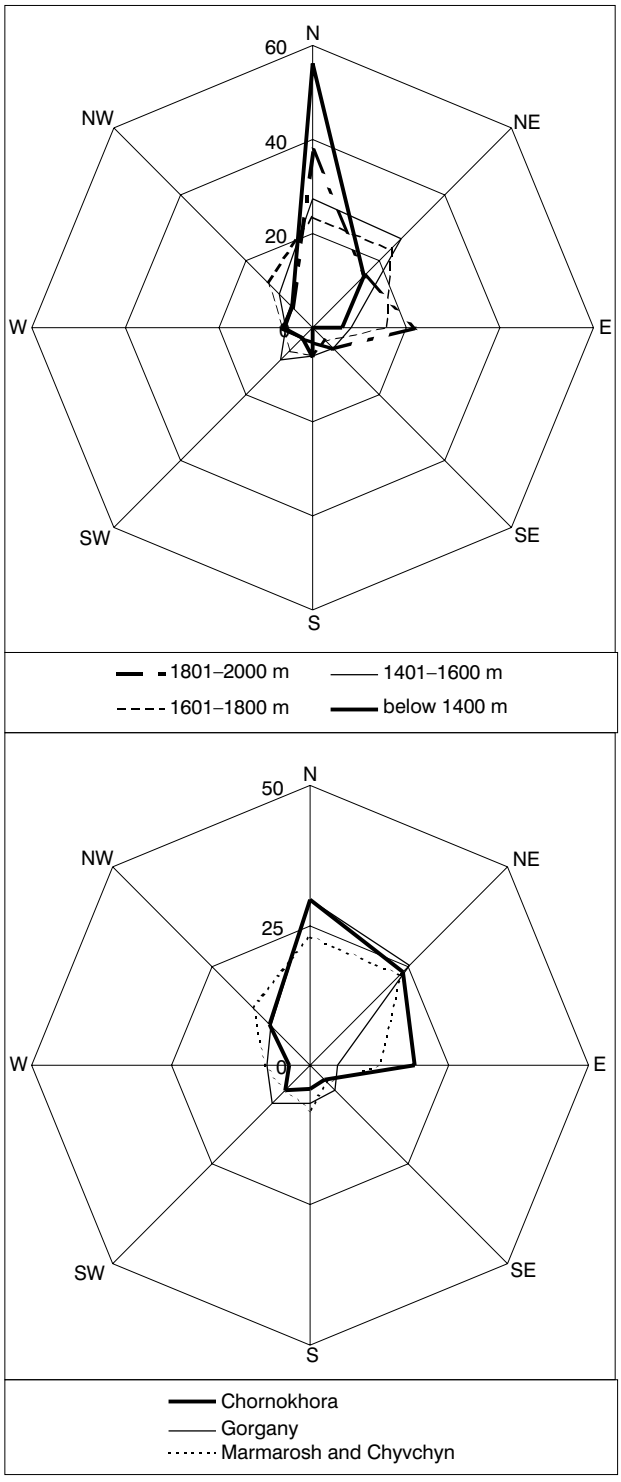

Fig. 4. Exposure of localities of *Pinus mugo* in the Ukrainian East Carpathians (on the base of 447 data from authors' field observations, herbaria and literature) in whole East-Carpathians ranges depending on the altitude (upper graph) and in particular main mountains (lower graph)

The considerably great part of the area of *Pinus mugo* occurrence in the Ukrainian Carpathians is protected in the Nature Reserves.

Discussion

Area of *Pinus mugo* distribution in the Carpathians appeared to be much more disjunctive (Fig. 1), than it was presented (Meusel et al. 1965; Jalas and Suominen 1973). The species communities cover there only the most elevated mountain massifs in the West, East and Meridional Carpathians. The species has rudimentary, relic character from the pre-Holocene, colder period in several mountains. The disjunctions in the species range in the Carpathians cover the mountain ridges not sufficiently elevated to develop subalpine belt. In the Tatras, the main species center in the West Carpathians, the subalpine belt with domination of *P. mugo* communities is developed between 1500 and 1800 m independently on substrate (Pawłowski 1956; Radwańska-Paryska 1974; Gostyńska-Jakuszewska 1976). The lowest localities are dispersed on the peat bogs as for example in the Nowy Targ Basin and Orava region, at about 600 m (Pawłowski 1956; Radwańska-Paryska 1974; Gostyńska-Jakuszewska 1976). The occurrence of *P. mugo* in the Tatras and other regions of the West Carpathians were strongly restricted by pasture activity in the past. The present day area of the species covers about 40% of their pre-humane range (Myczkowski and Lesiński 1974).

The East Carpathian center of distribution of *Pinus mugo* is isolated from the West Carpathians by distance of about 200 km where the mountains do not attain the altitudes sufficient for the species common occurrence. The species probably attain their upper climatic limit in that part of the range only in the most elevated mountain massifs at about 2000 m (Zapałowicz 1889; 1906; Środoń 1948). The occurrence of *P. mugo* was strongly reduced, to about 20% of potential species area (Pawłowski 1948; Środoń 1948) mostly as a result of pasturing (Vincenz 1936).

The South Carpathian localities of *Pinus mugo* are also reported from the most elevated mountains, and mostly on the Northern slopes. The community was also reduced and survived at altitudes between 1600–2000 m, with maxima at 2300 in the Bucegi and Făgăraş and minima at 1200–1300 m (Beldie 1952; 1967; Chifu and Mititelu 1992; Sanda et al. 1992; Doniţa and Coldea 1992; Coldea 1992).

The Transilvanian mountains are the region with only dispersed localities of *Pinus mugo*, known between 1200 and 1830 m (Coldea 1992). The species does not attain the climatic upper limit there.

The present day occurrence of taxa from *Pinus mugo* complex other than typical *Pinus mugo* (*P. mugo* subsp. *mugo sensu* Christensen) have not been confirmed during our study. We have not seen neither herbarium materials nor specimens in the field, which could confirm data from literature on occurrence of specimens resembling *P.* ×*rotundata*. Report of its occurrence from peat bog near Dolina (Windakiewicz 1873) was probably erroneous. We found only *P. sylvestris* during field investigations in 2004 there. The other locality of *P.* ×*rotundata* on the Kihola peat bog was reported (as *Pinus uncinata*) by Trampler (1937). We have not found the herbarium materials confirming occurrence of that taxon there.

The dispersed localities of the taxon of *Pinus mugo* complex, probably *P.* ×*rotundata*, reported from the Pogórze Przemyskie at the base of Bieszczady in Poland (Schramm 1925), but not confirmed more recently (Schramm 1973), can be either ephemeral spontaneous occurrence or a trace of the early-Holocene road of migration. Those data confirm, however, the possibility of existence of such dispersed localities of *P. mugo* out of the high mountains. The localities on the peat bogs at low elevations are susceptible to destruction and can easily disappear, as it have been described from other regions of Carpathians (Gostyńska-Jakuszewska 1976) and Sudethians (Boratyński 1994).

Other peat bog localities of typical dwarf mountain pine in the East Carpathians were reported from the regions closer to the high mountains, as in the stream valleys in the Gorgany (Lublinerówna 1928; Sulma 1929; Trampler 1937). At least some of them were probably the relicts of the late glacial period, similarly as in Podhale and Orawa regions (Obidowicz 1994; Rybníček and Rybníčková 2002). Unfortunately, most of them did not survive to the recent times.

The other localities of *P. mugo* below the main altitudinal range are predominantly determined by specific micro-site conditions, as very steep slopes, rocks, rocky slopes, etc. Some of them, mostly in the Gorgany mountains were recognized as of the landslip origin (Sulma 1929; Trampler 1937).

The map of distribution of *Pinus mugo* in the Ukrainian Carpathians (Fig. 2) and altitudinal distribution (Fig. 3) show the strong dependence of the species occurrence on the most elevated mountains. This was pointed out for the particular mountain massifs in previous publications (Rehman 1873; Weigl 1888; Zapałowicz 1889; Sulma 1929; Trampler 1937; Środon 1948; Komendar 1955; 1960; 1966; Chubaty 1965; Malinovsky 1980).

The present day range of *Pinus mugo* developed during Holocene. The dwarf mountain pine survived probably the last glacial period in the low locations of the East Carpathians (Pawłowski 1948), similarly as in the Podhale and Orawa regions in the Western Carpathians (Obidowicz 1994; Rybníček and Rybníčková 2002). The disjunction between West and East Carpathian areas of the species range covers the low

mountain ridges, predominantly without subalpine belt, but the period of isolation is probably longer than Holocene. Taking into account the contemporary variation of the species, it is also very probable, that the North-western parts of the Carpathians were colonized by *P. mugo* from other refugia, than South-eastern one (Staszkiewicz and Tyszkiewicz 1976; Boratyńska et al. 2004; Boratyńska 2004).

The course of low and upper limits of *Pinus mugo* in the East Carpathians are strongly modified by human activities, mostly by pasturing (Zapałowicz 1889; Trampler 1937; Pawłowski 1948; Środoń 1936; 1948; Komendar 1955; 1960). This concerns mostly the Chornokhora range characterized with large area of the natural alpine meadows, which were enlarged by burning and cutting down of the dwarf mountain pine thicket for centuries (Vincenz 1936). The community *Pinetum mugo* was reduced to only 20% of it's potential, primeval area (Zapałowicz 1889; Pawłowski 1948; Środoń 1948). The occurrence of the dwarf mountain pine thicket have been limited to the grounds hardly used for pasturing, such as steep slopes, rocks, narrow gorges, stony places, etc. The present day state of *P. mugo*, became more stable after stopping of pasturing on some areas and reduction of the number of sheep, cows and horses on others during last decades. The species populations look vigorous, especially on the protected terrains (Chubaty 1965; Malinovsky 1980, own field observations).

The enlargement of the pastures was generally responsible for the reduction of area covered with *Pinetum mugo* and descent of the species upper limit in the Chornokhora, Chyvchyn and in the Gorgan mountains. The *Vaccinietum myrtilli* developed as substitute of *Pinetum mugo* on large areas, as it was also reported earlier (Trampler 1937; Pawłowski 1948; Malinovsky and Kricsfalusy 2000).

The reduction of *Pinus mugo* in the Chornokhora takes place also during the World War I, where Austrian – Russian front stood in 1915–1917. The thicket of dwarf mountain pine did not regenerated till now along the line of trenches, which follow the main ridge of Chornokhora and are still well recognizable.

The other activity, which also caused strong reduction of *Pinus mugo* in the Chornokhora and in the Gorgany mountains was the production of the pine essential oil in the first half of the 20th century (Szafer 1932; Trampler 1937).

The isolation of localities of *Pinus mugo* in mountain massifs with restricted area of subalpine vegetation belt makes it vulnerable to the global climate changes. The warming can lead to the elimination of *P. mugo* by rise of *Picea abies* forest, as it takes place also on the abandoned pastures in the Carpathians (Boratyński and Bugała 1998, Table 3B) and in the Alps (Dullinger et al. 2003, 2004; Dirnbock et al. 2003). The distribution of the species on the Bukovyna and in the Hryniava can be the examples of reduced occurrence of the species in the mountains without well- developed climatic upper forest line (Kontny 1938).

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