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Cotoneaster integerrimus (Rosaceae) within the Ukrainian Carpathians: Ecological and phytocoenotic characteristics

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Cotoneaster integerrimus is a rare species in the Ukrainian Carpathians and a valuable medicinal plant. However, information on its distribution, ecological, and phytocenotic preferences in this part of its range has been lacking until now, both in Ukraine and in international databases (Euro+Med Base; POWO). Based on an analysis of materials from national herbaria of various scientific institutions in Ukraine and on the basis of our own field research, information on the distribution of *C. integerrimus* in Ukraine and the Ukrainian Carpathians has been summarized for the first time; phytocenoses involving this species have been identified, and their syntaxonomic affiliation and specific ecological conditions have been determined. It has been established that this species is rare in the Ukrainian Carpathians, and currently 29 locations are reliably known, 18 of which are recorded in the highlands of the Ukrainian Carpathians and 11 in the forest zone. The species has been found in the following floristic regions of the Ukrainian Carpathians: the Pre-Carpathians, the Chyvchyny-Hryniavy Mountains, Svidovets, Chornohora, the, and the Eastern Beskids. In the forest zone, the species occurs extremely rarely and sporadically. In the subalpine zone, in certain ecotopes, it exhibits high phytocenotic activity and, together with other montane species, forms rare communities of the *Cetrario islandicae-Cotoneasteretum integerrimi* association, which we describe for the first time and which differs significantly from all previously described associations with *C. integerrimus* in Central Europe. The association belongs to the class *Loiseleurio procumbentis–Vaccinietea* Eggler ex Schubert 1960, order *Rhododendro ferruginei-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926, and alliance *Loiseleurio procumbentis–Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926. The habitats of these plant communities are characterized by extreme conditions, including high solar radiation, high air humidity, and a short growing season. These are rocky mountain peaks at elevations of 1,200–1,700 m a.s.l. with a thin soil layer, subject to strong cold winds, water erosion, and significant temperature fluctuations throughout the year. The floristic composition is rich in montane, boreal, arctoboreal, and arcto-alpine species, including five endemic species of the Carpathians. The communities identified in the Ukrainian Carpathians are a component of the biotope "Alpine and subalpine heath" (No. 4060), protected by EC Directive 92/43. To protect these rare communities and the aforementioned priority biotope, it is proposed to expand the area of the Pryvododilnyi Forest Reserve and the Pikui Landscape Reserve in the Eastern Beskids to protect the primary high-altitude relict communities of the Ukrainian Carpathians. The question of why this species has not been mentioned to date in phytosociological studies of the Ukrainian Carpathians remains a matter of debate. Presumably, in high-altitude areas under conditions of climate warming, the species is expanding its range and increasing its competitiveness among boreal and arcto-alpine species, acting as a temperature-sensitive element of the flora that signals gradual changes in the vegetation cover of the subalpine zone under current conditions.

Keywords: cotoneaster; distribution; vegetation; Latorica River; *Loiseleurio procumbentis–Vaccinietea*; biotopes; conservation.

Introduction

The genus *Cotoneaster* comprises approximately 500 species distributed across the nontropical regions of Eurasia and North Africa, with a center of diversity in the Himalayas and Southwestern China (Dickoré & Kasperek, 2010). Species of this genus have traditionally been used in the folk medicine of Asian peoples, particularly in Iran, Pakistan, Turkey, Mongolia, and Tibet, for the treatment of diabetes, hemorrhoids, and cardiovascular diseases (Kicel, 2020). The bark, leaves, flowers, and fruits of *C. integerrimus* contain a wide range of bioactive compounds with antioxidant, anti-inflammatory, antimicrobial, antiparasitic, and other pharmacological effects. A decoction of its leaves and fruits is recommended as a potent antimicrobial agent for treating digestive disorders, diabetes, fever, and cough (Kicel et al., 2019). Species of the genus *Cotoneaster* are also broadly used in ornamental gardening. Three species of the genus *Cotoneaster* are listed in the natural flora of Ukraine: *Cotoneaster melanocarpus* Fisch. ex Blytt., *C. integerrimus* Medik., and *C. tauricus* Pojark. (Mosyakin & Fedoronchuk, 1999; Grevtsova & Drabinyuk, 2020). The latter occurs exclusively in the Mountainous Crimea. In the lowland part of Ukraine, *C. melanocarpus* or its hybrids are most commonly found. All of them are experiencing a reduction in their ranges due to human activity (Grevtsova & Kolesnik, 2003; Grevtsova et al., 2014; Grevtsova & Drabinyuk, 2020).

The flora of the Ukrainian Carpathians includes two natural species, *C. integerrimus* and *C. melanocarpus* (Bunge) Loudon, (syn. *C. laxiflorus* Jacq. ex Lindl.), and one cultivated species – *C. lucidus* Schlecht., which has escaped cultivation and is becoming naturalized (Chopyk & Fedoronchuk, 2015). Several other species of this genus are grown in botanical gardens and do not escape cultivation. Due to their high hybridizing capacity and the presence of apomixis (in about 90% of species), species of the genus *Cotoneaster* are characterized

by significant polymorphism, which manifests as variations in the size, shape, and nature of leaf pubescence, as well as in the morphology of flowers, inflorescences, and fruit shape. Many species are tetraploids (Grevtsova et al., 2014; Fedoronchuk, 2017). Consequently, the taxonomic delimitation of this genus remains unresolved in several European countries.

Cotoneaster integerrimus is a relatively rare species in Ukraine. It forms a hybrid with *C. melanocarpus*, and therefore taxonomists distinguish two hybrid forms in which the characteristics of one parent species predominate: *C. melanocarpus* x *C. integerrimus* and *C. integerrimus* x *C. melanocarpus* (Grevtsova, 2014). In the Ukrainian Carpathians, both species are rare. *Cotoneaster integerrimus* grows mainly in the highlands and in the upper forest zone (i.e., above 800 m a.s.l.) and is rarely found in the lower forest zone. *Cotoneaster melanocarpus* is most commonly recorded in the foothills and in the lower forest zone of the Carpathians (Fodor, 1974; Grevtsova & Drabinyuk, 2020). However, the literature contains no information regarding the cenotic distribution of these species, not only in the Ukrainian Carpathians but also in Ukraine as a whole. Therefore, recent phytocenotic syntheses for *C. integerrimus* across Europe were compiled without data from Ukraine (Świerkosz & Reczyńska, 2022), and similarly, some European databases lack data on this species from Ukraine (Euro+Med Base, 2026; POWO, 2026).

Cotoneaster integerrimus grows primarily in the temperate climate zone. The native range of this species extends from Europe to North Korea and the Western Himalayas. It is found in China, Korea, Southwest Asia, Central and Eastern Europe, in the Balkans, in the northern part of Crimea, in Northern Turkey, in the Caucasus, and in Northern Iran (Krügel, 1999). It grows in carbonate soils, on rocky slopes, and in forests, reaching elevations of up to 2,800 m a.s.l. in the mountains (Blamey & Grey-Wilson, 1989).

The species has been recorded throughout the Carpathian Mountain range. In Romania, it occurs in dry areas, on rocky slopes of the subalpine zone among stands of *Festuca picturata*, and in forest clearings. It is recorded in several regions of Romania, including Baia Mare, Cluj, Craiova, Ploiești, Pitești, Constanța, and others (Săvulescu, 1956). In Slovakia, this species occurs more or less uniformly throughout almost the entire country, from the lower forest zone (550 m a.s.l.) to the alpine zone (1,850 m a.s.l.), predominantly in small, clonal populations in nutrient-poor substrates. It is a common species in xerothermic rocky communities on limestone outcrops of the *Festuco-Brometea* Br.-Bl. et Tx ex Soó 1947 class, and the *Bromo pannonici-Festucion csikhegyensis* Zólyomi 1966 corr. Mucina in Di Pietro et al. 2015 (syn. *Seslerio-Festucion duriusculae* Klika 1931 and *Prunion fruticosae* Tx. 52 alliances (Baranec et al., 1992).

In Poland, *C. integerrimus* is known from the Sudetes and is classified as a rare plant. It is recorded at 14 locations. In the Sudetes, the species reaches the northern limit of its range. However, most of the sites for this species are located in the foothills and, most often, in the lower parts of mountain ranges, at elevations of 400–600 m a.s.l. In contrast to its occurrence at high elevations in the Eastern and Southern Carpathians, in the Sudetes *C. integerrimus* is a foothill-low mountain species. It occurs predominantly on limestone or basalt substrates. The communities form a narrow belt between meadows and forests. Occasionally, the species occurs in sparse oak forests. It grows in communities of the *Berberidion* Br.-Bl. 52 alliance together with *Prunus spinosa*, *Juniperus communis*, *Cornus sanguinea*, *Crataegus monogyna*, *Rosa canina*, *Berberis vulgaris*, and other species (Boratynski et al., 1999).

In Hungary, the species occurs across the foothills and hills east of Lake Balaton, extending northeastward to the Western Carpathians. There, it is listed among the country's rare tree species (Bartha et al., 2005).

In the Czech Republic, it is a common species, widespread from the average-height to the high mountains. The highest recorded elevation is at Hrubý Jeseník, Červená hora, 1,330 m a.s.l. It grows on sunny, nutrient-rich rocky slopes, in calcareous and silicate soils ranging from skeletal to stony. It is widespread in the communities of the *Quercion pubescenti-petraeae* Br.-Bl. 1932 and *Prunion fruitcosae* Tx.52 alliances (Kovanda, 1992).

In national floristic compilations, *C. integerrimus* was previously recorded only for Crimea and the Carpathians (Fodor, 1974; Didukh, 2016). According to more recent data, this species grows in the Mountainous Crimea, in the Steppe and Forest-Steppe zones of Ukraine within the Dnipropetrovsk, Kyiv, Kirovohrad, Zaporizhzhia, and Mykolaiv regions, on the Volyn-Podillia Plateau (Ternopil Region, Kremenets Mountains National Nature Park), and in the Ukrainian Carpathians (Grevtsova & Drabinyuk, 2020). Furthermore, based on the analysis of the herbarium collections of Chernivtsi National University, we determined that this species also occurs in the Prut-Dniester interfluve within the Ivano-Frankivsk and Chernivtsi regions. For the Ukrainian Carpathians, it was previously recorded in only two floristic regions: the Chyvchyny-Hryniavy Mountains and the Marmaros Alps (Chopyk & Fedoronchuk, 2015).

A common feature of *C. integerrimus* habitats in Europe and Asia is their association with limestone soils (Kurto et al., 2013; Lee et al., 2025). Habitats with calcareous soils serve as habitats for a significant number of rare species in many regions of the world, providing a characteristic substrate for calciphile plants and holding significant ecological value from a nature conservation perspective (Mazerolle et al., 2018; Craw et al., 2025).

In the European part of its range, *C. integerrimus* is a diagnostic species of open calcareous shrub communities (Mucina et al., 2016; InfoFlora, 2025), whereas in East Asia, particularly in Korea, populations are restricted to forest understory (Lee et al., 2025).

In the Carpathian region, *C. integerrimus* occurs on carbonate and silicate cliffs (habitats 1A Calcareous cliff and 1B Siliceous cliff) (Sadlo et al., 2007). In the Czech Republic, it is a component of precisely such habitats (Chytrý et al, 2021).

Cotoneaster integerrimus is not mentioned in the description of habitats in the Ukrainian Carpathians (Prots et al., 2012), nor is it mentioned in the catalog of biotopes of the Mountainous Crimea (Dydukh, 2016) or in the national catalog of biotopes of Ukraine (Kuzemko et al., 2018).

In the *Prodromus of the Vegetation of Ukraine* (2019), *C. integerrimus* is listed as a diagnostic species of the alliance *Berberidion vulgaris* Br.-Bl. ex Tx. 1952, order *Prunetalia spinosae* Tx. 1952, class *Rhamno-Prunetea* Rivas Goday et Borja Carbonell ex Tx. 1962. These communities are characterized by an azonal distribution. They are partly natural forest-edge communities that form an ecotone with species of the *Trifolio-Geranietea sanguinei* T. Müller 1962 class, directly adjacent to the forest and bordering meadow or meadow-steppe communities. They may also occur as fragmented forest complexes in areas of sparse tree cover at the forest edge (Fitsailo, 2019). *Cotoneaster integerrimus* is also a diagnostic species of the *Genisto albidae-Stipetum lithophilae* Didukh et Mucina 2014 association (alliance *Androsaco tauricae-Caricion humilis* Didukh in Didukh et Mucina 2014, order *Festucetalia valesiacae* Soó 1947, *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947), which is restricted to the Western and Central Mountainous Crimea (Vinokurov, 2019).

There are generally few syntaxonomic studies of communities with *C. integerrimus* in Europe. They were first described in the phytosociological literature from the territory of Central Bohemia (Firbas & Sigmond, 1928) as the *Cotoneaster integerrimus-Polygonatum odoratum* community. Later, Tüxen (1952), based on the data from Faber (1936), described an association named *Cotoneastro-Amelanchieretum* Faber 1936 ex Tx. 1952. Faber ex Th. Müller 1966. This association comprised transitional vegetation between shrub and herbaceous communities on rocky outcrops. Later, Hoffmann (1958) described a community involving *C. integerrimus* co-dominated by *Juniperus communis* and *Sorbus aria*, ecologically similar to the previous association, under the name *Junipero-Cotoneasteretum*. Subsequently, Stöcker (1962) described another association, *Sarothamno scoparii-Cotoneasteretum integerrimi*. However, these associations were highly heterogeneous in their floristic composition, as noted by Rauschert (1990). Based on the floristic differences among the communities involving *C. integerrimus*, he proposed distinguishing six plant associations. These include the previously described *Cytiso scoparii-Cotoneasteretum integerrimi* (syn. *Sarothamno scoparii-Cotoneasteretum*), *Cotoneastro-Amelanchieretum*, and

Junipero-Cotoneasteretum, as well as three associations new to science: *Seslerio-Cotoneasteretum*, *Roso ellipticae-Cotoneasteretum*, and *Lembotropido-Cotoneasteretum*. Subsequently, in later phytosociological reviews, all of the listed associations were treated as synonyms of either *Cotoneastro-Amelanchieretum* or *Junipero-Cotoneasteretum*.

Świerkosz & Reczyńska (2022) conducted a specialized study on the syntaxonomy of plant communities involving *C. integerrimus*. Based on the historical and contemporary phytosociological data and using modern statistical and ordination methods, the authors established the syntaxonomic structure of communities dominated by *C. integerrimus*. They also conducted a detailed nomenclatural revision of all previously proposed syntaxonomic names. According to their data, three plant associations occur in Central Europe. The first, *Cytiso scoparii-Cotoneasteretum integerrimi* Stöcker 1962, comprises xerothermic shrub communities of open structure, notable for the presence of acidophilic species, succulents, and species characteristic of rocky outcrops. The vegetation of this association is found at elevations up to 670 m a.s.l. in moderately nutrient-rich mountain soils in the Czech Republic, Poland, and Germany. The second association, known as *Cotoneastro integerrimi-Amelanchieretum ovalis* Faber ex Th. Müller 1966, occupies calcareous habitats at elevations of up to 700 m a.s.l. and is enriched with xerophytic and calciphilous species of the *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947 class. The vegetation of the association has been recorded in Germany, the Czech Republic, Slovakia, Austria, Poland, and Hungary. The communities of the third association, *Cotoneastro integerrimi-Sorbetum chamaemespili* Gillet in Gallandat et al. 1995, are widespread in calcareous soils under colder climatic conditions at elevations ranging from 900 to 1,350 m a.s.l. and is characteristic of the Alps of Germany and Austria.

As our research has shown, in the Ukrainian Carpathians this species occurs on open, rocky, and stony mountain peaks in the subalpine zone, where it forms rare shrub communities with a significant admixture of calcephilic species and is a component of the habitat "Alpine and subalpine heath" (No. 4060), which is protected by EC Directive 92/43. However, these habitats are threatened with extinction due to the planned construction of a wind farm specifically in the Eastern Beskids, where the concentration of the species' natural habitats is particularly high. The threat of vegetation degradation in the subalpine belt affects most regions of the Ukrainian Carpathians (Felbaba-Klushyna, 2020, 2023).

The objective of our research was to determine the current distribution of the species in the Ukrainian Carpathians, identify its phytocenotic and biotopic preferences in the high mountains, asses threats to its existence, and propose conservation measures.

Materials and methods

The study was conducted from 2021 to 2025 within the following floristic regions of the Ukrainian Carpathians: the Eastern Beskids, Chornohora Range, and Marmaroskyi Massif. The names of the floristic regions are given in accordance with V. I. Chopyk's floristic zoning of the Ukrainian Carpathians (Chopyk et al., 1978). Nomenclature of vascular plant species follows the Euro+Med Plant Base (https://europlusmed.org). Nomenclature of bryophytes follows the latest bryological inventory of Ukraine (Virchenko & Niporko, 2022). Nomenclature of lichens are taken from Index Fungorum (2026). Geobotanical surveys were conducted on 6–18 m² plots, following the methodology of Braun-Blanquet (1964). During the surveys, in addition to the species composition and the projective cover of each species, the elevation a.s.l., slope orientation, and geographic coordinates of each site were recorded. All *relevés* were entered into the database using Turboveg software (Hennekens & Schaminée, 2001) and then exported to the Juice program (Tichý, 2002) for further analysis. The new association is described in accordance with the *Code of Phytosociological Nomenclature* (Theurillat et al., 2021). The species in the phytocenotic table (Table 2) are listed in descending order of constancy. The description number selected as the nomenclatural type of the associations is indicated in bold.

We analyzed herbarium specimens of *Cotoneaster integerrimus* from the herbarium collections of Uzhhorod National University (UU), the Institute of Carpathian Ecology of the National Academy of Sciences of Ukraine (LWKS), Yuriy Fedkovych Chernivtsi National University (Cher), the Carpathian Biosphere Reserve (CBR), and the M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine.

The GPS coordinates of the surveyed sites are listed in Table 1 (site numbers correspond to the GPS coordinates of the surveyed sites (site numbers correspond to the *relevé* numbers in Table 2).

Table 1
The GPS coordinates of the surveyed sites

Number of releve	The GPS coordinates
1	48°39′19.5″ N 23°12′56.7″ E
2	48°39′16.9″ N 23°12′59.6″ E;
3–4	48°37′17.4″ N 23°11′23.2″ E
5	48°10′12.5″ N 24°25′01.1″ E
6	47°55′23.2″ N 24°19′42.2″ E
7–8	48°53′14.0″ N 22°55′54.0″ E
9	48°53′14.0″ N 22°55′53.0″ E
10	48°53′14.0″ N 22°55′52.0″ E
11	48°53′15.0″ N 22°55′50.0″ E
12	48°53′16.0″ N 22°55′48.0″ E
13	48°49′54.7″ N 22°59′35.5″ E
14	48°49′54.5″ N 22°59′45.4″ E
15	48°49′47.6″ N 22°59′59.0″ E
16	48°49′47.6″ N 22°59′59.0″ E

The Ukrainian Carpathians are part of the Eastern Carpathians, also known as the Wooded Carpathians. They lie on the relatively narrow section of the Carpathian Arc, which curves eastward and serves as a corridor between the Southern and Western Carpathians. Based on relief and flora, the highland regions include Chyvchyny-Hryniavy Mountains, Marmaros, Chornohora, Svydovets, Polonyna Krasna, Gorgany, Polonyna Borzhava, and Beskids. (Malyanovsky & Krichfalushiy, 2002). Highlands are defined as landscapes located above 1,200 m a.s.l., corresponding to the upper forest limit of this part of the Carpathians. The average monthly air temperature in the subalpine zone is approximately 3.2°C, and the average annual precipitation exceeds 1,400 mm (Milkina, 1988a), with local maxima reaching 2,500 mm per year (Ando, 1999). Based on the results of regular monitoring at 11 meteorological stations in the Ukrainian Carpathians, a clear trend of rising air temperatures was observed (Vyshnevskyi & Donich, 2021).

Brown mountain forest soils are widespread in the study area, while gravelly meadow-sod soils are found on the peaks (Milkina, 1988b).

On the slopes of the Vododilny Ridge and the Borzhava Massif, as well as in the Marmaros Alps and the Svidovets Massif (where localities of the studied species were found), old-growth beech, beech-maple, and, less commonly, beech-fir forests have been preserved, many of which are under legal protection. In particular, on the slopes of the Vododilnyi Ridge, the Pryvododilnyi Forest Reserve of local significance (720 ha) and the Pikui Landscape Reserve of national significance (711 ha) have been established. Rare primary sites of shrub-moss vegetation have been preserved on the highest rocky areas near the mountain ridges, while high-mountain meadows (*polonyny*) host primary mixed-grass and grass communities featuring *Festuca amethystina* subsp. Orientalis, *F. inarmata*, and others. The highlands of the Ukrainian Carpathians represent the primary refugia of rare flora and vegetation (Didukh, 2009; Felbaba-Klushyna & Bizilia, 2015; Felbaba-Klushyna & Huklyvska, 2021).

Results

According to the data from herbarium collections (UU, LWKS, CHER, CBR) and our own research, it has been established that in the Ukrainian Carpathians, the species occurs at at a minimum of 29 localities, spanning elevations from the foothills to the subalpine zone. In the Chernivtsi and Ivano-Frankivsk regions, the species occurs in the floristic regions of the Pre-Carpathians and in the Chyvchyny-

Hryniavy Mountains. In the Chyvchyny-Hryniavy Mountains, this species is primarily recorded in the forest zone, and only isolated records exist from the subalpine zone. In the Zakarpattia region, the species was collected in the Svidovets Massif on the cliffs of Mount Dohiaska, in the Chornohora Massif on Mounts Hoverla and Petros Chornohorskyi, in the Marmaros Alps on Mounts Petros Marmaroskyi; and La-Tundra, in the Eastern Beskids on Mount Pikui and on the Polonynian Beskids in the Uzhanskyi National Nature Park.

We confirmed previously recorded locations of the species on Mount Pikui (Eastern Beskids), on Mount Petros (Chornohora Range), and on Mount Petros Marmaroskyi (Marmaroskyi Range). We first recorded this species in the subalpine zone on the peaks and slopes of the Vododilno-Verhovynskyi Range (Fig. 1) and in the Borzhava Highlands, which are part of the Eastern Beskids region in the Latorica River basin (Felbaba-Klusina & Huklivska, 2023).

According to the analysis of herbarium collections, the largest number of known locations has been recorded in the Chyvchyny-Hryniavy Mountains of Ivano-Frankivsk and Chernivtsi regions.

Thus, based on the herbarium data and recent findings, 29 locations of *C. integerrimus* have been recorded to date in the Ukrainian Carpathians, 18 of which are in the subalpine zone (Fig. 2).

Fig. 1. *Cotoneaster integerrimus* on the peaks and slopes of the Vododilno-Verhovynskyi Range (Felbaba-Klusyna, 2025)

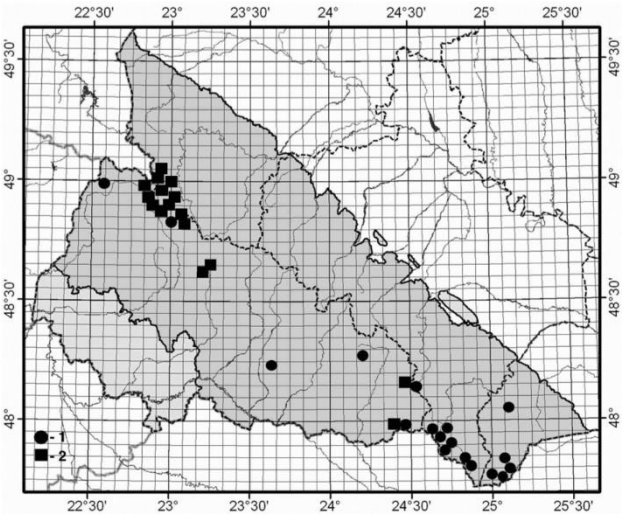

Fig. 2. Map showing the distribution of *Cotoneaster integerrimus* in the Ukrainian Carpathians: *1* – based on herbarium collections, *2* – based on the authors' own data

The highest recorded elevation is over 1,700 m a.s.l., near the summit of Mount Chyvchyn. The species has been recorded in most high-mountain regions of the Ukrainian Carpathians, but is absent from the Gorgany and Krasne high-mountain regions. It is rare everywhere. The species is regionally rare in all three regions where it has been recorded, namely Chernivtsi, Ivano-Frankivsk, and Zakarpattia (Krichfalushiy et al., 1999; Andrienko et al., 2012).

According to the ecological scales developed by Didukh (2011), this species is a submesophyte in terms of water regime, a neutrophil in terms of acidity regime, a subnitrophil in terms of available nitrogen content, and a microtherm in terms of temperature regime; a mesoaridophyte in terms of climate humidity (ombro-regime); a hemioceanist in terms of climate continentality (contrast-regime); and a hemicryophyte in terms of winter severity (cryo-regime).

With respect to almost all ecological indicators, the species exhibits a narrow ecological amplitude (hemistenotopic). According to the ecological scales of Didukh (2011), the species has the widest ecological amplitude in relation to climate continentality. *Cotoneaster integerrimus* shows the narrowest ecological tolerance with respect to the temperature regime of the climatic zone. These data are similar to the ecological characteristics of *C. integerrimus* from some other regions of the Carpathians (Sádlo, 2007).

Under such environmental conditions, communities of *C. integerrimus* form, as we have described from the Ukrainian Carpathians. Thus, according to the phytogeographic analysis (Fig. 3a), the vegetation we have described is quite sensitive to the substrate water regime and nitrogen content (Fig. 3b). At the same time, the communities we studied are capable of tolerating significant fluctuations in soil acidity and its saturation with carbonate compounds. In terms of all climatic indicators (Fig. 3c), communities involving *C. integerrimus* have a very narrow climatic ecological amplitude.

The communities within the Ukrainian Carpathians are predominantly three-layered and cover an area of 6–18 m². The total number of species in them ranges from 13 to 24. The total ground cover of the plant communities is 60–90%; the moss–lichen layer is generally well-developed and accounts for 20–40% of the ground cover (Table 2).

The first layer is a shrub layer, formed by *C. integerrimus*, about 40–60 (70) cm tall, with a projective cover of 30–70% (*Deschampsia cespitosa*, *Luzula alpinopilosa* subsp. *obscura*, *Festuca airoides*, *F. amethystina* subsp. *orientalis*).

The second shrub layer (about 10–15 cm tall) sometimes accounts for up to 40% of the total projective cover, consisting of *Vaccinium vitis-idaea* (15–30%), *V. myrtillus* (5–15%), and somewhat less *Vaccinium uliginosum* (2–3%). It includes *Thymus pulcherimus*, *Antenaria dioica*, *Hypochaeris uniflora*, *Hieracium alpinum*, and some other species, which are found primarily in crevices between stones and rock fissures in areas where substrate accumulates. The third moss-lichen layer is dominated by *Cetraria islandica*, species of the genus *Cladonia*, as well as *Hylocomnium splendens*, *Polytrichum piliferum*, and several other species. It also contains synusia of *Sempervirum montanum*, which in the most recent survey (16) accounts for 5% of the projective cover (Fig. 4).

Species found in no more than one *relevé* were as follows: *Anemonastrum narcissiflorum* (L.) Holub (5: +); *Bartsia alpina* L. (5: +); *Cerastium alpinum* L. (2: +); *Leucanthemopsis alpina* (L.) Heywood (1: +); *Cladonia pyxydata* (L.) Hoffm. (3: +); *Alnus viridis* (Chaix) DC. (6:1); *Gentiana acaulis* L. (6: r); *Gentiana lutea* L. (6: r); *Hypochaeris uniflora* Vill. (2: +); *Festuca amethystina* subsp. *orientalis* Krajina (2:+); *Juncus trifidus* L. (5:2); *Polygonum bistorta* Delarbre (5:1); *Pulsatilla alpina* subsp. *alba* Zämelis & Paegle (5: +); *Rhododendron myrtifolium* Schott & Kotschy (5:3); and *Soldanella hungarica* Simonk. (6:1).

Sampling locations in accordance with the *relevé* numbers are as follows: 1, 2 – Borzhava Range, Mount Velykyi Verh (15.07.2023, Felbaba-Klushyna L.); 3, 4 – same location, Mount Stii (16.07.2023, Felbaba-Klushyna L.); 5 – Chornohora Range, Mount Petros (11.08.2022, Voloschuk M.); 6 – Marmaros Alps, Mount Petros Marmaroskyi (14.08.2021, Voloschuk M.); 7–13 – the summit ridge of the Vododilnyi Range between the villages of Pashkivtsi, Perehresnyi, Kichernyi, and Roztoka, on the side of the Zdenievo Territorial Community in Zakarpattia Region and the village of Lybohora in Lviv Region, Borynia Territorial Community (05.09.2025, Felbaba-Klushyna L. & Byzilja A.); 14–16 – the southwestern slope of Mount Pikui (09.09.2025, Felbaba-Klushyna L. & Byzilja A.).

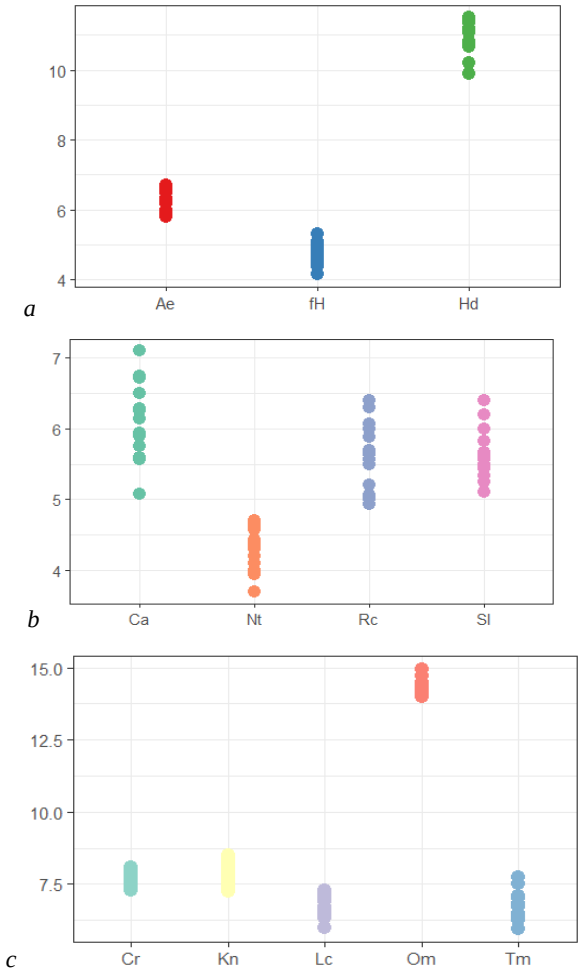

Fig. 3. Phytoindication analysis of plant communities involving *Cotoneaster integerrimus* based on key ecological parameters (n = 12): *a* – soil moisture and aeration regime; *b* – soil chemical properties; *c* – climatic parameters; Ae – soil aeration; fH – soil moisture variability; Hd – soil moisture; Ca – carbonate content; Nt – soil nitrogen content; Rc – soil acidity; Sl – salinity regime; Cr – cryoregime; Kn – continentality; Lc – light regime; Om – precipitation regime; Tm – temperature regime

Discussion

The plant communities with *C. integerrimus* we described do not resemble any of the associations described by Świerkosz & Reczyńska (2022) in terms of species composition. However, in terms of ecological conditions, they are somewhat similar to the xerothermic, more continental communities represented by the *Cotoneaster integerrimus-Sorbetum chamaemespili* association, known in the Alps.

Relevés of different parts of the Ukrainian Carpathians have certain distinctive features. The communities described within the Borzhava Massif (*relevés* 1–4), include relatively more grasses, with *Antennaria dioica*, *Festuca airoides*, *Linum extraaxillare*, and *Deschampsia cespitosa*. In the communities from the Chornohora and Marmaros Alps (*relevés* 5, 6), diagnostic species of the class *Juncetea trifidi* Hadač in Klika et Hadač 1944 are present: *Campanula alpina*, *Juncus trifidus*, *Pulsatilla alpina* subsp. *alba*, as well as *Anemonastrum narcissiflorum*, a diagnostic species of the class *Elyno-Seslerietea* Br.-Bl. 1948, and *Carex sempervirens*, a diagnostic species of the *Festuco saxatilis-Seslerion bielzii* (Pawłowski et Walas 1949) Coldea 1984 alliance within the same class. In addition, other components of subalpine meadows were noted in the area, such as *Crocus heuffelianus*, *Polygonum bistorta*, *Soldanella hungarica*, and *Rhododendron myrtifolium*, which do not appear in other *relevés*. The communities within the Eastern Beskids (releves 7–16) are characterized by the significant phytocenotic role of lichens (*Cetraria islandica*, *Cladonia rangiferina*, *C. gracilis*), bryophytes (*Tortella tortuosa*, *Polytrichum piliferum*), as well as many species of the class *Loiseleurio procumbentis–Vaccinietea* Eggler ex Schubert 1960 (*Vaccinium myrtillus*, *V. vitis-idea*, less frequently *Empetrum nigrum*), which unites arctoboreal, subalpine shrubby and subshrubby acidophilous communities of Eurasia and North America on rocky substrates. *Sempervirum montanum*, *Festuca amethystina* subsp. *orientalis*, as well as some diagnostic species of the *Elyno-Seslerietea* Br.-Bl. 1948 class, notably *Thymus pulcherimus* and *Scabiosa lucida* subsp. *barbata*, are frequently found in these communities.

Within the *Loiseleurio procumbentis–Vaccinietea* Eggler ex Schubert 1960 class, a number of associations have been described from the Ukrainian Carpathians, which are grouped under the order *Rhododendro ferruginei-Vaccinetalia* Br. -Bl. in Br.-Bl. et Jenny 1926, by the alliance *Loiseleurio procumbentis–Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926. In terms of growth conditions and floristic composition, these associations are similar to the communities we have described, where the diagnostic species are predominantly *Cetraria islandica* and one of the shrubs. These include the associations *Loiseleurio-Cetrarietum* Br.-Bl. et al. 1939, *Cetrario-Vaccinietum gaultheriodis* Hadač 1956, and *Empetro-Vaccinietum gaultherioidis* Br.-Bl. in Br.-Bl. et Jenny 1926 corr. Grabherr 1993. This gives us grounds to distinguish a new association, *Cetrario islandicae-Cotoneasteretum integerrimi*, within this same alliance.

A common feature of all the communities described is the key role played by *C. integerrimus* and the diagnostic species of the *Loiseleurio procumbentis-Vaccinietea* class (*V. myrtillus*, *V. vitis-idaea*). *Cetraria islandica* is found at nearly all of the described localities.

A description of the new association is provided below.

Loiseleurio procumbentis–Vaccinietea Eggler ex Schubert 1960, *Rhododendro ferruginei-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926, *Loiseleurio procumbentis–Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926.

Cetrario islandicae-Cotoneasteretum integerrimi ass. nova hoc loco.

The diagnostic species: *Cotoneaster integerrimus*, *Cetraria islandica*.

The constant species: *Vaccinium myrtillus*, *Vaccinium vitis-idea*, *Thymus pulcherimus*, *Polytrichum piliferum*, *Tortella tortuosa*, *Cladonia gracilis*, *Cladonia rangiferina*.

Nomenclatural type (holotypus hoc loco): *relevé* 13 in Table 2 (Description by L. Felbaba-Klushyna, September 5, 2025, in the subalpine zone on the rocky peaks of the Vododilno-Verhovynskyi Ridge (Eastern Beskids floristic region) at an elevation of 1,251 m a. s. l. on the border between Zakarpattia and Lviv regions).

The habitats of these communities are characterized by extreme ecological conditions, marked by high insolation, high air humidity, and a short growing season. These are rocky mountain peaks at elevations of 1,200–1,700 m a.s.l. with a thin soil layer, subject to strong cold winds, water erosion, and significant temperature fluctuations throughout the year. The soils are sod-brown, with a significant content of organic matter, gravelly, and predominantly acidic (pH 3.8–4.5) (fig. 4–6). In the ecological-cenotic series, it is situated next to the associations along the moisture gradient: *Loiselerio-Cetrarietum* Br.-Bl. et al. 1993 and *Cetrario-Vaccinietum gaultherioidis* Hadač 1954.

The floristic composition is rich in montane, boreal, arctoboreal, and arcto-alpine species. Only *C. integerrimus*, as already mentioned, is characterized by a wide range and altitudinal distribution. A significant role in the community is played by boreal shrubs (*Vaccinium. myrtillus*, *V. vitis-idaea*, *V. uliginosum*), which typically grow on stony acidophilic substrates, though they also occur on silicate, low-carbonate, or carbonate-indifferent substrates. Lichens play a significant role in these communities; they prefer acidic substrates or occur in environments ranging from very acidic to acidic (*Cladonia gracilis*), or even from very acidic to subneutral (*Cetraria islandica*, *Cladonia rangiferina*). Bryophytes also exhibit diverse ecological characteristics. In particular, *Tortella tortuosa* is a bioindicator of carbonate substrates. At the same time, *Polytrichum piliferum* is a cosmopolitan, xerophytic moss, a pioneer species in the colonization of bare rocks, adapted to dry, open, and nutrient-poor (oligotrophic) acidic environments.

Table 2
Phytocoenotic characteristics of plant communities with *Cotoneaster integerrimus*

Number of releves	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Elevation above sea level, m	1371	1372	1412	1412	1750	1706	1217	1218	1230	1227	1232	1230	1251	1320	1355	1353
Total projective coverage, %	60	60	60	70	90	70	60	90	60	90	70	70	70	60	60	70
Area, m^2	8	9	6	8	16	12	8	16	18	18	8	14	16	18	12	8
Number of species in the community	15	14	13	14	24	20	15	17	22	13	18	18	18	19	16	14
Slope exposure	SW	SW	SE	SE	SE	SE	SW	NE	NE	NE	NE	SW	SW	SW	SW	NE
D.s.ass.*Cetrario islandicae-Cotoneasteretum integerrimi*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cotoneaster integerrimus Medik.	2	2	2	3	2	1	2	4	2	4	3	2	2	2	3	2
Cetraria islandica (L.) Ach.	+	–	+	1	2	+	+	2	+	1	+	1	1	2	1	1
D.s. cl. *Loiseleurio procumbentis-Vaccinietea*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vaccinium myrtillus L.	+	+	1	+	2	2	2	1	1	1	+	1	1	1	1	+
Vaccinium vitis-idea L.	+	1	+	1	1	2	+	2	2	2	2	2	1	2	2	2
Empetrum nigrum L.	1	–	–	–	–	–	1	–	–	–	–	–	–	1	+	1
D.s. cl. *Juncetea trifidi*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Festuca airoides Lam.	1	+	1	1		+	–	+	+	–	–	–	+	–	–	–
Huperzia selago (L.) Schrank & Mart.	+	–	–	–	+	–	+	–	–	–	–	–	+	+	+	+
Campanula alpina Jacq.	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–
D.s. cl. *Elyno-Seslerietea*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Thymus pulcherrimus Schur	1	+	1	+	+	–	1	+	+	–	+	+	+	1	+	–
Scabiosa lucida subsp. *Barbata* Nyár.	–	–	–	–	–	–	–	+	+	–	1	+	+	–	–	+
Other species	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Antennaria dioica (L.) Gaertn.	+	1	+	+	+	–	+	+	+	–	–	+	–	+	–	–
Sempervivum montanum L.	–	–	–	–	+	+	–	+	–	+	+	1	1	1	1	1
Vaccinium uliginosum L.	1	+	+	1	2	2	–	–	–	+	–	–	–	+	+	–
Luzula alpinopilosa subsp. *obscura* S. E. Fröhner	+	+	+	+	–	–	1	+	–	+	–	–	+	+	–	–
Silene nutans subsp. *dubia dubia* (Rohrb.) Zapał.	–	–	–	–	–	–	–	+	+	+	–	+	–	+	+	+
Dianthus carthusianorum L.	–	–	–	–	–	–	–	–	+	+	–	+	–	+	–	+
Juniperus communis subsp. *nana* Syme	–	–	–	–	–	+	–	–	+	–	+	–	+	–	+	–
Linum extraaxillare Kit.	+	+		+	–	–	–	+	–	–	–	–	+	–	–	–
Epilobium angustifolium L.	–	–	–	–	–	–	+	–	+	–	+	–	–	–	–	–
Potentilla aurea L.	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–
Solidago virgaurea L.	–	–	–	+	–	–	–	–	+	–	–	+	–	–	–	–
Carex sempervirens Vill.	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Crocus heuffelianus Herb.	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Deschampsia cespitosa (L.) P. Beauv.	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Hieracium alpinum L.	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Phleum alpinum L.	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Picea abies (L.) H. Karst.	–	–	–	–	–	–	–	–	+	–	+	–	–	–	–	–
Salix silesiaca Willd.	–	–	–	–	–	–	–	–	+	–	–	+	–	–	–	–
Sorbus aucuparia L.	–	–	–	–	–	–	–	–	+	–	+	–	–	–	–	–
Polytrichum piliferum Hedw.	+	–	–	–	2	1	–	+	+	+	1	1	+	+	+	2
Tortella tortuosa (Schrad. ex Hedw.) Limpr.	–	–	+	–	–	–	1	1	1	+	+	+	1	1	1	+
Dicranum scoparium Hedw.	–	–	–	–	–	–	–	+	–	–	+	+	1	–	+	–
Pleurozium schreberi (Willd. ex Brid.) Mitt.	–	–	–	–	1	1	+	–	–	–	+	–	+	–	–	–
Hylocomnium splendens (Hedw.) Schimp.	–	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–
Cladonia gracilis (L.) Willd.	–	–	–	–	+	–	2	1	1	+	+	+	1	+	1	+
Cladonia rangiferina (L.) Weber ex F.H.Wigg.	–	–	–	+	+	+	+	+	+	+	+	+	+	1	+	–
Umblicaria polyphylla (L.) Baumg.	–	–	–	–	–	–	+	–	+	–	+	+	–	+	–	+

Note: the GPS coordinates in the *relevés* correspond to the data in Table 1.

The main ecological characteristics of most species include high heat and drought tolerance, as well as adaptation to oligotrophic substrates. The association includes Carpathian endemics such as *Thymus pulcherimus*, *Festuca amethystina* subsp. *orientalis*, *Scabiosa lucida* subsp. *barbata*, *Soldanella hungarica*, and *Sempervirum montanum* (Fig. 5).

The communities of this association are rare, occupy relatively small areas, have high conservation value, and play a significant role in water regulation and soil protection. This is due to the fact that the highlands of the Ukrainian Carpathians receive the highest amount of precipitation (1,500 to 2,500 mm per year) (Ando, 1999), which, when the integrity of the vegetation cover is compromised, can cause flash floods and mudslides, leading to water erosion of the soil (Felbaba-Klushyna, 2010). On the summits of mountain ridges, where stony and gravelly substrates predominate (Fig. 4–6), under conditions of strong winds and frequent downpours, the soil cover is thin and particularly vulnerable to water and wind erosion. Vegetation stabilizes the soil and promotes its formation, retaining precipitation in part due to the high hygroscopicity of lichens and mosses.

The plant communities in the Borzhava Massif are the poorest in terms of species composition. This massif has been the most significantly altered by human activity. Traditionally, the Borzhava highlands, such as the Eastern Beskids as a whole, have been the site of active livestock grazing, haymaking, and the harvesting of blueberries, lingonberries, and other medicinal plants. Over the past 100 years, the vegetation cover of the Eastern Beskids has lost a significant amount of biomass and, to a large extent, its ability to perform basic ecosystem functions (Houbets et al., 1994). At the same time, the Chornohora and Marmaroskyi massifs are difficult to access; large parts of them belong to the Carpathian Biosphere Reserve and are protected. Therefore, the natural vegetation there is well preserved. The plant communities described in the area include rare species such as *Anemonastrum narcissiflorum*, *Bartsia alpina*, *Gentiana lutea*, *Pulsatilla alpina* subsp. *alba*, and *Sempervirum montanum*, which are listed in *The Red Book of Ukraine* (Dydukh, 2009). Given its phytocenotic affiliation with the class *Loiseleurio procumbentis-Vaccinietea* Eggler ex Schubert 1960, in the Ukrainian Carpathians the species is a component of the biotope "Alpine and subalpine heath" (No. 4060), which is protected by EC Directive 92/43. Our research is, in essence, the first to provide specific information regarding the biotopic preferences of *C. integerrimus* in Ukraine.

In particular, our research highlights the uniqueness of the vegetation in the Eastern Beskids, which has now become the focus of environmental concerns due to the development of wind energy. The very section of the Vododilnyi Ridge where communities of *C. integerrimus* were discovered is now at risk of destruction.

Fig. 4. The communities of *Cetrario islandicae-Cotoneasteretum integerrimi* on the peaks of the Vododilnyi Ridge (Felbaba-Klushyna, 2025)

Fig. 5. The rare endemic *Sempervirum montanum* in communities with *Cotoneaster integerrimus* (Felbaba-Klushyna, 2025)

Fig. 6. Plant communities of *Cetrario-Cotoneasteretum integerrimi* association on the steep rock faces of the Vododilnyi Ridge in the Eastern Beskids (Felbaba-Klusyna, 2025)

At the same time, this provides grounds to oppose the implementation of this economic project and to initiate, in particular, the expansion of the Pryvododilnyi Forest Reserve to include the summit areas of the Vododilnyi Ridge, the expansion of the Pikui Landscape Reserve to include the southwestern sections of Mount Pikui, and the creation of the Polonyna Borzhava Landscape Nature Park in the Borzhava Massif, as we previously proposed (Felbaba-Klushyna, 2020).

Conclusions

Cotoneaster integerrimus is a rare species in the Ukrainian Carpathians; to date, 29 locations are reliably known, of which 18 are recorded in the high mountains of the Ukrainian Carpathians and 11 in the forest zone. The species has been found in the following floristic regions of the Ukrainian Carpathians: the Pre-Carpathians, the Chyvchyny-Hryniavy Mountains, Svidovets, Chornohora, the Marmaros Alps, and the Eastern Beskids.

Communities containing *C. integerrimus* differ significantly from all previously described associations in Central Europe. They occur in communities of the class *Loiseleurio procumbentis–Vaccinietea* Eggler ex Schubert 1960, order *Rhododendro ferruginei-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926, alliance *Loiseleurio procumbentis–Vaccinion* Br. -Bl. in Br.-Bl. et Jenny 1926, and form the *Cetrario islandicae-Cotoneasteretum integerrimi* association. In the Ukrainian Carpathians, *C. integerrimus* is a component of the biotope "Alpine and subalpine heath" (No. 4060), which is protected by EC Directive 92/43. Given the high abundance of endemic, rare, and endangered vascular plant species in the identified communities, as well as the high ecosystem value of the Vododilnyi Ridge as a whole and the Borzhava Massif of the Ukrainian Carpathians, and in order to preserve the unique plant communities of the *Cetrario islandicae-Cotoneasteretum integerrimi* association associated with them, it is necessary to expand the boundaries of the existing nature reserve areas to include the studied sites.

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