sciendo

ASN, Vol. 10, No 3, Pages 1–20, 2023

Acta Scientifica Naturalis

Former Annual of Konstantin Preslavsky University of Shumen: Chemistry, Physics, Biology, Geography

Journal homepage: https://content.sciendo.com/view/journals/asn/asn-overview.xml

Opuntia humifusa (Raf.) Raf. (Cactaceae) in the Bulgarian flora

Dimcho Zahariev

Department of Plant Protection, Botany and Zoology, Faculty of Natural Sciences, Konstantin Preslavsky University of Shumen, 115 Universitetska Str., 9700 Shumen, Bulgaria

Abstract: *Opuntia humifusa (Raf.) Raf. is included in the List of Top 10 of the worst invasive alien plant species in Bulgaria. This is the fastest spreading species of the four species of the Opuntia genus found so far in natural habitats in Bulgaria. In the period 2010-2023, 3 new localities of the species were established in 3 new floristic regions of Bulgaria: Black Sea Coast (North), Stara Planina (East) and Strandzha Mountain. They describe the northernmost and easternmost distribution limits of the species in Bulgaria. The described localities are different in area: from 0.08 ha to 21.11 ha. The characteristics of the abiotic environment are presented such as: slope, exposure, elevation, bedrock, soil, climatic region and subregion. The habitats in which individuals of the species are found are indicated. Accompanying plant species were studied. The spatial structure of O. humifusa populations was studied. The reasons for the appearance and spread of this invasive alien plant species in territories that have not been inhabited by it until now have been examined, considering that these reasons are not natural, but have an anthropogenic character. Our findings support the opinions of other researchers about the key role of nature lovers in the spread of this invasive species. Factors favoring the increase in population size in established localities are indicated. Methods have been proposed to control the spread of the species.*

Keywords: Bulgaria, cacti, floristic regions, population, reasons for distribution, control measures

Introduction

The genus *Opuntia* Mill. from Cactaceae Family includes 233 species [1]. They are distributed naturally throughout the Americas from British Columbia to the Strait of Magellan [2]. Of these, 34 species

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

are distributed in natural habitats in Europe and the Mediterranean as naturalized, introduced or casual species [3]. In Volume IV of Flora of the People's Republic of Bulgaria [4] five species are described, of which only two are distributed in natural habitats. These two species are also included in the Conspectus of the Bulgarian vascular flora published in 2012 [5]: *Opuntia humifusa* (Raf.) Raf. (syn. *O. vulgaris* Mill., *O. compressa* (Salisb.) MacBr.) and *O. macrorhiza* Engelm. (syn. *O. tortispina* Engelm.). In 2019, data were published on the natural distribution of two new species for the flora of Bulgaria - *O. engelmannii* and *O. fragilis* [6]. The Key to the native and foreign vascular plants in Bulgaria [7] includes seven species of the genus *Opuntia*. Three of them are distributed only as ornamental plants: *O. ficus-indica* (L.) Mill., *O. phaeacantha* Engelm., and *O. stricta* (Haw.) Haw., and the remaining four species are distributed except as ornamentals and as spontaneously distributed in natural natural habitats: *O. engelmannii* Salm-Dyck ex Engelm., *O. fragilis* (Nutt.) Haw., *O. humifusa* (Raf.) Raf., and *O. macrorhiza* Engelm.

The main limiting factors for the distribution of *Opuntia* species in Europe and specifically in the Mediterranean region are low temperatures and altitude. The maximum altitude up to which cacti of this genus are found is 800 m a.s.l. [8]. In Bulgaria, the highest altitude at which a population of *O. humufusa* has been found is 720 m a.s.l. in Lozenska Planina [9]. The population above the village of Lucky in the Pirin Mountains reaches up to 686 m a.s.l. [10]. Like many other species of cacti, their appearance in natural habitats at first seems harmless and even useful. Over time, however, the situation changes in a negative direction. An example of this is the invasions caused by cacti in various parts of the world. For example, cacti are not characteristic of the continent of Africa. In it, they were brought from South and North America. One of these species has already caused problems. This is *Opuntia stricta* (Haw.) Haw. It is widespread and abundant in parts of Kenya, Tanzania, and Ethiopia and present at low densities in Uganda. In Laikipia County, Kenya *O. stricta* had been present for more than 10 years. 50–75% of valuable grazing land had been invaded, and all felt that it contributed to the ill-health and death of livestock. Other negative impacts included reductions in native plant populations, rangeland condition, human health, and mobility of humans and animals. These negative impacts resulted in economic losses of 500–1000 USD per household per year for 48% of households. Research was conducted by interviewing 200 households in the area. The results show that all respondents believed a reduction in the abundance of this weed would improve well-being [11].

O. humifusa is included in the List of Top 10 of the worst invasive alien plant species in Bulgaria [12]. The populations of this species have the following impacts [13]:

- It increases the total vegetation cover in most localities of the species, and especially in sparsely vegetated areas, e.g., in Pobiti Kamani locality near town of Beloslav. In the latter location the total vegetation cover was increased by 10-30% in 80% of the studied plots.
- It reduces the local native floristic diversity. In Pobiti Kamani locality in 70% of the studied pairs

Corresponding author: d.zahariev@shu.bg Full Paper
DOI: 10.2478/asn-2023-0019

of plots the floristic diversity was reduced by 10-34%, in 20% there was no change (in the plots with smaller projective cover of *Opuntia*), and only in one plot was observed increase of the floristic diversity within the *Opuntia*-plot which was due to high projective cover of two of the local native species.

- It significantly reduces the grazing area in strongly invaded localities since domestic stock avoids the large groups of *Opuntia*. Moreover, the large stands of *Opuntia* change the local paths of both the domestic stock and wild animals, since it forms impassable groups.
- It threatens some rare habitats in Bulgaria, e.g. E1.9B: Standing stone inland dune in Pobiti Kamani locality by changing completely the vegetation (often *Opuntia* becomes the dominant species) and flora.
- It competes with some local plant species of high conservation concern, e.g. Dianthus nardiformis ("Endangered" at national level), and Centaurea arenaria ("Vulnerable" at national level) Pobiti Kamani locality.
- It competes with local plant species for pollinators.

Among the measures to control the spread of *O. humifusa* in natural habitats, prevention is the most important. It is necessary to inform the lovers of ornamental plants about the danger that this species of cacti represents to the native flora and the risks that the accidental or intentional planting of the species in the wild entails. The disposal of parts of the plant or its use for greening of terrains without vegetation in the mountains should be stopped, since these terrains are part of the succession of natural phytocoenoses, and it is also possible that they include spring sinuses with a short duration of vegetation, which not accounted for by lovers of exotic plants. Other measures to limit populations of the species include biological and chemical control. Biological control is often considered the most cost-effective and successful method of controlling invasive species. In the specific case, phytophagous insects such as *Cactoblastis cactorum* (Berg, 1885) and *Dactylopius opuntiae* (Cockerell, 1896) can be used. The safest and most secure for the rest of the plant species is the mechanical method of combating *O. humifusa* by uprooting and destroying individual individuals before the fruits ripen [9].

Material and Methods

The present study was conducted by the route method in the period April – June 2023 according to data from our field work in the period 2010-2020. The type of bedrock and soil is defined in the GIS environment under the Bedrock and Soils layers. In determining the associated species with *O. humiffusa*, was used Handbook for Plants in Bulgaria [14] and Key to the Native and Foreign Vascular Plants in Bulgaria [7]. The names of the taxa are according to The World Flora Online [1]. The marking of the boundaries of the

Corresponding author: d.zahariev@shu.bg Full Paper
DOI: 10.2478/asn-2023-0019

populations of the species was done with the help of a GPS receiver Garmin Oregon 450. The WGS 84 UTM 35N coordinate system was used. The distances from the locality to neighboring sites were measured over the air using software Google Earth Pro Portable ver. 7.1.5. The distribution maps in the new localities were created using QGIS 3.32.0 Lima software and Google Satelite images.

Results and Discussion

Morphology

Shrubs, forming clumps or often prostrate, usually only 1 or 2 stem segments tall, to 0.5 m (except in Florida where they may be erect and reach to 2+ m with short trunk), flattened to obovoid, sometimes from tuberlike rootstocks (Fig. 1A). Stem segments not disarticulating, dark or bright shiny green, wrinkling when stressed, circular to broadly oblong to obovate, 5-17.5 × 4-12 cm, fleshy, usually tuberculate, glabrous; areoles 4-6 per diagonal row across midstem segment, oval to circular, 2-4 mm diam., not raised, sometimes somewhat sunken; wool tan to brown. Spines often absent or 1-2(-3) per areole, spreading, whitish to brownish, terete, straight, and usually stout, 25-60 mm; occasionally also 1 deflexed spine present. Glochids in dense crescent of adaxial edge of areole and in dense tuft overtopping crescent in age, yellow to red-brown, to 4 mm. Flowers: inner petals pale to bright yellow throughout, 20-30 mm diam.; filaments yellow to orange; anthers pale yellow to cream; style and stigma lobes white (Fig. 1B). Fruits greenish, tardily becoming apricot to brownish red, elongate, 30-50 × 12-20 mm, fleshy, tapering at base; pulp green and sour, becoming reddish and sweet under ideal conditions; areoles 10-18. Seeds tan, 3.5-4.5 mm diam., thickish; girdle protruding to 1 mm [15].

A **B**

Figure 1. Habitus of *O. humifusa*: A. Vegetative individual (Photo D. Zahariev, July 19, 2010), B. Flowering individual (Photo D. Zahariev, July 19, 2020)

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Reproduction

O. humifusa reproduces in two ways [12]:

1. Generative – forming fruits and seeds. The fruits (Fig. 2A) can be used for food by birds and mammals and so the seeds can be carried to new locations. Individuals that develop from seeds need 6-8 years until they begin to flower and form fruit.

2. Vegetatively - stems and even their parts root easily and form new plants (a form of natural cloning). This is the faster and more successful way of reproduction in cacti (Fig. 2B).

A **B**

Figure 2. Reproduction of *O. humifusa*: A. Generative reproduction (Photo D. Zahariev, October 13, 2013), B. Vegetative reproduction (Photo D. Zahariev, November 6, 2022)

Ecology

Populations of the species are distributed in open sunny places on stony, sandy grassy terrains. They also grow well on sand dunes. Tolerant of partial shading - found in thin stands of black pine. Resistant to prolonged drought, high temperatures, low temperatures (some species withstand up to -30°C), fires.

Populations in Bulgaria have different sizes and numbers - from a few scattered individuals to hundreds and even thousands of individuals. Most often they form groups with an area of several tens of square centimeters to 5-10 square meters [12].

The species has been recorded in the following EUNIS habitat types [13]:

E1.1: Inland sand and rock with open vegetation;

E1.2: Perennial calcareous grassland and basic steppes;

E1.9: Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland (e.g., E1.9B: Standing stone inland dune);

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

G3.F: Highly artificial coniferous plantation.

Most invaded localities are in a habitat of conservation concern according to the EU's Habitats Directive (Council Directive 92/43/EEC): 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia).

Identification

Key to the determination of the species of the genus Opuntia Mill. [7]:

1. Tall trees 2-6 m, with a trunk up to 45 cm in diameter. Stem segments 25-60 cm. Spines inconspicuous, up to 2 mm. Fruits 50-100 × 40-90 mm. Seeds 3.7-5 × 3.7-4.3 mm ..... ***O. ficus-indica***

1*. Shrubs - prostrate or in tufts. Stem segments rarely to 20-30 cm. Spines 2 mm 2

2. Shrubs, usually up to 10-15 cm; forming mats; terminal stem segments subcylindric, easily detached. Flowers with a diameter 25-35 mm. Fruits dry, 10-30 × 8-15 mm. Seeds 5-6 mm ….... ..... ***O. fragilis***

2*. Shrubs, usually up to 10-15 cm; prostrate or forming clumps but not mats; terminal stem segments flat, not easily detached. Flowers with a diameter of over 35 mm. Fruits juicy or fleshy ... 3

3. Spines absent, rarely 1-3 per areole. Fruits red, elongated. Flowers with a diameter ca. 40-60 mm. Stem segments light green, wrinkled at unfavorable conditions, up to 15-17 cm in diameter. Fruits 30-50 × 12-20 mm. Seeds 3.5-4.5 mm ..... ***O. humifusa***

3*. Areoles with 1-6 spines each. Fruit purple, ovoid to barrel-shaped. Flowers over 50 mm in diameter 4

4. Stem segments green, distinctly wrinkled under stress, with a length of up to 15-17 cm. Flowers with a diameter 60-100 mm. Fruits 25-40 × 15-28 mm. Seeds 4-5 mm ..... ***O. macrorhiza***

4*. Stem segments blue-green, usually wrinkled under stress, up to 40 cm in diameter. Flowers with a diameter 50-80 mm 5

5. Stem segments ± warty, on borders with scales between border areoles; Fruits 40-60 mm, juicy, barrel-shaped, downward narrowed, purplish .... ***O. stricta***

5*. Stem segments with margins entire, without scales; fruits juicy or fleshy 6

6. Spines scattered, unevenly long, surrounding the areolae, also in the subapical region, often enclosed in hairs. Fruits 35-90 × 20-40 mm. Seeds 2.5-6 × 2-5 mm ..... ***O. engelmannii***

6*. Spines nearly equal or increasing in length towards adaxial margin, dense also in subapical region. Fruits 30-50 × 20-30 mm. Seeds 4-5 mm ..... **O. phaeacantha**

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Worldwide distribution

Native to North America. On rocks, shores, sand-dunes, or sandy prairies [1]. **USA**: Ont., Ala., Ark., Conn., Del., Fla., Ga., Ill., Ind., Iowa, Kans., Ky., La., Mass., Md., Mich., Minn., Miss., Mo., N.C., N.J., N.Y., Nebr., Ohio, Okla., Pa., R.I., S.C., S.Dak., Tenn., Tex., Va., W.Va., Wis. [15], **Canada**: Ontario [16].

Distribution in Europa and Mediterranean Basin

In Europe and Mediterranean Basin [3], the species is found as naturalized alien in the following countries: France, Italy, Croatia, Bosna and Herzegovina, Bulgaria, Greece, and Russia (Crimea Peninsula). It is distributed as an introduced species in the following countries: Spain, Germany, Switzerland, Austria, Ukraine, Belarus, Georgia, Armenia, Abkhazia, Dagestan, Israel and Palestina, and Lebanon. In Romania it is doubtfully introduced (perhaps cultivated only) species. In Lithuania and Latvia, it is cultivated species (Fig. 3).

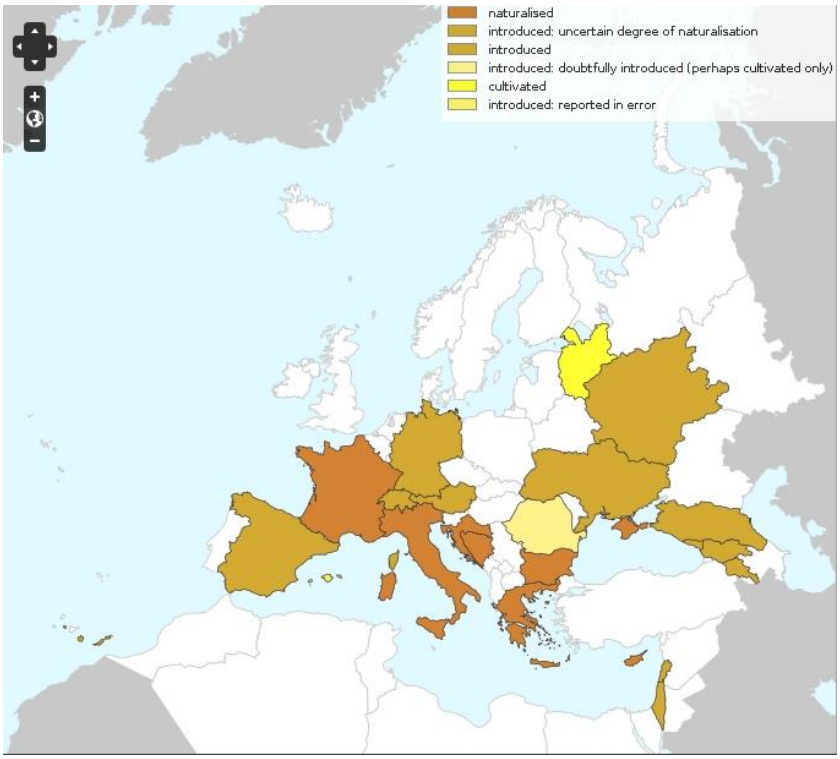

Figure 3. Distribution of *O. humifusa* in Europa and Mediterranean Basin (Euro+Med PlantBase, Website [3])

Distribution in Bulgaria

O. humifusa occurs in dry grassy and stony places and on rocks. It is distributed from sea level to 700 m a.s.l. in 8 floristic regions (in brackets are the nearest settlements and the quadrant code from the UTM Grid

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

10x10 km): Black Sea coast (Sveti Toma Island (Zmiyski ostrov), NG68; town of Beloslav, NH58 and NH68), Balkan Foothill Region (Eastern) (Pushevo village, LH48), Struma Valley (FM57, FM82), Pirin Mountain (Southern) (GM30, Lucky village, GL29), Sredna Gora (Western) (German village, FN91 and GN01), Rhodope Mountains (Central) (Spoluka village, LG41), Thracian Plane (LG16, LG17, LG57, town of Harmanli, MG04), and Tundzha Hilly Plain (MH50) [6, 10, 14, 17, 18]. We established *O. humifusa* in 3 new floristic regions: North-Eastern Bulgaria (near to town of Aksakovo, NH69), Stara Planina (Eastern) (near to Slavyantsi village, MH73), and Strandzha Mountain (near to Brodilovo village, NG75) (Fig. 4).

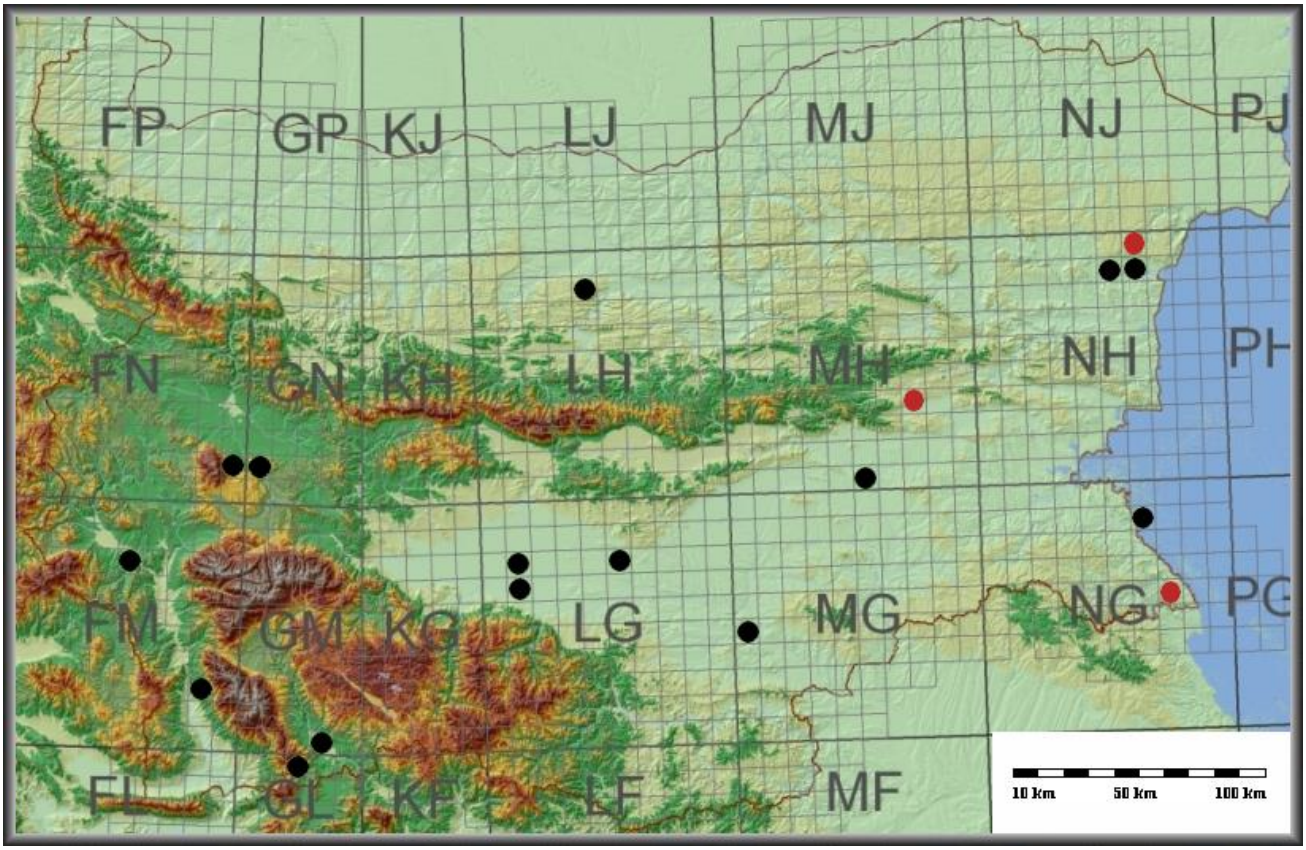

Figure 4. Distribution of *O. humifusa* in Bulgaria:
black spot - known locality, red spot - new locality (Original Map)

Characteristics of some of the known populations

For the first time in the **Black Sea coast floristic region**, and also on the territory of Bulgaria, *O. humifusa* was naturalized on Sveti Toma Island (Zmiyski ostrov) near Sozopol town in 1933. A few individuals of *O. humifusa* and *O. macrorhiza* were planted with an area of ca. 0,12 ha, in order to examine their naturalisation capacity. By 1970s the two species occupied most of the territory of the island (1,2 ha), making dense stands [6].

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

For the first time in the **Balkan Foothill Region floristic region**, *O. humifusa* was found near Pushevo village, Veliko Tarnovo municipality, Veliko Tarnovo district. The GPS coordinates of the beginning of the path to the locality are as follows: 43.069195, 25.479019. The population area is about 0.25 ha. The main rock is limestone. The exposure is southeast. The altitude varies between 200-215 m a.s.l. Individuals form groups of different sizes. According to the author, the probable explanation for the appearance of cacti could be the disposal of an already useless individual grown as a houseplant [19].

For the first time in the **Pirin Mountain (Southern) floristic region** Kenderova [10] describes a locality of *O. humufusa* southwest of the village of Lucky, Hadzhidimovo municipality, Blagoevgrad district. The area occupied by the site is 0.2 to 0.3 ha in size with coordinates 41°28'04.2" N, 23°42'53.2" E, at 686 m a.s.l. at 10–25° slope inclination. According to the author, the appearance of the species in this part of the country can be perceived as ornithochoria or agestochoria, but it could be an accidentally discarded indoor cactus or carried by a hobbyist not understanding the threat of invasive species.

For the first time in the **Sredna Gora (Western) floristic region** в Mt Lozenska, in open stony and eroded places on a slope with siliceous bedrock and ca. 40–50° inclination, SW exposition, 630–680 m a.s.l., occupying an area (extent of occurrence) of ca. 0.15 ha between the following points: 42.59698°N, 23.71750°E (the correct coordinates are 23.41750°E); 42.59714°N, 23.41760°E; 42.59668°N, 23.41873°E; 42.59734°N, 23.41876°E, 02.09.2016. It grows together with two other *Opuntia* species – *O. engelmanii*, and *O. fragilis*. Other accompanying species (28 species in number) are described. Individual small trees were also observed: *Fraxinus ornus* L., *Pinus nigra* J.F. Arnold, *Pyrus pyraster* (L.) Burgsd., *Quercus pubescens* Willd. Other alien species in close proximity were *Robinia pseudoacacia* L. and *Platycladus orientalis* (L.) Franco [6, 20].

For the first time in the **Thracian Lowland floristic region** the species was found in the area of the town of Harmanli [18]. The locality is triangular in outline and covers an area of ca. 6 ha. It lies on a steep southern slope. Its highest point is at 175 m a.s.l., with coordinates 41°55'08.8"N and 25°53'28.0"E. The lower eastern part of the locality borders on a gully and lies at 122 m a.s.l., with coordinates 41°55'01.4"N and 25°53'16.9"E. The lower western part of the locality borders on the same gully and lies only several meters off the parking site of the hotel complex. It is at 94 m a.s.l., with coordinates 41°55'01.0"N and 25°53'08.5"E. Denivelation between the uppermost and lowermost parts of the locality is about 80 m. *O. humifusa* occurs singly, or more frequently in small groups, represented either by several individuals, or by approximately large patches with an area of 10–15 m^2. The patches are scattered randomly close to each other, or are distanced at tens or hundreds of meters. Associated species of *O. humifusa* in the population (89 species in number) are described.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Characteristics of newly established populations

Population near town of Aksakovo (North-Eeastern Bulgaria floristic region)

The population was established by us for the first time in 2010. The field work on its study was carried out on June 10, 2023. The species is new for the North-Eeastern Bulgaria floristic region.

The population is located immediately next to the town. It occupying an area of ca. 26586 m^2 (2,66 ha), between GPS points with coordinates: 43.262320°N, 27.823891°E; 43.257246°N, 27.827039°E; 43.257012°N, 27.826220°E; and 43.262267°N, 27.823077°E (Fig. 5).

Figure 5. The location of the population eastern of the town of Aksakovo (Original Map)

The majority of the population is located on the territory of xerophilic grasslands, represented mainly by habitat 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) – habitat on Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. The rest of the population enters different types of deciduous forests: mainly *Quercus cerris* with Carpinus orientalis and *Q. pubescens*. The individuals of *O. humifusa* are distributed most often in groups with different densities: smaller groups (Fig. 6A) or larger groups with an area of up to 12 square meters (Fig. 6B) and rarely as single plants.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

A **B**

Figure 6. View of the population of *O. humifusa* near the town of Aksakovo, Bulgaria:
A. Smaller groups of individuals, B. Larger group of individuals (Photo D. Zahariev, June 10, 2023)

The main rocks in the area are represented by clays. The soils are eroded calcareous and typical chernozems. The slope varies from 1° to 30°, with an average of about 10°. The exposure is southwest. The altitude varies from 158 m a.s.l. up to 187 m a.s.l.

Associated species of *O. humifusa* in the population eastern of the town of Aksakovo (96 species in number) are following: *Achillea clypeolata* Sm., *A. millefolium* L., *Acinos arvensis* (Lam.) Dandy, *Aegilops geniculata* Roth, *Agrimonia eupatoria* L., *Anchusa procera* Besser, *Anthemis cotula* L., *Artemisia austriaca* Jacq., *A. campestris* L., *Asperula cynanchica* L., *Bothriochloa ischaemum* (L.) Keng, *Bromus hordeaceus* L. (= B. mollis L.), *B. tectorum* L., *B. racemosus* L., *B. sterilis* L., *Carduus nutans* subsp. *leiophyllus* (Petrovič) Stoj. & Stef., *Carpinus orientalis* Mill., *Centaurea cyanus* L., *Cephalaria uralensis* (Murr.) Roem. & Schult., *Cerastium pumilum* Curtis, *Chondrilla juncea* L., *Chrysopogon gryllus* (L.) Trin., *Cleistogenes serotina* (L.) Keng., *Clinopodium vulgare* L., *Convolvulus cantabrica* L., *Cota tinctoria* (L.) J. Gay., *Crataegus monogyna* Jacq., *Cruciata pedemontana* (Bell.) Ehrend, *Dactylis glomerata* L., *Dasypyrum villosum* (L.) Cand., *Elymus elongatus* (Host) Greut., *Erodium cicutarium* (L.) ĽHer., *Eryngium campestre* L., *Erysimum diffusum* Ehrh., *Euphorbia agraria* M. Bieb., *E. esula* L., *Festuca valesiaca* Schleich. ex Gaudin, *Fragaria viridis* Duchesne, *Fraxinus ornus* L., *Galium aparine* L., *Helianthemum nummularium* (L.) Mill., *Herniaria incana* Lam., *Hieracium pilosella* L., *Hypericum perforatum* L., *Koeleria nitidula* Velen., *Lactuca serriola* L., *L. viminea* (L.) J. & C. Presl., *Linaria genistifolia* (L.) Mill., *Lychnis coronaria* (L.) Desr., *Marrubium peregrinum* L., *Medicago minima* (L.) Bart., *Melica ciliata* L., *Moehringia trinervia* (L.) Clairv., *Muscari neglectum* Guss. ex Ten., *Myrrhoides nodosa* (L.) Cannon, *Onobrychis arenaria* (Kit.) DC., *Orlaya grandiflora* (L.) Hoff.,

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Paliurus spina-christi Mill., *Papaver rhoeas* L., *Poa bulbosa* L., *Potentilla argentea* L., *P. pedata* Willd. ex Hornem., *Petrorhagia prolifera* P. W. Ball & Heywood, *Pinus nigra* Arn., *Plantago lanceolata* L., *Prunus spinosa* L., *Poa compressa* L., *P. pratensis* L., *Quercus cerris* L., *Q. pubescens* Willd., *Reseda lutea* L., *Robinia pseudoacacia* L., *Rosa canina* L., *Salvia sclarea* L., *Sanguisorba minor* Scop., *Scabiosa hispidula* Boiss., *Sedum acre* L., *Senecio leucanthemifolius* Poir. subsp. *vernalis* (Waldst. & Kit.) Greuter, *Sherardia arvensis* L., *Sideritis montana* L., *Silene conica* L., *Stachys atherocalix* C. Koch., *Stipa capillata* L., *Teucrium capitatum* L., *T. chamaedrys* L., *Thlaspi alliaceum* L., *Tragopogon dubius* Scop., *Trifolium angustifolium* L., *T. arvense* L., *T. campestre* Schreb., *Verbascum purpureum* (Janka) Hub.-Mor., *Vicia grandiflora* Scop., *V. sativa* L., *V. villosa* Roth, *Viola arvensis* Murr., *Vulpia myuros* (L.) C.C.Gmel., *Xeranthemum annuum* L.

Population near the Slavyantsi village (Stara Planina (Eastern) floristic region)

The population was established by us for the first time in 2020. The field work on its study was carried out on April 25, 2023. The species is new for the Stara Planina (Eastern) floristic region.

The population is located 14-15 m from the end of the village. It occupying an area of ca. 211 203 m^2 (21,11 ha), between GPS points with coordinates: 42.771230°N, 26.731674°E; 42.766484°N, 26.735605°E; 42.766223°N, 26.730478°E; 42.768282°N, 26.727818°E; and 42.771832°N, 26.729032°E (Fig. 7).

Figure 7. The location of the population northern of the Slavyantsi village (Original Map)

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

The individuals are distributed in two groups of habitats: ruderalized terrains and natural habitats, which are protected by the ecological network "Natura 2000" in Bulgaria. The population begins in ruderalized places, immediately next to the village, where the most densely located groups of *O. humifusa* are. The main part of the population is located on the lower slopes of the mountain within the boundaries of three types of natural habitats according to the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, which form a mosaic: habitat 91AA *Eastern white oak woods, habitat 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia), and habitat 6110 *Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi. They are distributed most often in groups with different densities: smaller groups (Fig. 8A) or larger groups (Fig. 8B) and rarely as single plants.

A **B**

Figure 8. View of the population of *O. humifusa* near the Slavyantsi village, Bulgaria:
A. Smaller groups of individuals, B. Larger groups of individuals (Photo D. Zahariev, April 25, 2023)

Substrate includes skeletal soil and exposed bedrock blocks. The main rocks in the area are represented by interbedding of sandstones, siltstones, limestones and marls, flysch alternation of sandstones, siltstones, clays. The soils are cinnamonic podzolic (pseudopodzolic). The slope is about 20°. The exposure is southern. Altitude varies from 232 m a.s.l. up to 345 m a.s.l.

Associated species of *O. humifusa* in the population northern of the Slavyantsi village (78 species in number) are following: *Achillea millefolium* L., *Agrimonia eupatoria* L., *Alyssum alyssoides* (L.) L., *A. desertorum* Stapf, *Anacamptis morio* (L.) R.M.Bateman, Pridgeon & M.W.Chase, *Astragalus onobrychis* L., *Bothriochloa ischaemum* (L.) Keng, *Buglossoides arvensis* (L.) I.M.Johnst., *Capsella bursa-pastoris* (L.)

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Medik., *Carpinus orientalis* Mill., *Cerastium brachypetalum* Desp. ex Pers., *C. glomeratum* Thuill., *Chrysopogon gryllus* (L.) Trin., *Cleistogenes serotina* (L.) Keng, *Convolvulus cantabrica* L., *Crataegus monogyna* Jacq., *Crepis sancta* (L.) Bornm., *C. setosa* Haller f., *Crucianella angustifolia* L., *Cynosurus echinatus* L., *Daucus carota* L., *Erodium cicutarium* (L.) L'Hér., *Eryngium campestre* L., *Euphorbia cyparissias* L., *E. esula* L., *E. myrsinites* L., *Festuca valesiaca* Schleich. ex Gaudin, *Galium aparine* L., *G. verum* L., *Genista januensis* Viv., *Helianthemum nummularium* (L.) Mill., *Iris pumila* L., *Koeleria splendens* C.Presl, *Lamium amplexicaule* L., *L. purpureum* L., *Lathyrus sphaericus* Retz., *Linaria genistifolia* (L.) Mill., *Malva sylvestris* L., *Marrubium peregrinum* L., *Medicago minima* (L.) L., *Minuartia setacea* (Thuill.) Hayek, *Muscari botryoides* (L.) Mill., *M. neglectum* Guss. ex Ten., *Myosotis ramosissima* Rochel, *Orchis simia* Lam., *Origanum vulgare* L., *Orlaya grandiflora* (L.) Hoffm., *Ornithogalum comosum* L., *O. orthophyllum* Ten. subsp. *kochii* (Parl.) Zahar., *Paliurus spina-christi* Mill., *Phleum phleoides* (L.) H.Karst., *Plantago lanceolata* L., *Poa bulbosa* L., *Polygala monspeliaca* L., *Potentilla argentea* L., *P. pedata* Willd. ex Hornem., *Quercus pubescens* Willd., *Rumex pulcher* L., *Scandix pecten-veneris* L., *Scolymus hispanicus* L., *Sedum annuum* L., *Senecio leucanthemifolius* Poir. subsp. *vernalis* (Waldst. & Kit.) Greuter, *Sideritis montana* L., *Stachys atherocalyx* K.Koch, *Teucrium capitatum* L., *T. chamaedrys* L., *Thymus callieri* Borb. ex Velen., *T. moesiacus* Vel., *Trifolium angustifolium* L., *Tulipa sylvestris* L., *Ulmus minor* Mill., *Valerianella turgida* (Steven) Betcke, *Veronica polita* Fr., *Vicia grandiflora* Scop., *V. hirsuta* (L.) Gray, *V. sativa* L., *Viola arvensis* Murray, *Vulpia myuros* (L.) C.C.Gmel.

Favorable factors for increasing the size of the population are: a southern slope that provides sunny and warm conditions, the presence of mosaic grass and forest habitats, the presence of sheep and goat crossing paths. Although the possibility of cladodia transmission by grazing animals has not been established, due to the lack of long spines, individuals of *O. humifusa* are more often found near trails.

Population near the Brodilovo village (Strandza Mountain floristic region)

The population was established by us for the first time in 2020. Field work on its survey was carried out on May 20, 2023. The species is new to the Strandzha Mountain floristic region.

The population is located 80-115 m from the end of the village. It occupying an area of ca. 789 m^2 (0,08 ha), between GPS points with coordinates: 42.088420°N, 27.862469°E; 42.088150°N, 27.862804°E; 42.088003°N, 27.862556°E; and 42.088269°N, 27.862259°E (Fig. 9). In the western direction, there is a separate group of cacti, which is also part of the locality, but is not included in its area. The coordinates of this point are as follows: 42.088371°N, 27.861587°E. In it, on an area of 2 m^2 (4 x 0.5 m), there are 6 tufts, each of which has a large number of stems.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Figure 9. The location of the population eastern of the Brodilovo village (Original Map)

The individuals of *O. humifusa* are distributed in a shrub habitat dominated by *Quercus coccifera* L. and *Paliurus spina-christi* Mill. They are distributed most often in groups with different densities: smaller groups (Fig. 10A) or larger groups (Fig. 10B) and rarely as single plants.

Substrate includes skeletal soil and exposed bedrock blocks. The main rocks in the area are represented by sediments - fine to block breccia with packets of sandstones, siltstones, shales, marls, clayley limestones and volcanics-basalts, trachybasalts, trachyandesitobasalts in extrusive, explosive and subvolcanic facies. The soils are iellow podzolic (pseudopodzolic). The slope varies from 15° to 40°, with an average of about 25°. The exposure is southeast. Altitude varies from 27 m a.s.l. up to 44 m a.s.l.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

A **B**

Figure 10. View of the population of *O. humifusa* near the Brodilovo village, Bulgaria: A. Smaller groups of individuals, B. Larger group of individuals (Photo D. Zahariev, July 19, 2020)

Associated species of *O. humifusa* in the population eastern of the Brodilovo village (54 species in number) are following: *Achillea millefolium* L., *Aegilops geniculata* Roth, *Aira elegantissima* Schur, *Anthemis cotula* L., *Avena barbata* Pott ex Link, *Bromus hordeaceus* L. (= *B. mollis* L.), *B. sterilis* L., *Capsella bursa-pastoris* (L.) Medik., *Carex divulsa* Stokes, *Cerastium glomeratum* Thuill., *Cleistogenes serotina* (L.) Keng, *Cota tinctoria* (L.) J.Gay, *Crepis setosa* Haller f., *Cynosurus echinatus* L., *Eryngium campestre* L., *Euphorbia helioscopia* L., *Fumaria petteri* subsp. *thuretii* (Boiss.) Pugsley, *Galium aparine* L., *Geranium lucidum* L., *G. robertianum* L., *Hordeum bulbosum* L., *Hymenocarpos circinnatus* (L.) Savi, *Hypericum perforatum* L., *Linaria pelisseriana* (L.) Mill., *Medicago minima* (L.) L., *M. orbicularis* (L.) Bartal., *Moehringia trinervia* (L.) Clairv., *Moenchia mantica* (L.) Bartl., *Orlaya grandiflora* (L.) Hoffm., *Paliurus spina-christi* Mill., *Parentucellia latifolia* Caruel, *Plantago lanceolata* L., *Poa annua* L., *Poa bulbosa* L., *Quercus coccifera* L., *Rumex pulcher* L., *Sanguisorba minor* Scop., *Scolymus hispanicus* L., *Sedum annuum* L., *S. album* L., *S. pallidum* M.Bieb., *Sherardia arvensis* L., *Silene pendula* L., *Teucrium chamaedrys* L., *Thymus glabrescens* Willd., *Tordylium maximum* L., *Trifolium campestre* Schreb., *T. echinatum* M.Bieb., *T. hirtum* All., *Valerianella carinata* Loisel., *Veronica polita* Fr., *Vicia hirsuta* (L.) Gray, *V. sativa* L., *Viola arvensis* Murray, *Vulpia myuros* (L.) C.C.Gmel.

Along the northern and western borders of the population pass paths made by the grazing sheep and goats in the area. There are currently no cacti in the village's cemetery park, which is located nearby, and it cannot be said for sure if their spread started there.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

Reasons for the spread of cacti

The reasons for the spread of cacti in territories that were not previously inhabited by them are not natural. It is easiest to make a connection with climate change and global warming [21, 22]. The warming of the climate in Bulgaria is a fact and has a beneficial effect on the development of cactus populations, but this does not explain why species of the genus *Opuntia* are found in such different places in the country. If the spread is in a natural way, then colonization of neighboring, closely located territories should be observed from already existing populations. Possible carriers of the fruits and seeds would be running water – e.g., rivers and the birds that could use the fruits for food and spread the ingested seeds. The distribution of cacti in natural habitats in Bulgaria shows that they are often found near settlements - in the cases of the localities near the town of Beloslav, the village of Pushevo and the town of Harmanli, or in hard-to-reach places - as in the case of the populations near the village of German and the village of Lucky.

The locality near the village of Pushevo is on the slopes of the Dola area in the eastern part of the settlement. Slopes in the immediate vicinity of villages have traditionally been used for waste disposal - a practice that continues today, long after the introduction of organized waste collection in small settlements. The situation is similar with the locality near the town of Beloslav. South of the city there are still unregulated municipal waste dumps. A locality near the town of Harmanli is close to the right bank of the Harmanliiska river and decades ago, when it was created, it was also a suitable place for dumping unwanted plant waste.

Localities of cacti near the village of German and the village of Lucky are remote from settlements. In both cases, however, we are close to hiking trails. This is not a coincidence and again shows the results of people's presence. In this case, the cacti were not thrown away - no one would have made it that far, but probably carefully transported and planted in order to "ennoble" the desert rocky landscape.

Once they appear near a settlement, cacti quickly become the local attraction. Residents of some villages put up signs indicating how to get to the locality or signs prohibiting the destruction of cacti. In the Pushevo village in Veliko Tarnovo district, they even organize a Cactus Festival with the first edition in 2013.

Methods to control the spread of the species

Prevention is the best and most effective method to control the spread of invasive alien plant species. When establishing the occurrence of individuals of *O. humifusa* in natural habitats, the best solution is to destroy them immediately. Practice shows that the longer measures are not taken, the more difficult and expensive it is to eradicate invasive alien plant species. If eradication is impossible, containment and long-term control are needed to stop further spread. The methods of destroying these plants are in several groups:

- **Mechanical control.** It is carried out by manual or mechanized removal of specimens of invasive species.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

- **Chemical control.** It consists in using herbicides to which the species do not show resistance and which do not accumulate in the food chain.
- **Biological control.** It represents the deliberate use of natural enemies of invasive species.
- **Habitat management.** Includes various activities affecting habitats – e.g. grazing, controlled burning.
- **An integrated approach.** The use of several forms of control as a result of ecological studies, regular monitoring and careful coordination [12].

Measures for the destruction of cacti localities

Organized measures for the destruction of cacti localities have been undertaken for the first time in Bulgaria within the framework of a project BG16M1OP002-3.021-0005-C01 Improvement of the conservation status of natural habitat 2130 Fixed coastal dunes with grass vegetation (grey dunes) by parameter "Structure and functions" and "Future prospects" and natural habitat 2180 Wooded dunes by parameter "Area", "Structure and functions", and "Future prospects". As a result, the team I led in 2022 in the Ropotamo Reserve destroyed several *O. humifusa* habitats created by humans. The mechanical method of extermination was applied by uprooting, moving the cacti, including their fruits, outside the invaded territory and disposing of them in a landfill where they could be buried to avoid further spread. In 2023, monitoring and destruction of the few surviving stem segments was carried out.

Conclusions

The first organized action to destroy invasive species of cacti in Bulgaria is already a fact. Continued actions to control the spread of *O. humifusa* and other cactus species that are established in natural habitats are needed. It is necessary to attract the local communities who want to preserve the existing populations as a tourist attraction. Avoiding confrontation and attracting them as partners that do not allow populations to increase is the future of biodiversity conservation.

Acknowledgement

This article is published with the financial support of Project No. RD-08-140/24.02.2023 of the Konstantin Preslavsky University of Shumen.

References

[1] The World Flora Online, Website: http://www.worldfloraonline.org/taxon/wfo-4000027003#feedback Modal.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

[2] Plants of the World Online, Website: https://www.kew.org/science/collections-and-resources/data-and-digital.

[3] Euro+Med PlantBase, Website: https://europlusmed.org/cdm_dataportal/taxon/b0ff1130-9671-412b-bf68-08fe9096d62f.

[4] Yordanov, D. (chief editor), Flora of the People's Republic of Bulgaria, Vol. IV, Bulgarian Academy of Sciences, Sofia, **1970** (in Bulgarian).

[5] Asyov, B.; Petrova, A.; Dimitrov, D.; Vasilev, R., Conspectus of the Bulgarian vascular flora. Distribution maps and floristic elements. Bulgarian Biodiversity Foundation, Sofia, **2012** (in Bulgarian).

[6] Naydenova, T.; Vladimirov, V.; Bancheva, S., Contribution to the knowledge of naturalised *Opuntia* species (Cactaceae) in the Bulgarian flora. *Phytologia Balcanica*, **2019**, *25(1)*, 39-46.

[7] Stoyanov, K.; Raycheva, Ts.; Cheschmedzhiev, I., Key to the Native and Foreign Vascular Plants in Bulgaria. Agricultural University Plovdiv Academic Press, Plovdiv, **2021** (in Bulgarian).

[8] Erre, P.; Chessa I.; Nieddu G.; Jones P.G., Diversity and spatial distribution of *Opuntia* spp. in the Mediterranean Basin. *Journal of Arid Environments*, **2009**, *73*, 1058-1066.

[9] Glogov, P.; Georgieva, M.; Pavlova, D.; Gyudorova, S.; Dodev, Y., Characteristics of the locality of *Opuntia humifusa* (Raf.) Raf. (Cactaceae) on the territory of the Lozenska Mountain, *Forest Science*, **2020**, *1*, 29-44 (in Bulgarian).

[10] Kenderova, R. Report 49. In: New floristic records in the Balkans, Compiled by Vladimirov, V., F. Dane & K. Tan. *Phytologia Balcanica*, **2012**, *18(2)*, 205-230.

[11] Shackleton, R.; Witt, A.; Piroris, F.; Wilgen, B., Distribution and socio-ecological impacts of the invasive alien cactus *Opuntia stricta* in Eastern Africa. *Biological Invasions*, **2017**, *19*, 2427-2441. DOI 10.1007/s10530-017-1453-x.

[12] Petrova, A.; Vladimirov, V.; Georgiev, V., Invasive alien plant species in Bulgaria, Institute of Biodiversity and Ecosystem Research, BAS, Sofia, **2012**.

[13] Naydenova, T.; Bancheva, S.; Vladimirov, V., Distribution and habitat preferences of the alien species *Opuntia humifusa* (Cactaceae) in Bulgaria and risks of its spread. ESSENIAS Website: https://www.esenias.org/files/BBC_Opuntia_OK_1.pdf.

[14] Delipavlov, D.; Cheshmedzhiev, I.; Popova, M.; Teriyski, D.; Kovachev, I., Handbook for Plants in Bulgaria. Publishing House of Agricultural University, Plovdiv, **2011** (in Bulgarian).

[15] Flora of North America, Website: http://floranorthamerica.org/Opuntia_humifusa.

[16] Canadensys, Website: https://data.canadensys.net/vascan/name/Opuntia%20humifusa?lang=en.

[17] Glogov, P.; Pavlova, D.; Georgieva, M.; Kachova, V., Analysis of Anthropophitic Flora on the Territory of Lozenska Mountain, Bulgaria. *Ecologia Balcanica*, **2019**, *11(2)*, 181-191.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019

[18] Tashev, A., Characteristics of the *Opuntia humifusa* (Cactaceae) locality in the Harmanli district, South Bulgaria. *Phytologia Balcanica*, **2012**, *18(1)*, 11-16.

[19] Prodanova, H., Cacti of Pushevo - an unusual attraction or a hidden danger? *Geograf*, **2016**, *1(1)*, 92-101 (in Bulgarian).

[20] Vladimirov, V.; Delcheva, M.; Tashev, A.; Bancheva, S. Reports 78-87. In: Vladimirov, V. & al. (comp.), New floristic records in the Balkans: 32. *Phytologia Balcanica*, **2017**, *23(1)*, 139-140.

[21] Glogov, P.; Dimitrov, D. Influence of climate change on the spread of invasive alien plant species in the territory of the Lozenska Mountain. *Ecological Engineering and Environment Protection*, **2021**, *1*, 78-82.

[22] Bratanova-Doncheva, S.; Gocheva K., Advisory Services on a National Climate Change Adaptation Strategy and Action Plan, Appendix 2: Assessment of the Biodiversity and Ecosystems Sector, World Bank, Ministry of Environment and Water, **2018**.

Corresponding author: d.zahariev@shu.bg
Full Paper
DOI: 10.2478/asn-2023-0019