

Contribution to the knowledge of naturalised *Opuntia* species (*Cactaceae*) in the Bulgarian flora

Tsvetelina Naydenova^{1*}, Vladimir Vladimirov^{1, 2} & Svetlana Bancheva¹

¹ Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Acad. Georgi Bonchev St., bl. 23, 1113 Sofia, Bulgaria, *e-mail: tsvety_n@yahoo.co.uk (corresponding author)

² Faculty of Forestry, University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, Bulgaria

Received: March 05, 2019 ▷ Accepted: March 25, 2019

Abstract. Three alien species of *Opuntia* (*Cactaceae*) have been studied in a locality in Mt Lozenska, Mt Sredna Gora (*Western*) floristic region in Bulgaria. One of the species – *O. humifusa*, has already been reported for the area, whereas the other two species – *O. engelmannii* and *O. fragilis* are reported here for the first time for the Bulgarian flora. Most likely, the species were initially deliberately planted in the area but later adapted well, spread further, and now dominate the local vegetation. The three species propagate easily by vegetative means, since numerous recently rooted stem segments have been found in the locality. Moreover, reproduction by seeds has been observed in *O. engelmannii* and *O. humifusa*. The species are represented by self-sustaining and enlarging populations, and hence they have to be considered naturalised and locally invasive. Concise morphological description based on the studied occurrences of *O. engelmannii* and *O. fragilis*, as well as some data about the habitat and populations are provided. The text is amply illustrated with photos from the locality.

Key words: alien species, Cacti, invasive plants, *Opuntia engelmannii*, *Opuntia fragilis*, Pricklypears

Introduction

Opuntia L. (*Cactaceae*) comprises ca. 150 species distributed in North America, Mexico, West Indies, South America, including the Galápagos Islands (Pinkava 2004). Many of these have long been cultivated as ornamental, edible or animal-fodder plants, and some of them have escaped from cultivation and got established in natural or semi-natural environments in many places across the world (Pinkava 2004). In Bulgaria, some species of the genus were introduced in the 1930s in warmer parts of the country (Jordanov 1970): *O. humifusa* (Raf.) Raf. (sub *O. vulgaris* Mill. and *O. compressa* (Salisb.) Macbr.), *O. macrorhiza* Engelm. (sub *O. tortispina* Engelm.), *O. ficus-indica* (L.) Mill., and *O. engel-*

mannii Engelm. (sub *O. procumbens* Engelm.). Jordanov (1970) mentioned that ‘in 1938 a few specimens of *O. tortispina* and *O. compressa* were planted on the Zmiyski Ostrov [Snake Island]’ near Sozopol town (now ‘Sveti Thoma’ [St. Thomas] Island, with an area of ca. 0.12 ha), in order to examine their naturalisation capacity, and by 1970s the two species occupied most of the territory of the island, making dense stands.

In Bulgaria, the *Opuntia* species are valued mainly for their ornamental and exotic appearance, often associated with the Mediterranean coastal environment (where the *Opuntia* species are non-native and invasive, in fact). Therefore, in some places in the country, *Opuntias* had been deliberately planted in dry, rocky habitats which resulted in the

adaptation, establishment and local spread mostly of *Opuntia humifusa*, e.g. in the Black Sea Coast, Forebalkan (*Eastern*), Valley of River Struma, Pirin Mts (*Southern*), Mt Sredna Gora (*Western*), Thracian Lowland, and Tundzha Hilly Country floristic regions (Assyov & Petrova 2012; Petrova & al. 2012; Tashev 2012). *Opuntia macrorhiza* has naturalised in the Black Sea Coast (*Southern*) floristic region (Jordanov 1970; Assyov & Petrova 2012, sub *O. tortispina*). Photos of *Opuntias* taken by nature-lovers have been published in the Internet or in popular journals (Tsvetanov 2006) during the past two decades. Thus, it became evident that at least two more species had already naturalised in the Bulgarian flora, e.g. in Mt Lozenska near the city of Sofia.

The aim of the present article is to report the occurrence of two *Opuntia* species as new non-natives to the Bulgarian flora, and to discuss their alien and invasive status in the observed populations.

Material and methods

Plant material has been studied and collected in Mt Lozenska. The *Opuntia* species have been identified using several keys and on-line determination tools (Britton & Rose 1919; Pinkava 2004; <https://www.opuntiads.com/>, <https://www.discoverlife.org/mp/20q?guide=Opuntia>). Morphological characters were noted mostly from the plants in the studied locality and compared with data from relevant literature (Britton & Rose 1919; Jordanov 1970; Pinkava 2004). Since we were unable to find earlier reports on the occurrence of two of the *Opuntia* species in Bulgaria – *O. fragilis* and *O. engelmannii*, we provide here a concise morphological description of the taxa based on the material from the Bulgarian occurrences. The taxonomy and nomenclature of the *Opuntia* species follow Korotkova & Raab-Straube (2017), The Plant List (TPL 2013) and World Flora Online (WFO 2019), whereas of the other species – follow Delipavlov & Cheshmedzhiev (2011). Data about the populations and invasive success of the *Opuntias* were taken from the field. The characters used in the determination key are relevant to the material in the Bulgarian occurrences and do not cover the morphological variation of the species across their entire range worldwide.

Results and discussion

Opuntia engelmannii Salm-Dyck ex Engelm.,
Boston J. Nat. Hist., 6 (1850) 207 (Fig. 1).

Shrubs, with or without trunk (without trunk in the Bulgarian locality), somewhat spreading, up to 3 m high (to 0.7 m in the Bulgarian locality). Stem segments not easily detached, circular to obovate, 15–40 × 10–35 cm, glabrous, glaucous; areoles 5–8 per diagonal row across mid-stem segments, evenly distributed. Spines 1–6 per areole, whitish, usually with reddish-brown base and tip, subulate, straight, flatten to angular near base, 15–30(40) mm. Glochids of irregular length, up to 8 mm. Flowers usually uniformly yellow, occasionally pink. Fruits purple, usually barrel-shaped or ovate, juicy. Flowering VI, fruiting VIII–IX.



Fig. 1. *Opuntia engelmannii* in Mt Lozenska, West Bulgaria (photo V. Vladimirov).

Distribution in Bulgaria: Mt Sredna Gora (*Western*): 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; 42.59714°N, 23.41760°E; 42.59668°N, 23.41873°E; 42.59734°N, 23.41876°E, 02.09.2016, Ts. Naydenova & V. Vladimirov obs. (photos); *loc. ibid.* 14.04.2019, V. Vladimirov obs. (photos) (Fig. 2).

Several dozen shrubs/groups of varying size were observed – from individual recently rooted stem segments to groups of *ca.* 1.5 m², and height up to 0.5–0.7 m. The area of occupancy is much smaller than the extent of occurrence. It grows together with two other *Opuntia* species – *O. humifusa*, which is the



Fig. 2. The habitat of *Opuntia engelmannii*, *O. fragilis* and *O. humifusa* in Mt Lozenska (photo V. Vladimirov).

most abundant of the three species, and *O. fragilis*. Other accompanying species were: *Acinos rotundifolius* Pers., *Ajuga chamaepitys* subsp. *chia* (Schreb.) Arcang., *Alyssum* sp., *Astragalus onobrychis* L., *Botriochloa ischaemum* (L.) Keng, *Campanula lingulata* Waldst. & Kit., *Cephalaria flava* (Sibth. & Sm.) Szabó, *Cleistogenes serotina* (L.) Keng, *Comandra elegans* (Spreng.) Rchb., *Cota tinctoria* (L.) J. Gay, *Cotynus coggygria* Scop., *Crupina vulgaris* Cass., *Euphorbia cyparissias* L., *Jasminum fruticans* L., *Leontodon crispus* Vill., *Linaria genistifolia* (L.) Mill., *Muscari* sp., *Rosa gallica* L., *Sanguisorba minor* Scop., *Satureja montana* subsp. *kitaibelii* (Heuff.) P.W. Ball, *Sedum hispanicum* L., *Sideritis montana* L., *Silene* sp., *Stachys recta* L., *Syringa vulgaris* L., *Teucrium chamaedrys* L., *Tragopogon pterodes* Petrović, *Verbascum banaticum* Schrad., *Viola arvensis* Murray. 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 (Vladimirov & al. 2017).

General distribution: *Opuntia engelmannii* is native to North America (Mexico, southern parts of USA) (Pinkava 2004; Corral-Díaz & al. 2017). It has been introduced and established in some places in East and South Africa (BioNET-EAFRINET 2019), Australia (ALA 2019), Europe, and West Asia (Korotkova & Raab-Straube 2017). In Europe, the species has been reported for France, Bulgaria (Korotkova & Raab-Straube 2017) and Italy (Piovan & al. 2014) as 'naturalised', for Georgia as 'alien' (Korotkova & Raab-Straube 2017), and for Crimea as 'invasive' alien (Bagrikova & Chichkanova 2018). The record for Bulgaria is based on Greuter & al. (1984). However, we were unable to find any reference to a precise locality in the country. Most likely, this statement rests on the information provided in Jordanov 1970, who stated that the species (sub *O. procumbens*) is 'cultivated in the open in the

Botanical Garden of Balchik town. Despite these facts, the species has not been included in any of the recent sources on the entire Bulgarian flora (cf. Kozhuharov 1992; Delipavlov & Cheshmedzhiev 2011; Assyov & Petrova 2012).

Opuntia fragilis (Nutt.) Haw., Suppl. Pl. Succ. (1819) 82 (Fig. 3)

Low shrubs, forming mats, 2–10 cm high. Stem segments easily detached when terminal, dark-green, subspheric to subcylindric, 2–5 × 1.5–3 cm. Areoles 3–5 per diagonal row across mid-stem segments. Spines 3–8 per areole, spreading, gray, straight, ca. 10–20 mm. Glochids inconspicuous, up to 3 mm. Flowers yellow, occasionally basally red. Fruits dry, glabrous. Flowering VI.

Distribution in Bulgaria: Mt Sredna Gora (Western): Mt Lozenska, in open stony and eroded places on a slope with siliceous bedrock and ca. 40–50° inclination, SW exposition, 630–660 m a.s.l., occupying an area (extent of occurrence) of ca. 100 m², mainly around 42.59668°N, 23.41803°E, and about 10 mats near 42.59676°N, 23.41878°E, 02.09.2016, Ts. Naydenova & V. Vladimirov obs. (photos); *loc. ibid.* 14.04.2019, V. Vladimirov obs. (photos).

Several dozen mats of varying size were observed – from individual recently rooted stem segments to mats of ca. 0.3 m², and height of ca. 10 cm. The accompanying species were: *Acinos rotundifolius*, *Astragalus onobrychis*, *Botriochloa ischaemum*, *Cleistogenes serotina*, *Comandra elegans*, *Cota tinctoria*, *Euphorbia cyparissias*, *Linaria genistifolia*, *Opuntia humifusa*, *O. engelmannii*, *Sanguisorba minor*, *Satureja montana* subsp. *kitaibelii*, *Sedum hispanicum*, *Sideritis montana*, *Silene* sp., *Stachys recta*, *Teucrium chamaedrys*, *Verbascum banaticum*, *Viola arvensis*, *Xeranthemum annuum* L.

General distribution: The species is native to North America (Canada, USA) (Pinkava 2004; Ribbens 2007; Pinkava & al. 2017; Discover Life 2019).

Key for determination of the naturalised *Opuntia* species in the studied locality:

1. Shrubs usually up to 10(15) cm high, forming mats; terminal stem segments subcylindric, easily detached; fruits dry ***O. fragilis***
- 1*. Shrubs usually higher than 10(15) cm, prostrate or forming clumps but not mats; terminal stem segments flat, not easily detached; fruits juicy 2



Fig. 3. *Opuntia fragilis* in Mt Lozenska, West Bulgaria (photo V. Vladimirov).

2. Stem segments somewhat shiny green, wrinkling when stressed, to 15(17) cm long; spines usually absent or 1–2(3) per areole; fruits red, elongate ***O. humifusa***
- 2*. Stem segments glaucous, usually not wrinkling when stressed, to 40 cm long; spines present, 1–6 per areole; fruits purple, ovate to barrel-shaped ***O. engelmannii***

One more species with flat, firmly attached stem segments – *O. macrorhiza*, was published as naturalised in the Bulgarian flora (Jordanov 1970, sub *O. tortispina*). The reported locality on Sveti Thoma Island has not been visited by us to confirm the taxonomic identity of the species. However, if present, *O. macrorhiza* would differ from *O. humifusa* in the presence of long spines in more than half of the areoles per stem segment, presence of 1–5 spines per areole, and the ovate to barrel-shaped fruits; *O. macrorhiza* would differ from *O. engelmannii* in the smaller stem segments – less than 15–17 cm (up to 30–40 in *O. engelmannii*), clearly prostrate habitus – clumps are usually not higher than 30 cm (somewhat prostrate to erect habitus of *O. engelmannii*, shrubs are often higher than 50 cm), and usually green stem segments, clearly wrinkled under stress (stem segments glaucous to bluish-green, not wrinkled under stress in *O. engelmannii*). We are aware that some authors consider *O. tortispina* a different species from *O. macrorhiza* (e.g. Pinkava 2004), however, we adopted here the taxonomic concept of Euro+Med Plant Base (Korotkova & Raab-Straube 2017) and The World Flora Online (WFO 2019).

Alien and invasive status

Three alien species of *Opuntia* – *O. engelmannii*, *O. fragilis*, and *O. humifusa*, are present in the studied locality. The most abundant and locally widespread is *O. humifusa*, whereas the least abundant is *O. fragilis*. Given the close proximity of the area to Sofia city, Kokalyane residential district, and to a local asphalt lane for walking and cycling, as well as the type of the habitat – steep eroded stony slope with naturally sparse vegetation, it can be assumed that the three *Opuntia* species have been deliberately planted in this place. Subsequently, the species adapted well to the area and spread further becoming the dominating species in the local vegetation. Presently, the total vegetation cover on the eroded slope is *ca.* 40–50 % and more than half of this cover is represented by the *Opuntias*. The species propagate by vegetative means – many dozens of stem segments from the three species have been observed in the area, as well as young, just rooted segments (Figs. 4, 5). Seedlings have been observed as well – rather common for *O. humifusa* (Fig. 6) and less common for *O. engelmannii* (Fig. 7). In fact, both species flower and fruit abundantly (Fig. 8). Taking into considerations the recommended terminology of Richardson & al. (2000), it can be stated that the three *Opuntia* species are naturalised in the studied locality since they ‘reproduce consistently ... and sustain populations over many life cycles without direct intervention by humans’. Considering the local spread of the species, it can be assumed that they have been present there for at least 30–40 years or even longer. Moreover, the species can be classified as locally invasive since they already dominate the vegetation on the eroded slope replacing the native plant species. This fact has already been noted by Jordanov (1970: 25) for the locality of *Opuntias* on Sveti Thoma Island. On the other side, given the very steep slope, the three *Opuntia* species undeniably have positive effect for stabilization of the substrate and erosion control in the studied locality. Fortunately, the neighbouring areas are covered by dense forests and this prevents a wider spread of the *Opuntias* in this mountain. However, given the appreciation of these species as ornamentals and exotics by many people, deliberate or accidental (Fig. 9) transfer of stem segments to other suitable habitats cannot be excluded.



Fig. 4. Detached and spreading stem segments of *Opuntia fragilis* (photo V. Vladimirov).



Fig. 5. Recently rooted stem segment of *Opuntia engelmannii* (photo V. Vladimirov).



Fig. 6. Seedlings of *Opuntia humifusa* (photo V. Vladimirov).

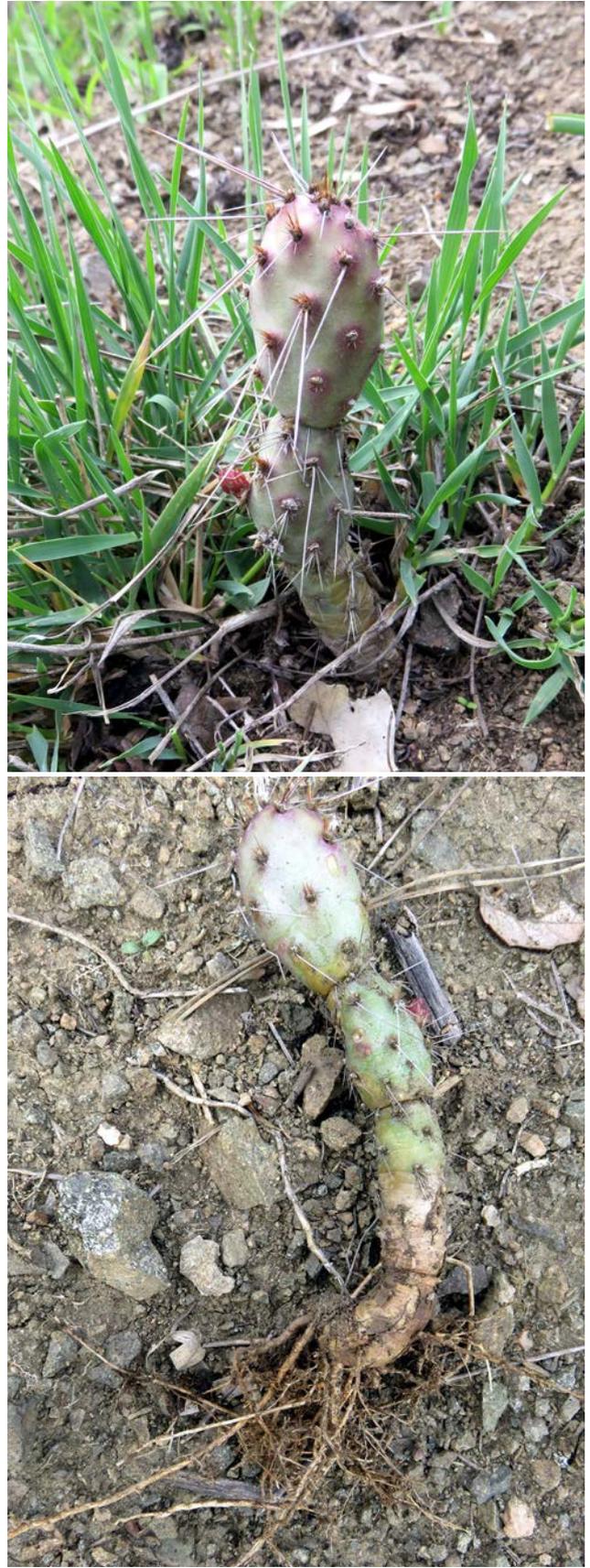


Fig. 7. *Opuntia engelmannii*, young specimen originated from seed (photo V. Vladimirov).



Fig. 8. *Opuntia engelmannii* with fruits (photo V. Vladimirov).



Fig. 9. Stem segments of *Opuntia fragilis* (photo V. Vladimirov).

Acknowledgements. Financial support of the Financial Mechanism of the European Economic Area under Programme BG03 'Biodiversity and Ecosystems', project IBBIS (Contract D-33-72/20.07.2015) is gratefully acknowledged.

References

- ALA 2019. *Opuntia engelmannii* Salm-Dyck ex Engelm. – In: Atlas of Living Australia, ala.org.au – <https://bie.ala.org.au/species/http://id.biodiversity.org.au/node/apni/2904181> (accessed 18.02.2019).
- Assyov, B. & Petrova, A. (eds). 2012. Conspectus of the Bulgarian Vascular Flora. Distribution Maps and Floristic Elements. Ed. 4. Bulgarian Biodiversity Foundation, Sofia.
- Bagrikova, N.A. & Chichkanova, E.S. 2018. About some morphological and morphometric features of *Opuntia engelmannii* subsp. *lindheimeri* (Cactaceae), naturalised in the 'Cape Martyan' Nature Reserve (Crimea). – Nature Conservation Research (Zapovednaya Nauka), 3 (Suppl. 2): 54-65 (in Russian).
- BioNET-EASRINET 2019. Keys and fact sheets: *Opuntia engelmannii* (Prickly Pear Cactus). – [https://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/Opuntia_engelmannii_\(Prickly_Pear_Cactus\).htm](https://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/Opuntia_engelmannii_(Prickly_Pear_Cactus).htm) (accessed 20.02.2019).
- Britton, N.L. & Rose, J.N. 1919. The Cactaceae. Descriptions and Illustrations of Plants of the Cactus Family. Vol. 1. The Carnegie Institution of Washington, Washington.
- Corral-Díaz, R., Goettsch, B.K., Gómez-Hinostrosa, C., Heil, K., Hernández, H.M. & Terry, M. 2017. *Opuntia engelmannii* (amended version of 2013 assessment). The IUCN Red List of Threatened Species 2017: e.T152531A121598710. <http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T152531A121598710.en> (downloaded on 05.03.2019).
- Delipavlov, D. & Cheshmedzhiev, I. (eds). 2011. Key to the Plants of Bulgaria. Agrarian Univ. Acad. Press, Plovdiv (in Bulgarian).
- Discover Life 2019. *Opuntia fragilis* (Nutt.) Haw. – Fragile prickly pear. – In: Discover Life – <https://www.discoverlife.org/20/q?search=Opuntia+fragilis> (accessed 24.02.2019).
- Greuter, W., Burdet, H.M. & Long, G. 1984. Med-Checklist. Vol. 1. Genève & Berlin.
- Jordanov, D. 1970. *Opuntia*. – In: Jordanov, D. (ed.), Fl. Reipubl. Popularis Bulgaricae. Vol. 4, pp. 25-27. In Aedibus Acad. Sci. Bulgaricae, Serdicae (in Bulgarian).
- Korotkova, N. & Raab-Straube, E. von. 2017. Cactaceae. – In: Euro+Med Plantbase – the information resource for Euro-Mediterranean plant diversity. – <http://ww2.bgbm.org/EuroPlusMed/query.asp> (accessed 20.03.2019).
- Kozhuharov, S. (ed.). 1992. Field Guide to the Vascular Plants in Bulgaria. Nauka & Izkustvo, Sofia (in Bulgarian).
- Petrova, A., Vladimirov, V. & Georgiev, V. 2012. Invasive Alien Species of Vascular Plants in Bulgaria. IBER-BAS, Sofia (in Bulgarian).
- Pinkava, D.J. 2004. *Opuntia*. – In: Flora of North America Editorial Committee (eds), Flora of North America North of Mexico. Vol. 4, Oxford Univ. Press, Oxford & New York. – http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=123045.
- Pinkava, D.J., Puente, R. & Baker, M. 2017. *Opuntia fragilis* (amended version of 2013 assessment). The IUCN Red List of Threatened Species 2017: e.T151913A121572262. <http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T151913A121572262.en>. Downloaded on 04.03.2019.

- Piovan, A., Caniato, R., Filippini, R., Chiesura, F. & Dalla Vecchia, F.** 2014. Morphological and phytochemical aspects of three alien *Opuntia* species on Euganean Hills in North-Eastern Italy. – *Plant Biosystems*, **149**(4): 788-796.
- Ribbens, E.** 2007. *Opuntia fragilis*: taxonomy, distribution, and ecology. – *Haseltonia*, **14**: 94-110.
- Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. & West, C.J.** 2000. Naturalization and invasion of alien plants: concepts and definitions. – *Diversity and Distributions*, **6**(2): 93-107.
- Tashev, A.** 2012. Characteristics of the *Opuntia humifusa* (*Cactaceae*) locality in the Harmanli district, South Bulgaria. – *Phytol. Balcan.*, **18**(1): 11-16.
- TPL.** 2013. The Plant List. – <http://www.theplantlist.org/> (accessed 22.02.2019).
- Tsvetanov, M.** 2006. Cacti in Mt Lozenska. – *Zelen Ray*, **51**: 10-11 (in Bulgarian).
- Vladimirov, V., Delcheva, M., Tashev, A. & Bancheva, S.** 2017. Reports 78-87. – In: **Vladimirov, V. & al.** (comp.), *New floristic records in the Balkans*: 32. – *Phytol. Balcan.*, **23**(1): 139-140.
- WFO.** 2019. The World Flora Online – <http://www.worldfloraonline.org/> (accessed 22.02.2019).
-