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RESEARCH PAPER

On biomorphological and phytocoenotic characteristics of *Microcnemum coralloides* subsp. *anatolicum* (Chenopodiaceae) in the Ararat valley of Armenia

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ABSTRACT

The article presents data on the bio-morphological characteristics of germination, flowering and fruiting of the endangered species *Microcnemum coralloides* subsp. *anatolicum*, preserved in the relict salt marshes of the Ararat valley within the *Juncus acutus* community. According to the monitoring results, the state of the *Microcnemum* population in terms of reproductive capacity and adaptive properties to the increasing aridity of the Ararat salt marshes can currently be assessed as satisfactory. The main threats to the population are the reduction and degradation of the habitat under the influence of anthropogenic factors.

Keywords: *Microcnemum coralloides* subsp. *anatolicum*, biomorphological characteristics, state of population, salt marshes, Ararat valley

РЕЗЮМЕ

Акопян Ж.А. О биоморфологических и фитоценотических характеристиках *Microcnemum coralloides* subsp. *anatolicum* (Chenopodiaceae) в Араратской долине Армении. В статье представлены данные о биоморфологических особенностях прорастания, цветения и плодоношения редкого и исчезающего вида *Microcnemum coralloides* subsp. *anatolicum*, сохранившегося на реликтовых засоленных болотах Араратской равнины в составе растительного сообщества *Juncus acutus*. По результатам мониторинга, состояние популяции *Microcnemum*, обусловленное репродуктивным потенциалом и адаптивными свойствами к возрастающей аридизации Араратских засоленных болот, в настоящее оценивается как удовлетворительное. Основными угрозами для популяции являются сокращение и деградация местообитания под воздействием антропогенных факторов.

Ключевые слова: *Microcnemum coralloides* subsp. *anatolicum*, биоморфологическая характеристика, состояние популяции, засоленные болота, Араратская равнина

Microcnemum coralloides (Loscos & J. Pardo) Font Quer subsp. *anatolicum* Wagenitz is one of the rarest species of Armenian flora preserved on the Ararat valley relic salt marshes within *Juncus acutus* community. *M. coralloides* comprises two subspecies, viz. subsp. *coralloides*, native to central and east Spain and subsp. *anatolicum* Wagenitz, occurring in Armenia, central and north-west Iran, central and south-west Anatolia, Syrian Desert. Ararat valley relic salt marshes are regarded as derivates of the ancient lagoons of the sea coast of the Mediterranean area, which existed in the Araks valley until the end of the Miocene (Leye 1962, 1968, Akopian 2013). The habitat represents considerable scientific interest due to its originality and rich floristic composition (Takhtajan 1941, 1946, Barsegyan 1991), and is identified as an Important Plant Area (IPA) of global conservation concern (Asatryan & Fayvush 2013). *M. coralloides* subsp. *anatolicum* was first discovered as a new species for the floras of Armenia and the U.S.S.R. in 1972 (Botschantsev & Barsegian 1972). Over the past forty years *Microcnemum* had not been collected in Armenia and was rediscovered in 2016 (Akopian et al. 2017). *M. coralloides* subsp. *anatolicum* is included in the Red Book of the Plants of the Republic of Armenia as Endangered Species (EN) and in the Annex 6 of the Berne Convention (Tamanyan et al. 2010). Taking into account insufficient data on biological and coenotic peculiarities of *M. coralloides* ssp. *anatolicum* of Armenian population and the intensification of the anthropogenic press on the species habitat we undertook this study.

MATERIAL AND METHODS

In order to monitor the *M. coralloides* ssp. *anatolicum* population, expeditions were carried out to the salt marshes of the Ararat valley in 2017–2021. Observations on the *Microcnemum* biomorphology were carried out in nature and in the Yerevan Botanical Garden NAS RA on plant specimens transplanted from the Ararat marshes. The following methods were utilized: a unified system of environmental monitoring (Hill et al. 2005), bio-ecological (Serebryakov 1962), phenological (Beideman 1964). Plants species abundance in the phytocoenosis was determined using the method of visual estimation according to the scale of Drude (1890). The following symbols are used: Cop 1 (copiosae) – abundance / frequency of occurrence 30–50 %; Sp1 (sparsae) – abundance / frequency of occurrence of 10–30 %, plants are scattered; Sol (solitariae) frequency of abundance / occurrence up to 10 %, plants are rare; Un (unicum) – plants are found singly.

For mapping, GPS data were used. For getting spatial distribution of plants species quadratic methods were used (Foody 2008, Seguarado 2004) inside ArcGIS 10.1 (ESRI

2012). Morphological features of plant samples were studied using MBC-9 stereo microscope. Plants and habitats were photographed with Nikon D3400 digital camera.

The following *M. coralloides* ssp. *anatolicum* specimens preserved in the Herbarium (ERE) of the A. Takhtajan Institute of Botany were examined (Armenia, Yerevan floristic region): Ararat village, swampy soils. 29.VII.1956. A.M. Barseghyan (ERE 63071, 63072); Ararat village. 15.VII.1957. A.M. Barseghyan (ERE 136860); Artashat district, Burastanvillage, near the river Araks. 10.X.1960. Gabrielyan, Barseghyan (ERE 70970); Near vil. Masis x Burastan. 15.VI.1961. A. Barseghyan (ERE 87497, 87498); Ararat village. 10.X.1961. Barseghyan (ERE 68683); Ararat village, salt marshes, near a cement plant. 5.IX.1961. Barseghyan (ERE 97805, 97806); To the east of Ararat town. 5.IX.1961. A.M. Barsegyan (ERE 136819); Ararat valley, middle course of the Araks river (Vedi district) 10.X.1971. Gambaryan, Galstyan (ERE 146051, 146052); Ararat village. 18.IX.1976. Barseghyan (ERE 108135); Ararat village. 29.VIII.1978. Barseghyan (ERE 147330). In the vicinity of Ararat town, salt marshes. 39°49'57.075"N 44°43'17.616"E. 4.IX.2017. J. Akopian, A. Ghukasyan, Zh. Hovakimyan, Z. Paravyan.

RESULTS AND DISCUSSION

In Armenia the only remaining population of *M. coralloides* ssp. *anatolicum* is currently located on the Ararat valley salt marshes to the south-east of Ararat town (Fig. 1). The territory of Ararat salt marshes is flat, with minor micro-depressions in the north-east and north-west, located at an altitude from 792 to 822.5 m a.s.l. The hydro-geological state monitoring revealed that the soils here are slightly alkaline, with a pH 7.6–8.0, referred to sulfate-alkaline. The salt content in the soil is about 0.2 %, and in groundwater about 0.3 %.

The groundwater level is unstable, the highest water level is noted in the spring. During our observations in the early spring in a few relief micro-depressions of marshes a slight water rise of about 10–15 cm above the soil level was noted. In the 1970–80s the *Juncus acutus* community occupied an area of 150 hectares (Barseghyan 1991), currently the area is about 90 hectares (Akopian et al. 2018), where vegetation xerophytization and degradation of the characteristic composition of the phytocenosis is observed. This conducts to the dominance of more drought tolerant plant species in the composition of the *Juncus acutus* community, as well as leads to the reduction in the phytocoenosis of the species of Cyperaceae, Juncaceae, Juncaginaceae families and of such marsh flora species as *Triglochin maritima* L., *T. palustris* L. (Juncaginaceae), *Alisma lanceolata* With. (Alismataceae), *Butomus umbellatus* L. (Butomaceae). Despite the changes taking place, the habitat is of considerable scientific interest. Rare and endangered, as well as endemic and relic species of plants growing on Ararat salt marshes are among natural objects of special protection. Currently, besides *Microcnemum* in this small area the following 10 species included in the Red Book of the RA occur: *Cirsium alatum* (S.G. Gmel.) Bobrov*, *Falcaria falcarioides* (Bornm., H. Wolff) H. Wolff*, *Inula aucheriana* DC., *Iris musulmanica* Fomin, *Linum barsegianii* Gabr. et Dittr.*, *Merendera sobolifera* C.A. Mey.*, *Juncus acutus* L.*, *Puccinellia grossheimiana* V.I. Krecz, *Sphaerophysa salsula* (Pall.) DC., *Thesium compressum* Boiss.*. It should be emphasized that 6 species marked with * from the list above are known in the flora of Armenia only from this particular habitat.

M. coralloides ssp. *anatolicum* is an annual hygro-halophyte plant 5–10 (15) cm tall with articulated stems and vestigial leaves (Fig. 2A). Plant color is variable and it was used as a distinguishing feature for *Microcnemum* two subspecies: crimson or blue-greenish for *M. coralloides* subsp. *coralloides* and yellowish green for subsp. *anatolicum* (Wagenitz 1959, Aellen 1967). The color of the plants from Iran was described as magenta (Akhani 1988, Hedge 1997). Comparative studies by Kadereit et al. (2008) have shown that the coloration of *Microcnemum* two subspecies does not allow to reliably distinguish between the two subspecies and is probably changeable, as well as slight differences in its habit (height, succulence and branching) are evaluated as dependent on influence by seasonal fluctuation of rainfall and salinity. Our observations over the Ararat valley population of *M. coralloides* subsp. *anatolicum* revealed plants color changes during the growing season: from reddish-green or light green in seedlings, dark or light yellow-green in flowering and reddish in fruiting. This confirms the plasticity of the *Microcnemum* coloration and its dependence on the influence of environmental conditions in the process of seasonal development.

Microcnemum seeds germination is observed in late March – early April. Seedlings are reddish-green or light green (Fig. 2B–C). Cotyledons are 2.2(2.5) × 1.5(1.6) mm, ovate, tapering at the apex, convex below, flat above, glabrous, succulent. The hypocotyl is cylindrical, glabrous, light reddish, 0.5–0.7 mm wide and 7 mm long, sharply tapering into a thin light-yellow root up to 10 mm in length. The first leaves are in the

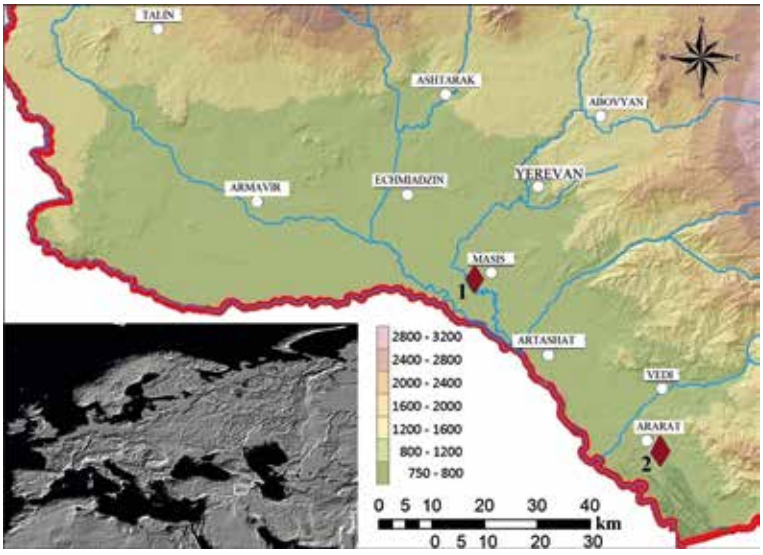

Figure 1 *Microcnemum coralloides* subsp. *anatolicum* locations (rhombus) in the Ararat valley of Armenia 1 – location known until the 1960s; 2 – recently discovered location. Basic map according to Takhtajan & Fedorov (1972)

Figure 2 Morphological features of *Microcnemum coralloides* subsp. *anatolicum*. A – general view of plants in Ararat salt marshes, the first decade of August; B, C, D – seedlings (C – scale bar 1 mm, D – scale bar 2 mm); E – fragment of inflorescence with exposed tips of stigmas (a) and anther (b) (scale bar 1 mm); F – seeds (scale bar 0.5 mm)

form of conical, small opposite tubercles (Fig. 2B–D). The free part of the seedling leaves is 0.8 mm in length, along the edge with a light, fleshy border and with a soft beak-shaped tip at the top. Each of the seedling segments is 3.5 mm long and 1.3–1.5 mm wide. The apical segment of the seedling is reddish, the lower ones are light green. The stems of the plants are erect with several opposite, articulate branches. Lateral branches grow starting from the fourth to sixth segment of the seedling, and from the axils of the cotyledons.

In the Ararat valley natural climatic conditions *M. coralloides* subsp. *anatolicum* flowers in July–September. All the branches of *Microcnemum* end in a cone-like inflorescence of 1–3 cm long. In the axils of each opposite bract 3 tiny flowers arranged in a line (or 6 flowers in one whorl) are immersed. The opposite bracts are succulent, cup-like connate in the lower part, 2.2 mm long with free part of 0.8(1) mm long, and with membranous edge of 0.5 mm wide, pointed at the apex. Bracteoles are absent. The flowers and seeds are freely arranged in a row.. The perianth is formed of only one membranous lobe. The remnants of membranous perianth are sometimes present on fruits. The hermaphroditic central flower of the cyme has one adaxial stamen and an ovary with two stigmas; lateral flowers are unisexual, pistillate. The anther consists of two thecae fused by almost half of the length, sometimes with minute, seta-like appendage on the top.

The dichogamy is a characteristic feature for the tribe *Salicornieae* species (Connor 1984), expressed as

protogyny or protandry. The dichogamy in *Salicornieae* has been revealed by Knuth (1909) for slightly protogynous *Salicornia* flowers. Certain species of *Sarcocornia* (Soriano 1947) and *Microcnemum coralloides* (Scott 1978) are identified as gynomonoecious. Our research data confirmed that *M. coralloides* subsp. *anatolicum* is gynomonoecious species. Hermaphroditic central flower of the cyme is morphologically proteroandric. During the flowering only anther is exposed, stamen filament is not protruding from the perianth (Fig. 2E). Anthers exposition and pollen dispersion are observed in the afternoon around 1:30 – 2:30 p.m. Pollen is spread by wind. The flower and inflorescence characters of *Microcnemum* indicate the possibility of geitonogamy.

In the Ararat salt marshes *Microcnemum* fruiting and seed ripening is observed in September–October. Seeds productivity is high. A characteristic way of *Microcnemum* seed dispersal is mature seeds self-sowing. As a result of autumn self-sowing, the seed germination around the parent plants in the next year is observed. Seeds can also be dispersed by water in the marshes area with lifting groundwater level. On the Iranian material of *Microcnemum*, 4–6 seeds are noted, maturing in each whorl (Hedge 1997). In *Microcnemum* plants of Ararat valley population 6 seeds usually mature in each whorl. Seeds are ovate, somewhat flattened, 0.8 × 1 mm, with crustaceous granular testa, reddish magenta or reddish dark brown (Fig. 2F). Embryo terete, curved, perisperm is vestigial. Seeds are vertical in orientation, placentation is basal. For differentiation of *Microcnemum* micromorphological characters of seed (by a set of signs for the subfamily Salicornioideae family Chenopodiaceae) we followed Shepherd et al. (2005) and Sukhorukov (2014). According Sukhorukov (2014) the thickness of the testa in *Microcnemum* seeds is 20–25 μm, significantly exceeding the tegmen, the surface of testa is mammillate, deposits of tannins are noted in the outer cell wall of testa. The ornamentation of the walls of the outer epidermal cells of the exotesta are convex with undulate walls, which form uneven bumps. This ornamentation type is observed in Salicornioideae in *Arthrocnemum* and *Microcnemum coralloides*; seed coat ornamentation of *Microcnemum* and *Arthrocnemum* (*A. macrostachyum* (Moric.) K. Koch, *A. subterminale* (Parish) Standl.) is distinct from other Salicornioideae as the elongated epidermal cells of the exotesta have convex walls (Shepherd et al. 2005). Sculpture of *Microcnemum* seed testa is recognized as a distinctive feature for the two subspecies: for the *M. coralloides* subsp. *anatolicum* with densely papillose seed, while for *M. coralloides* subsp. *coralloides* with obscurely papillose seeds. These distinctive features were confirmed by SEM studies of seeds of two *Microcnemum* subspecies (Kadereit et al. 2018: fig. 3, p. 422).

The population of *M. coralloides* subsp. *anatolicum* currently occupies an area of about 52.75 hectares in the Ararat salt marshes. The dominant species of the community is *Juncus acutus* L. The leading role in the vegetation cover belongs to perennial herbs, while other life forms are represented much less. The grassy vegetation is dense, with a cover of about 80–100 %. By the end of summer and in autumn, the cover is reduced compared to the spring vegetation, due to dehumidification of the habitat and due to intensive grazing. The observed processes of desertification, lowering of the groundwater level and drainage, anthropogenic factors impact (expansion of arable lands, grazing, vegetation burning, fragmentation of main area of distribution) lead to a disturbance of the ecological balance of the habitat and have a negative influence on the marsh flora and vegetation. The main components of the community are distributed over 4 layers – from the upper (1.5–2 m) to the lower layer (1–15 cm). In some areas, the vegetation is represented only by the lower layer with the participation of species such as *Microcnemum coralloides* ssp. *anatolicum*, *Aeluropus littoralis* (Gouan) Parl., *A. pungens* (M. Bieb.) K. Koch, *Petrosimonia brachiata* (Pall.) Bunge, *Frankenia hirsuta* L., *Crypsis aculeata* (L.) Aiton, *Linum barsegianii* Gabr. et Dittr., *Cynodon dactylon* (L.) Pers.. In wet areas in the lower layer of vegetation, *Lysimachia maritima*, *Merendera sobolifera* and *Carex pachystylis* J. Gay are distributed. *Acorellus pannonicus* (Jacq.) Palla is found on some strongly moistened small fragments.

The spatial distribution and abundance of *Microcnemum* observed on the investigated territory of salt marshes are reflected in the map (Fig. 3). *Microcnemum* is characteristic to the lower sublayer of *Juncus acutus* community, consisting of plants from 1 to 10–15 cm in height. *M. coralloides* subsp. *anatolicum* has adaptability capacities to the micro-conditions of the Ararat salt marshes, and it grows both on relativity dry places with a deep level of ground water (sometimes more than 2 m depth), on excessively moistened small relief depressions, and also on *Juncus acutus* old tussocks (Fig. 4).

The tussocks of *J. acutus* are consider as "minimal phytogenic fields" (Uranov 1965, Barseghyan 1991), on which other marsh plant species settle. Due to the density of the salt marshes perennial grass cover and the low competitiveness of *Microcnemum* plants, especially at the seedling

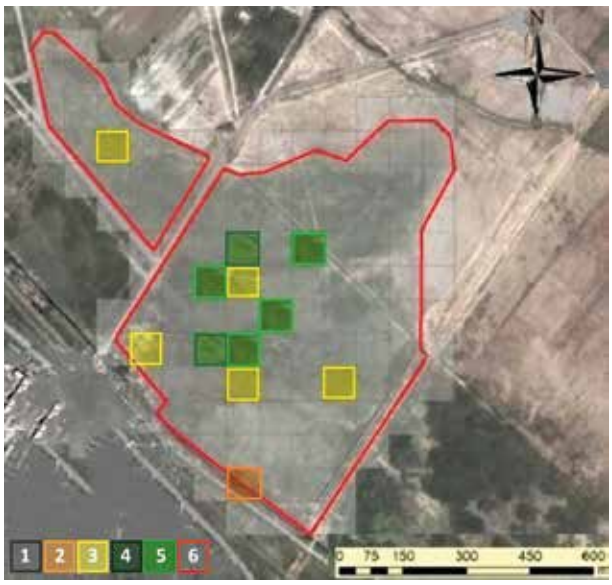

Figure 3 Map of the *Microcnemum coralloides* subsp. *anatolicum* distribution and abundance on the salt marshes in the vicinity of the Ararat town. The total area of the territory marked with the red line is 52.75 ha (8.19 ha small shape and 44.55 ha large shape). 1 – species has not been found, 2 – species abundance Un, 3 – species abundance Sol, 4 – species abundance Sp1, 5 – species abundance Cop1, 6 – Salt marshes in the vicinity of Ararat town

Figure 4 Plants of *Microcnemum coralloides* subsp. *anatolicum* (circled) on the *Juncus acutus* tussocks, autumn aspect

stage, they find refuge on the old dried tussocks of *Juncus*, which rise 20–30 cm above the lower layer of phytocoenosis. *Microcnemum* seeds germinate and seedlings develop with high density in the center of *Juncus* tussocks. In small spaces of salt marshes ranging from 1–2 to 5–6 m² *M. coralloides* subsp. *anatolicum* forms compact pure (single-species) groupings with the projective covering about 90 (80–100) %. Micro-associations of *Microcnemum* with *Aeluropus littoralis*, *A. pungens*, *Cynodon dactylon*, *Petrosimonia brachiata*, *Suaeda heterophylla*, *S. salsa* are also noted.

CONCLUSION

The presented data contribute to the biomorphology of germination, flowering and fruiting, as well as to coenotic state of endangered plant *Microcnemum coralloides* subsp. *anatolicum* in the natural conditions of Ararat valley relic salt marshes. According to the results of *Microcnemum* population monitoring, the state of its reproductive ability and adaptive properties to increasing aridity of the Ararat salt marshes can be estimated as satisfactory. The main threats of extinction of the species population are habitat territory reduction and degradation under the influence of anthropogenic factors.

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