https://communications.science.ankara.edu.tr

Commun.Fac.Sci.Univ.Ank.Ser. C Biology
Volume 29, Number 2, Pages 243-253 (2020)
ISSN 1303-6025 E-ISSN 2651-3749
https://dergipark.org.tr/en/pub/communc/issue/55192/714890

Received by the Editors: April 05, 2020; Accepted: June 02, 2020

ALTHENIA ORIENTALIS (POTAMOGETONACEAE) IN TURKEY: HABITAT CONDITIONS, MORPHOLOGY AND ANATOMY

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ABSTRACT. *Althenia* F.Petit is a submerged aquatic plant genus, which is represented by two species in the world. *Althenia* species are found mainly in brackish water lagoons and in salt lakes. The genus has only one species in Turkey, *Althenia orientalis* (Tzvelev) García-Mur. & Talavera which was collected from Turkey in 1959 and published in 1975. Since then, it could not be collected again and was assessed as extinct in Turkey. We performed field studies to collect the species in May 2017 and June 2017. We managed to find the species in its original locality. We measured chemical and physical properties of the water bodies it is growing. Additionally, we provide the stem anatomy of the species based on Turkish material for the first time. The single locality of the species in Turkey is a hypersaline lagoon lake (Lake Tuzla, Adana). Only dense *Ruppia maritima* L. population accompanies the species. *Althenia orientalis* grows in slightly alkaline and warm waters. The population size is small, covering approximately 500 m^2 area. The plants future presence is threatened by severe human pressure (i.e. pollution due to construction waste deposits and dense agricultural activities).

The genus *Althenia* F.Petit was originally included in Zannichelliaceae Chevall. family [1-2]. However, all genera in the family were transferred to Potamogetonaceae Bercht. & J.Presl [3-4]. Recent molecular phylogenetic studies also support Zannichelliaceae as a synonym of Potamogetonaceae [5]. On the other hand, Talavera and Garcia-Murillo [6] continue to treat it under the family Zannichelliaceae. The genus *Althenia* was first described from France with the type species as *A. filiformis* F.Petit [1]. For a long time, the genus was known mainly from the Mediterranean basin ranging from Morocco, Algeria, Portugal, Spain, Baleares,

Keyword and phrases. Potamogetonaceae, ecology, Althenia, Lake Tuzla, Adana, Türkiye

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Greece, and Sicily to Turkey. Later, new records were found from southern Russia and southern Iran [7-8]. Therefore, *Althenia* is considered to be a Eurasian-African genus. According to Garcia-Murillo and Talavera [9] *Althenia* s.str. consists of two species: *A. filiformis* and *A. orientalis* (Tzvel.) Garcia-Mur. & Talavera. They also described another subspecies: *A. orientalis* subsp. *betpakdalensis* (Tzvelev) García-Mur. & Talavera. However, Talavera and Garcia-Murillo [6] suggested that two subspecies were ecotypes and can be found in same ponds. Some authors proposed a broader concept for the genus *Althenia.* Ascherson and Graebner [2] treated *Althenia* and closely related genus *Lepilaena* J.Drum. ex Harv. as two sections of the genus *Althenia*. Recent studies by Macfarlane et al. [5] and Ito et al. [10] also suggested inclusion of all the previously defined *Lepilaena* species within *Althenia* sensu lato (s.l.) based on their molecular and morphological research.

It was given the species status to *A. orientalis* in 1986 [9]. Both *A. orientalis* and *A. filiformis* are monoecious plants with male flowers having two sporangiate anthers. Female flowers have long styles and peltate stigmas [11]. The leaf sheaths of *A. filiformis* are with conspicuous nerves and the leaf blade with one lateral nerve on each side of the midvein. On the other hand, the leaf sheaths of *A. orientalis* are without nerves and also leaf blade does not have conspicuous lateral nerves [5].

The genus *Althenia* is a typical brackish aquatic plant growing in waters close to sea and rarely found in continental salt lakes. It can occasionally be found in freshwaters, too. *Althenia* species are under collected due to several difficulties encountered during collection. One reason is that the color of the plant is very similar to substrate color. The other important reason for collection difficulty is the species sporadic occurrence which makes it sometimes unable to collect from the same locality every year [12]. Additionally, most of the time *Althenia* species coexists with *Ruppia* species, which are usually dominant in the vegetation. Therefore, it becomes difficult to distinguish *Althenia* species among dense *Ruppia* vegetation. The presence of such dense *Ruppia* populations also effects the growth of *Althenia* species negatively due to increased competition for nutrients and light. Kipriyanova and Romanov [8] also indicated that *A. orientalis* has a narrow ecological niche and is a poor competitive plant. Therefore, they suggested that it should be included in the Red Data Book of Novosibirsk Region as a rare species.

Herbarium specimens belonging to *A. orientalis* was first collected from Turkey by E. Hennipman in 1959. However, the occurrence of the species in Turkey was only published later by Hartog [13] as *A. filiformis*. In The Flora of Turkey [7], it was listed as *A. filiformis*. However, Güner et al. [14] in the Checklist of the Flora of Turkey, treated it as *A. orientalis*. Nevertheless, the species has been never collected

again after its initial record from Turkey. Later, as a result of comprehensive surveys in the Çukurova Delta region, Çakan et al. [15] assessed *A. orientalis* as an extinct species in Turkey. Therefore, it was very important to rediscover the species in Turkey and to determine the state of its population.

Consequently, in this study our aims are 1) to confirm the presence of *A. orientalis* in Turkey, (2) to evaluate the status of its population in Turkey, (3) to find the physical and chemical features of its habitat, (4) to prepare a new description of the species based on Turkish material and to study the stem anatomy of the species.

2. Materials and Methods

2.1. Herbarium specimen collection and limnological measurements

Field studies were performed in saline lake, Lake Tuzla in May 2017 and June 2017 (Figure 1). Herbarium specimens were collected and stored in AIBU Herbarium. Ten environmental variables were measured with a YSI-Professional Plus. Measured environmental variables are: Dissolved oxygen concentration (mg l^{-1}), percent oxygen saturation (%DO), water temperature (Tw, °C), electrical conductivity (EC, µS cm^{-1}), specific conductivity (SPC, µS cm^{-1}), pH, atmospheric pressure (mmHg), total dissolved solid (g l^{-1}), salinity (ppt) and ammonium (mg l^{-1}). Geographical data (elevation and coordinates) were recorded by using Magellan eXplorist 610.

2.2. Anatomical studies

Samples were taken to represent all parts of the plants and preserved in 70% alcohol solution for diagnosis and subsequent anatomical studies. The internode areas of the stem of the specimens were cut about 0.05 mm thick with the aid of razor blades. Samples were put into safranin or toluidine blue dye and transferred to distilled water. Stem fragments were examined under the light microscope at 4x, 10x and 40x magnifications. The stele types, shape of endodermal cells, pseudohypodermis, presence of subepidermal bundles and interlacunar bundles in the cortex were determined and photographed.

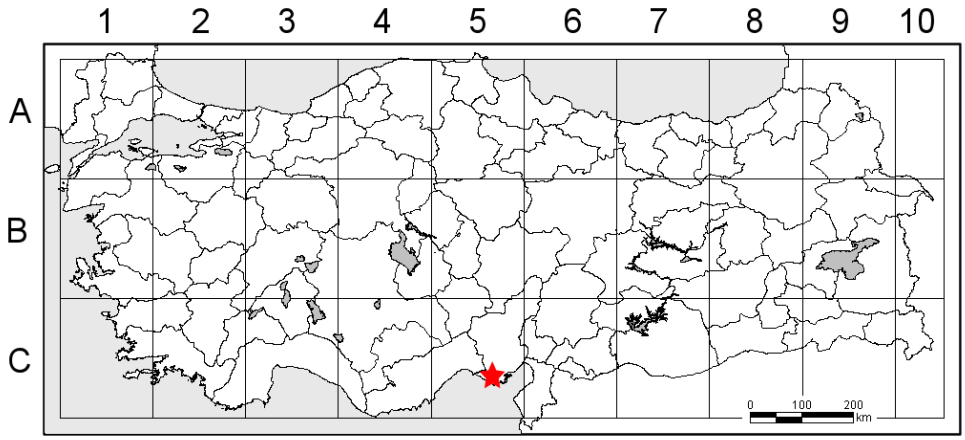

FIGURE 1. Collection site of *A. orientalis*, Lake Tuzla, Adana.

3. RESULTS

3.1. Taxonomy

Althenia orientalis (Tzvelev) García-Mur. & Talavera in Lagascalia 14: 108 (1986). Type: "Altaj occidentalis, pag. Aul, lacus amare salsus Gorczini, 26 VI 1921, V. Veresczagin" — (LE).
Sin: *Althenia filiformis* subsp. *orientalis* Tzvelev in Bot. Zhurn. (Moscow & Leningrad) 60: 390 (1975).
A. filiformis subsp. *betpakdalensis* Tzvelev in Bot. Zhurn. (Moscow & Leningrad) 60: 390 (1975).
A. orientalis subsp. *betpakdalensis* (Tzvelev) García-Mur. & Talavera in Lagascalia 14: 112 (1986).

Description:

Annual or perennial, rhizomatous aquatic plants. Stem slightly branched; mostly pale green, up to 15 cm. Leaves sessile, all submerged, alternate, entire, pale green, linear to broadly lanceolate, 1 veined, midrib without lacunae, 17-31 x 0.1-0.2 mm. Stipules adnate to leaf base, persistent, conspicuous, with auricles, c. 2 mm. Flowers unisexual, axillary; female flowers with 3 perianth segments. Fruit stipitate, c. 1.4-1.6 mm, ellipsoid, beak equal to fruit or longer.

3.2. Anatomy

Stem anatomy photographs of the species are given in Figure 2. Stele is circular type, endodermis is U-type, interlacunar bundles and subepidermal bundles are absent, and pseudohypodermis is 1-layered.

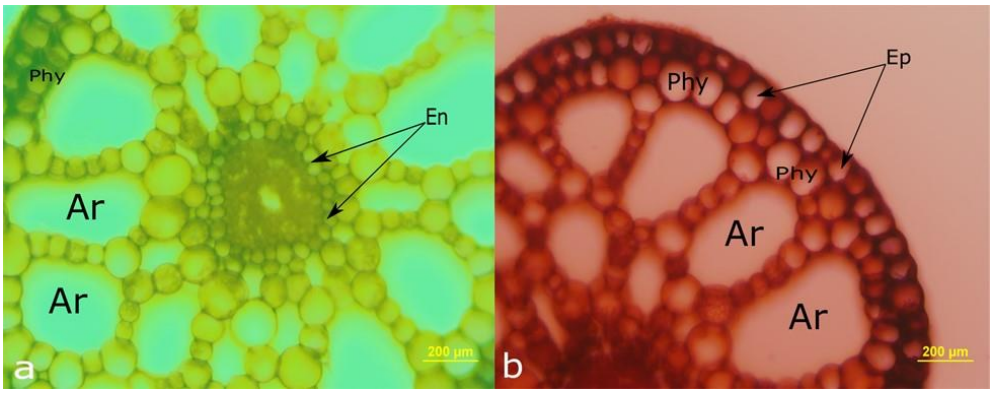

FIGURE 2. Stem anatomy of *A. orientalis* a) General view (4×), b) Epidermis and cortex (10×). Ar: aerenchyma, En: endodermis, Ep: epidermis, Phy: pseudohypodermis.

3.3. Collection Site

Althenia orientalis is a rare plant that has been collected in lagoon lake from Lake Tuzla in Adana (36° 40' 50''**N,** 35° 4' 47''**E)** in June 2017 in shallow waters (approximately 10-30 cm deep). Living fresh plant population size was small, covering a small area at the edge of the lake (Figure 3a). Additionally, plant remains in seed were observed in parts of the lake where the water dried up completely (Figure 3c, 3d). Total area of the population is approximately 500 m^2. Dense *Ruppia maritima* population coexists with *A. orientalis* (Figure 3b). There is too much agricultural activity around the lake. Freshwater coming from the fields surrounding the Lake via canals changes the salinity of the lake (Figure 4b).

FIGURE 3. a) Habitat of *A. orientalis.* b) *A. orientalis* with *Ruppia maritima* L. in lake Tuzla (Adana). Arrows shows *A. orientalis.* c) *A. orientalis* in dried up aquatic habitat. d) Inflorescence of *A. orientalis.*

FIGURE 4. a) Fresh material of *A. orientalis* (rhizomatous) b) Freshwater canals coming from agricultural fields.

3.4. Water chemistry measurements

Althenia orientalis was collected in slightly alkaline (pH = 8.05) and warm waters (water temperature = 34.3 °C). Salinity level and ammonium ion concentration were extremely high (Table 1).

TABLE 1. Water chemistry measurements for *A. orientalis* (see materials and methods for abbreviations).

Alt. (m)	**Tw** (°C)	**%DO**	**DO** (mg l^{-1})	**EC** (µS cm^{-1})	**TDS** (g l^{-1})	**Salinity** (ppt)	**pH**	**Ammonium** (mg l^{-1})
11	34.3	112	6.53	63041	34.7755	35.04	8.05	33.3

4. DISCUSSION

The submerged aquatic plant *A. orientalis* was first collected from Turkey in 1959 and published in 1975 [13] as *A. filiformis*. Since then, the species could not be collected again and was thought to be regionally extinct in Turkey [15]. In 2017, during our field works, we manage to find the species in its original habitat. The species grows in a single aquatic habitat in Turkey, which is a lagoon at the Eastern Mediterranean coast (Lake Tuzla, Adana). When we analyze the stem anatomy of *A. orientalis*, we see that it is similar to *Ruppia maritima*, which occur in the same

habitat [16]. Taxonomically closest genus to *Althenia* is *Zannichellia* L. in Turkey. *Zannichelia palustris* L. is the only representative of this genus in Turkey. We observed that in both species (*A. orientalis* and *Z. palustris*) interlacunar and subepidermal bundles are absent. However, some *Potamogeton* L. and *Stuckenia* Börner species have interlacunar or subepidermal bundles. We have observed only circular stele type in *A. orientalis* but four different types of stele can be seen in other *Potamogeton* species growing in Turkey [6, 16-17]. The habitat of *A. orientalis* had the most extreme values for the recorded water chemistry parameters compared to other Potamogetonaceae species in Turkey [18]. These values were for water temperature (34.3 °C), salinity (35.04 ppt), electrical conductivity (EC, 63041 μS cm^{-1}) and ammonium ion concentrations (33.30 mg l^{-1}). High evaporation rates during certain periods of the year cause these values when no freshwater is received via irrigation canals. The species grows in slightly alkaline waters (pH = 8.05). We recorded only *Ruppia maritima* as accompanying species in the lake abundantly. Two species co-occur most of the time together in the other Mediterranean countries and in Russia [12-8]. Kipriyanova and Romanov [8] found the species in a hyperhaline lake in Russia where its habitat is subjected to complete drying out during certain years. They also stated that the species is an ancient Mediterranean relict with a possible Paleogene origin.

According to Conde-Álvarez et al. [19], *A. orientalis* grows in shallow and temporary hypersaline water bodies where *Ruppia* sp. and *Chara* sp. accompany it. Although *A. orientalis* is very rare in the Iberian Peninsula, its habitat is unprotected because *A. orientalis* and *Ruppia maritima* grow in brackish habitats [20]. Casha and Mifsud [21] indicated that *A. orientalis* can tolerate broad salinity variations and can survive under hypersaline and drought conditions during the summer months. They reported that it produces drought resistant seeds and observed it as being annual in Malta Island. In the Turkish population, we collected both rhizomatous perennials and annual plants in seed under complete dried up conditions (Figure 3 and Figure 4).

Althenia orientalis was assessed as Data Deficient (DD) by IUCN [22]. There is no clear information about IUCN category of *A. orientalis* mainly due to confusion with *A. filiformis*. Some authors accept monotypic treatment of the genus *Althenia* [12]. Therefore, it is difficult to define the true range of each species and their red list categories. There are possible risks for *A. filiformis*. These possible risks are similar for *A. orientalis*, too. *Althenia orientalis* has a distribution in Eurasia, extending from North Africa, all the Mediterranean basin to Siberia. However, it is a rare species throughout its distribution area [8, 22].

As stated above, *A. orientalis* is known only from a single site in Turkey (Figure 1). The size of the population is small, covering roughly 500 m^2 area at the one edge of Tuzla lake. The habitat of the species is surrounded by agricultural fields. In addition to excess nutrient loading from these agricultural fields, excess freshwater from the irrigation canals alters the salinity of the lake. The area is also close to a region of rapid urbanization and tourism activities which can also effect the species population. Additionally, construction wastes create a pollution around the lake. We can also expect climate warming to change the population of *A. orientalis* [23]. Possible effects of climate change will be increasing temperatures, decrease in snow and ice cover, rising sea levels, earlier arrivals of spring, droughts and upward migration of vegetation zones [24]. Some of these factors will have a direct impact on the population of *A. orientalis*. Additionally, in Turkey the Mediterranean region will be among the most affected regions where especially temporary and shallow ponds and lakes will be subjected to change. In addition to increased temperatures, there will be a decrease in annual precipitation in the Mediterranean region of Turkey [24]. Due to all these reasons, the habitat of the species is under several threats. Precautions should be taken to protect the species and its habitat.

As a conclusion, our study confirms the presence of *A. orientalis* in Turkey and provides valuable information about its population size, habitat properties and morphological and anatomical characters of the samples from Turkey. Data provided here can be used for future monitoring of this rare species.

Acknowledgments. This study was funded by Bolu Abant Izzet Baysal University Scientific Research Projects Coordination Unit (Project no: 2015.03.01.895). Ali Nihat Gökyiğit Foundation provided a three-year grant for the first author to make a revision of the Turkish Potamogetonaceae family for the Illustrated Turkish Flora Project and supported herbarium visits.

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