



Short communication

First discovery of flowering *Wolffia arrhiza* in Central Europe

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ABSTRACT

Flowering of *Wolffia arrhiza* was discovered for the first time in Germany. This record is also the first observation of flowers in this species for Central Europe. The locality is described and the plants are photographically documented. Hitherto, flowering *W. arrhiza* had never been reported for the whole of Europe, with the only exception being two records from the 1980s in Istria (former Yugoslavia, South-East Europe). A further report about alleged flowering plants in the northern forelands of the Caucasus turned out to be erroneous, due to mistranslation and the wrong citation of an original publication from 1957 in Slovak language.

1. Introduction

The genus *Wolffia* Horkel ex Schleiden or watermeal includes the smallest spermatophytes in the world (Daubs, 1965; Fintha, 1979) and comprises 11 species worldwide (Crawford and Landolt, 1995; Sree et al., 2016). In Europe, *Wolffia arrhiza* (L.) Horkel ex Wimm. is the only native species of this genus. Recent occurrences of the American alien *Wolffia columbiana* H. Karst. have been discovered (Schmitz et al., 2014, 2016; Ardenghi et al., 2017; Garve et al., 2017). Records of two additional alien species have been recently reported in Europe from the Netherlands (*Wolffia australiana* (Benth.) Hartog & Plas, native to Australia and New-Zealand: NDFP, 2017) and from Bulgaria (*Wolffia globosa* (Roxb.) Hartog & Plas, native to the palaeotropic region: Kirjakov and Velichkova, 2013). Therefore, examination of a number of *Wolffia* samples using a stereoscopic microscope was initially done in order to determine species identity and to find out the current distribution of native and alien *Wolffia* species (Schmitz et al., 2016; Garve et al., 2017). This enabled the detection of flowering specimens during this examination. While the alien *Wolffia columbiana* is known to develop flowers regularly both in its native area in the Americas (Landolt, 1986) as well as in its introduced range in Europe (Schmitz et al., 2014, 2016), flowers of *Wolffia arrhiza* have never been found in Europe before with the only exception being two records from Istria (former Yugoslavia, South-East Europe) in the 1980s by Krajncič (1989).

2. Material and methods

The plant sample was collected by the second author (HK) on 21 September 2016 in Germany, Lower Saxony, district Lüchow-

Dannenberg, 1.5 km NNE Siedlung Prezelle, (Latitude 52.98005 N, Longitude 11.440662 E). The site was a small pond (Fig. 1) at the edge of extensively managed grassland in the middle of the Gartow forest, much frequented by several game species (red deer, fallow deer and wild boar). The water surface was shaded after 3 pm. The *Wolffia* plants grew together with *Lemna minor* L., *Spirodela polyrrhiza* (L.) Schleid., *Alopecurus aequalis* Sobol., *Eleocharis palustris* (L.) Roem. & Schult. s. l., *Glyceria fluitans* (L.) R. Br., *Potamogeton natans* L. and *Ranunculus aquatilis* L. agg. Because of slow drying up of the waterbody, a part of the *Wolffia* fronds lay on the dried out mud banks at the edge of the pond. At the time of sampling, they appeared slightly paler than at other locations of *Wolffia* in the surroundings. The occurrence of *Wolffia* at this site is known since 2015.

The sampled plants were examined with a stereo microscope using incident and lateral light. Frond size was measured by eyepiece micrometer at 32 × magnification. Species determination followed the keys of Landolt (1980, 1986, 1994) and Armstrong (2017). Macro photos were taken with a digital camera (Canon PowerShot SX60 HS and Raynox MSN 202 macro conversion lens). The pictures were stacked by means of the software combine ZP (General Public License, developer A. Hadley).

3. Results and discussion

The plants were identified as *Wolffia arrhiza* by the first author (US). In contrast to the alien *W. columbiana*, which also regularly occurs in Germany, the fronds have a deep green upper surface with more than fifteen stomata. During examination, it turned out that the sample contained numerous flowering specimens (Fig. 2). This record is the

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Fig. 1. Habitat of flowering *Wolffia arrhiza* near Prezelle, district Lüchow-Dannenberg, Germany. Many footprints of game animals are visible at the edge of the pond. Photo H. Kelm, 21 Sept. 2016.



Fig. 2. Flowering plants of *Wolffia arrhiza*. Photo U. Schmitz, 06 October 2016.

first observation of flowering *Wolffia arrhiza* for Central Europe.

The frequency of flower formation differs for the various *Wolffia* species (Landolt, 1986). The alien *Wolffia columbiana*, which has been frequently found in Europe since its first discovery 2013 (Schmitz et al., 2014, 2016; Ardenghi et al., 2017; Garve et al., 2017), is known to develop flowers regularly both in its native area in the Americas (Landolt, 1986) as well as in its introduced area in Europe (Schmitz et al., 2014, 2016). The Old World species *W. arrhiza* is distributed in Europe, Africa, West Asia, and in Rio de Janeiro, Brazil, from where it has been reported since 1872 (Landolt, 1986). *W. arrhiza* has been also found introduced and probably naturalized in California (Armstrong, 1989, 2017). Landolt (1986) states a similar percentage of flowering plants between 1.5 and 3% in nature for both *W. arrhiza* and *W. columbiana* worldwide. However, flowers of *W. arrhiza* had only been reported for Africa (Landolt, 1986), and had never been found in Europe before, with the only exception being two records from Istria in the 1980s by Krajnčič (1989). Kandler (in Hegi 1980) claimed that flowering *W. arrhiza* had been found in the northern forelands of the Caucasus, citing Benková (1957), and Hegi (1980) then again has been cited similarly by other authors. This citation turned out to be wrong, basing on a mistranslation of the original text, written in Slovak language (Benková, 1957). A current review and translation of the Slovak text by the native speaker I. Stelzig, Neuss, showed that Benková (1957) just described a new record of *W. arrhiza* in Slovakia, but that she did not find any flowering specimens there, or elsewhere in Europe.

For the two additional introduced species *Wolffia australiana* and *Wolffia globosa*, which are still extremely rare in Europe (Kirjakov and

Velichkova, 2013; NDFF, 2017), flowering has not yet been reported. Landolt (1986) states a general flowering percentage of < 2% for *W. australiana* and 6% for *W. globosa* in their native area.

The flowering plants of *W. arrhiza* in Germany were found in September. Landolt (1986, p. 173) reports the flowering and fruiting time of *W. arrhiza* in Africa as April and from September to November. Krajnčič (1989) found flowering plants of *W. arrhiza* in Istria in September, which confirms laboratory results that *W. arrhiza* are long-short day plants (Krajnčič and Devidé, 1980, 1982). These authors managed to induce flowering in *W. arrhiza* by exposing plants after a long day pre-culture (35–40 days at 16 h light daily) and then at a short day photoperiodic (2–4 weeks, 8 h light daily). The percentage of flowering plants in this experiment was, however, very low (0.5–1%).

Botanists who find flowering or fruiting *Wolffia* plants should keep in mind that the presence of flowers can occur in both native *W. arrhiza* and different alien *Wolffia* species. This character therefore cannot be used for *Wolffia* species identification.

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References

- Ardenghi, N.M.G., Armstrong, W.P., Paganelli, D., 2017. *Wolffia columbiana* (Araceae, Lemnoideae): first record of the smallest alien flowering plant in southern Europe and Italy. Bot. Lett. 164, 121–127.
- Armstrong, W.P., 1989. *Wolffia arrhiza* (L.) Horkel ex Wimmer [Lemnaceae]. Madroño 36, 283–285.
- Armstrong, W.P., 2017. Wayne's Word Lemnaceae. Key to the genus *Wolffia*. (Accessed 28 June 2017). <http://waynesword.palomar.edu/1wokey.htm>.
- Benková, D., 1957. *Wolffia bezkorená* [*Wolffia arrhiza* (L.) Wimm.] na južnom slovensku. Biologia (Bratisl.) 12, 460–463.
- Crawford, D.J., Landolt, E., 1995. Allozyme divergence among species of *Wolffia* (Lemnaceae). Plant Syst. Evol. 197, 59–69.
- Daubs, E.H., 1965. A Monograph of Lemnaceae. Illinois Biological Monographs 34. Univ. of Illinois Press, Urbana.
- Fintha, I., 1979. Revision of the home distribution of *Wolffia arrhiza* (L.). Tiscia 15, 71–79.
- Garve, E., Kelm, H., Fischer, C., Thiel, H., Schmitz, U., 2017. Die Kolumbianische Zwergwasserlinse (*Wolffia columbiana* H. Karst.) – eine neue Wasserpflanze in Niedersachsen. Tuexenia 37, 355–362.
- Hegi, G., 1980. 3rd ed. Illustrierte Flora Von Mitteleuropa, vol. II/1 Paul Parey Verlag, Berlin.
- Kirjakov, I., Velichkova, K., 2013. *Wolffia globosa* (Roxburgh) Hartog et Plas (Lemnaceae): A New Species in Bulgarian Flora. J. Biol. Sci. Opin. 1, 356–357. <http://dx.doi.org/10.7897/2321-6328.01416>.
- Krajnčič, B., Devidé, Z., 1980. Report on photoperiodic responses in lemnaceae from Slovenia. Berichte des Geobotanischen Institutes der ETH 47. Stiftung Rübél, Zürich, pp. 75–86.
- Krajnčič, B., Devidé, Z., 1982. Photoperiodic responses in lemnaceae from north Croatia. Acta Bot. Croat. 41, 57–63.
- Krajnčič, B., 1989. Distribution of Lemnaceae in the region of Istria (Istra) and first discovery of flowering *Wolffia arrhiza* (L.) Horkel ex Wimmer in Yugoslavia. Berichte des Geobotanischen Institutes der Eidg. Techn. Hochschule Zürich, vol. 55. Stiftung Rübél, pp. 81–88.
- Landolt, E., 1980. Biosystematic investigations in the family of duckweeds (Lemnaceae) 1. Biosystematische Untersuchungen in der Familie der Wasserlinsen (Lemnaceae) 1. Key to determination. In: Cytological Variation. Amino Acid Composition and Sugar Content. Effects of Nitrogen and Phosphorus. Bibliography. List of Studied Material. – Veröff. Geobot. Inst. ETH, Stf. Rübél 70. Zürich. (247 pp).
- Landolt, E., 1986. Biosystematic investigations in the family of duckweeds (Lemnaceae) 2. In: The Family of Lemnaceae – a Monographic Study Vol. 1. – Veröff. Geobot. Inst. ETH, Stf. Rübél 71. Zürich. (566 pp).
- Landolt, E., 1994. Taxonomy and Ecology of the Section *Wolffia* of the Genus *Wolffia* (Lemnaceae). – Berichte des Geobotanischen Institutes der Eidg. Techn. Hochschule, vol. 60. Stiftung Rübél, Zürich, pp. 137–151.
- NDFF, 2017. Floron verspreidingsatlas vaatplanten, *Wolffia australiana*. <https://www.verspreidingsatlas.nl/6974>, website retrieved 15/05/2017.
- Schmitz, U., Köhler, S., Hussner, A., 2014. First records of American *Wolffia columbiana* in Europe – Clandestine replacement of native *Wolffia arrhiza*? BioInvasions Rec. 3,

213–216.

Schmitz, U., Köhler, S., Nesemann, H., 2016. Neue Nachweise der Kolumbianischen Zwergwasserlinse *Wolffia columbiana* in Europa –Bei wie vielen vermeintlichen Vorkommen von *Wolffia arrhiza* handelt es sich in Wirklichkeit um den Neophyten?, vol. 8. *Veröffentlichungen des Bochumer Botanischen Vereins*, pp. 1–10. [http://www.](http://www.botanik-bochum.de/publ/OVBBV8_1_Schmitz_Koehler_Nesemann_Wolffia_columbiana.pdf)

[botanik-bochum.de/publ/OVBBV8_1_Schmitz_Koehler_Nesemann_Wolffia_columbiana.pdf](http://www.botanik-bochum.de/publ/OVBBV8_1_Schmitz_Koehler_Nesemann_Wolffia_columbiana.pdf).

Sree, K.S., Bog, M., Appenroth, K.J., 2016. Taxonomy of duckweeds (Lemnaceae), potential new crop plants. *Emir. J. Food Agric.* 28, 291–302.