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Floral morphology of *Oxalis debilis* Kunth, 1822 (Oxalidaceae) naturalized in Algeria

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ABSTRACT This study provides a description of the floral morphology of populations of *Oxalis debilis* Kunth, 1822 from Algeria. Three floral forms were found: semi-homostylous (dominant), mid-styled (frequent) and short-styled (extremely rare). Two anther colors (yellow and white) were recorded with the dominance of the latter. A few fruits with seeds were observed. We conclude that populations of *O. debilis* in Algeria are polymorphic with low sexual reproduction success. The species was accidentally introduced into different parts of the country with growing substrates contaminated by bulbs, bulbils and probably also by seeds.

KEY WORDS Algeria; floral morphology; introduced species; *Oxalis*; sexual reproduction.

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INTRODUCTION

The Oxalidaceae family is globally represented by 7 genera including *Oxalis* L. a large genus with about 500 species (Lourteig, 2000; Mabberly, 2017) and two diversity centers, one in South America and the other in South Africa (Mathew, 1958). In Algeria, five number of species of the genus *Oxalis* have been reported in the different floras namely *Oxalis acetosella* L., *O. articulata* Savigny, *O. compressa* Thunb., *O. corniculata* L. and *O. pes-caprae* L. (Munby, 1847; Battendier & Trabut, 1888; Quezel & Santa, 1963). During the revision of the Flora of North Africa, Dobignard & Chatelain (2013) added three further species for Algeria to be considered as naturalized: *O. debilis* Kunth, *O. purpurea* L. and *O. reptatrix* Jacq. However, the latter name is now considered a synonym for *O. purpurea* (Plants of the World Online, https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:375350-1), in addition, *O. acetosella* was indicated in Algeria by French botanists but this finding has never been confirmed (Quezel & Santa, 1963) and has to be considered as extinct (Dobignard & Chatelain, 2013). Of the remaining six species of *Oxalis* confirmed for Algeria, the most widespread one is undoubtedly *O. pes-caprae* that has become invasive in different parts of the country (Sakhraoui et al., 2019), as in many other countries with Mediterranean climate (EPPO, 2022).

Oxalis species have been introduced to Algeria, mainly for ornamental or food purposes. In addition to the escaped crop species, several additional species of the genus are cultivated in Algeria such as *O. tuberosa* Molina introduced for its edible tubers between 1842 and 1867 (Carra & Gueit, 1952)

or *O. latifolia* Kunth cultivated e.g. in some gardens of the Skikda region (north-easternAlgeria) as an ornamental plant.

Oxalis debilis is another ornamental species of section *Ionoxalis*, native to South America (Lourteig, 2000) that has been introduced and naturalized in different parts of the world, including Egypt (Shamso et al., 2022) and the USA where it spreads aggressively (Nesom, 2009). The presence of this species in Algeria was first reported by Chevalier (1940) without precise indication of status and recently it was reported naturalized in Algiers by Raus & Zeddam (2008). The species is known to have a variable floral morphology with homostylous, semi-homostylous and tristylous flowers (Denton, 1973). In homostylous flowers, the stigmas are at the level of long stamens, in semi-homostylous flowers, the stigmas are slightly below the long stamens or at the level of short stamens, and in tristylous flowers, there are three kinds of styles, i.e. short, intermediate and long ones. In the first case, the stigmas are below two sets of stamens, in the second case, the stigmas are located between short and long stamens, in the last one, the stigmas are above two sets of stamens.

In order to provide information on the floral morphology of the Algerian populations of *O. debilis,* unknown until now, which will allow for a better understanding of its biology and dispersal strategies, we carried out this study in the wilaya (= district) of Skikda (north-eastern Algeria) where the species was observed in the various public and private green spaces, including nurseries (Fig. 1).

MATERIAL AND METHODS

In 2022, 851 flowers from 196 individuals of *Oxalis debilis* were collected by the first author at three sites from Skikda region: the Larbi Ben M'hidi nursery (36°52'56.6400" N, 6°58'47.1000" E), the El Hadaeik nursery (36°50'53.8800" N, 6°53'54.0240" E) and the green spaces of 'Service Commun de Recherche, Pôle de Vulgarisation Botanique' located at the Skikda University (36°50'57.1200" N, 6°53'30.7320" E).

We removed the petals and sepals of the blooming flowers and recorded the length of the stigmas and the color of the anthers. Further, we collected information on colonized habitats, flowering period, number of flowers per inflorescence, number of blooming flowers per inflorescence per day and production of fruits and seeds. To search for capsules, the study sites were meticulously surveyed.

RESULTS

At the level of nurseries in the study area, *O. debilis* is widely present in cultivation pots; also in pots introduced from other nurseries in neighboring wilayas such as Blida, Bejaïa and Jijel are infested by the species. However, young and mature escaped plants from pots were found on open ground or in greenhouses, but always in the vicinity of horticultural localities. In the green spaces of the University of Skikda, *O. debilis* forms dense and spontaneous populations between planted *Hibiscus rosa-sinensis* L.*, Malvaviscus arboreus* Dill. ex Cav. and *Washingtonia filifera* (Rafarin) H. Wendl. ex de Bary.

Peak flowering was observed from March to June, and a secondary flowering season was observed from October to December. The first flowers were observed on 21 March 2022.

A total of 196 inflorescences (from 196 individuals) were collected. Each inflorescence bears between 3 and 16 flowers of which 2 to 6 flowers started to bloom per day.

Twenty-one capsules with seeds were recorded: nine at the nursery of Larbi Ben M'Hidi and twelve at the green spaces of Skikda University (Fig. 5).

The first author recorded the presence of three floral morphs within the studied populations, i.e. with mid-styled (=intermediate) (Fig. 4), short-styled and semi-homostylous (Table 1); the latter are characterized by the stigma at the level of short stamens (Figs. 2, 3), and the presence of two anther colors (yellow and white) (Table 2). Among all recorded floral forms and anther colors, the semi-homostylous floral form and white anthers are dominant, they respectively represent 61.57% and 53.58%. The short-styled flower type is extremely rare, only ten flowers have been observed, representing 1.17% of the recorded floral forms. No long-styled flowers were recorded. The white anthers are dominant in the semi-homostylous form where they represent 57.63%, while the yellow anthers are dominant in the mid-styled form where they represent 54%.

The three studied populations are mixed populations, two populations (from El Hadaeik and University) present the three floral morphs while that of Larbi Ben M'Hidi presents only two forms (Table 1).

DISCUSSION

The populations of *O. debilis* in Skikda region are polymorphic, flowers with semi-homostylous form and white anthers are dominant. High floral polymorphism is also typical of other populations worldwide. In Taiwan, three floral morphs were observed, mid-styled, short-styled and semi-homostylous with dominance of the mid-styled-form, the two colors of anthers were also recorded, but no sexual reproduction nor the long-styled form were observed there (see Tsai et al., 2010). On mainland China, populations of *O. debilis* are monomorphic, with two floral morphs, mid and short-styled without strong dominance of one of these forms, while the long-styled and white anthers are absent and sexual reproduction was not observed (see Luo et al., 2006).

The populations growing in North America are short-styled and semi-homostylous, the long-styled form and sexual reproduction are absent (Denton, 1973). In Africa, the populations of *O. debilis* are short-styled in the west part of the continent and mid-styled in the east part (Baker, 1965; Kabuye, 1971).

The species reproduces sexually in its native environment where long-styled and mid-styled forms are dominant (Lourteig, 1980; Lourteig, 1983), in most introduced areas it does not reproduce sexually and therefore does not produce any seeds. However, in Indian populations, fruit production has been reported by Muzafar et al. (2015), but the floral forms have not been mentioned.

In Algeria, *O. debilis* produces capsules like the Indian populations, which suggests that fruit production is not exclusively related to the presence or dominance of long-styled floral forms. The pollen viability and the presence of adequate pollinators ensuring the success of pollination are probably other important factors in fruit production. Tsai et al. (2017) were able to obtain fruits through hand-pollination in one inter-morph crossing: semi-homostylous bearing yellow anthers (pollen receivers) x mid-styled bearing yellow anthers (pollen donors) confirming that the limitation of pollen transfer contributes at least partially to the lack of seed production.

Figures 1–5. *Oxalis debilis* in an urban green space at the Service Commun de Recherche, Pôle de Vulgarisation Botanique at Skikda University (north-eastern Algeria). Fig. 1: flower. Fig. 2: semi-homostylous flower type with white anthers. Fig. 3: semi-homostylous flower type with yellow anthers. Fig. 4: mid-styled flower type with yellow anthers. Fig. 5. capsule (photos by N. Sakhraoui, 18.05.2022).

White anthers are supposed to be empty, not containing pollen grains (Tsai et al., 2010; Tsai et al., 2015). The high abundance of flowers with

Study site/floral morphs	mid-styled	short-styled	semi-homostylous
Larbi Ben M'Hidi nursery	141	0	117
University green spaces	150	8	251
El Hadaeik nursery	26	2	156
Total	317	10	524

Table 1. Floral morphology of *Oxalis debilis* in the Skikda region (north-eastern Algeria). Three floral morphologies have been identified, the semi-homostylous form is best represented.

Study site/ floral morphs	mid-styled		short-styled		semi-homostylous	
	Yellow anthers	White anthers	Yellow anthers	White anthers	Yellow anthers	White anthers
Lari Ben M'Hidi nursery	23	118	0	0	41	76
University green spaces	130	20	0	8	93	158
El Hadaeik nursery	18	8	2	0	88	68
Total	171	146	2	8	222	302
Number of yellow and white anthers in all recorded populations	Yellow anthers	395		White anthers	456	

Table 2. Number of yellow and white anthers in each population of *Oxalis debilis* in the Skikda region (north-eastern Algeria). The three floral forms determined in the prospected horticultural localities have yellow and white anthers.

white anthers in the recorded floral morphs could explain the limited number of fruits in the studied populations.

At the nursery Larbi Ben M' Hidi, the species is found at the very edge of the locality, mixed with native vegetation between grasses and *Lathyrus* sp. In a few years, it is quite possible that it could escape from plantations and naturalize in Skikda region just like the widely naturalized *O. pes-caprae* and *O. compressa.* The distribution of *O. debilis* as

a weed in horticultural localities in Algeria, is not limited to the region of Skikda as flower pots from Blida, Bejaïa and Jijel, located in the North of Algeria, also contain this species as weed indicating a wider distribution likely to affect a much larger number of nurseries.

CONCLUSIONS

In Algeria, populations of *O. debilis* are polymorphic with low sexual reproduction success. The increase of interest of horticultural species in recent history has allowed the accidental introduction and subsequent spread of *O. debilis* in different parts of Algeria from growing substrates contaminated with bulbs and bulbils, and probably also by seeds. According to the observations of the first author, this species should be considered as an agricultural weed in Algeria.

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