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RESEARCH ARTICLE

Oxalis purpurea L. (Oxalidaceae): bulb morphostructure, recaulescence

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Abstract

The morphostructure of *Oxalis purpurea* bulbs during the growing season, with an emphasis on the number and functional purpose of their scales, has been investigated. It was found that two protective membranous scales, two leathery scales, and three fleshy scales are constantly present in the investigated species. The first fleshy scale has a narrow hyaline edge. Additionally, the phenomenon of metatopy in a representative of the Oxalidaceae family and recaulescence in a bulbous plant are described for the first time.

Keywords: Oxalidaceae, *Oxalis purpurea*, bulbs, scales, metatopy, recaulescence

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Introduction

Southern African bulbous representatives of the genus *Oxalis* L. (Oxalidaceae) comprise about 270 species, of which 122 originate from the Cape Floristic Kingdom (Freiberg & Manning, 2013). The species *Oxalis purpurea* L. is natively distributed in the Western Cape, a region in the winter-rainfall part of South Africa (Goldblatt & Manning, 2000). In its native range, this species is considered endemic, classified as LC (SANBI, 2025). However, *O. purpurea* is a highly decorative groundcover plant and is therefore widely cultivated in other parts of the world. This

species, characterized by the presence of true bulbs, also occurs in Ukraine.

The taxonomic structure and nomenclatural history of the genus *Oxalis* are complicated. In particular, the taxonomic revision of Southern African *Oxalis* based on morphological characters (Salter, 1944) does not align with palynological findings (Dreyer, 1996) and recent phylogenetic studies (Oberlander et al., 2004, 2009, 2011; Oberlander, 2009). However, it is considered the most complete. Considering Salter (1944), *O. purpurea* belongs to the section *Stictophyllae*. Following the POWO (2025) list, it has 34 heterotypic and two homotypic synonyms. Several

morphological synapomorphies support the clade *Purpurea*, which combines Southern African bulbous *Oxalis*, based on molecular data (Gebregziabher, 2004; Jooste et al., 2016). However, the discrepancy between molecular phylogeny and morphological data (Oberlander et al., 2011; Vaio et al., 2013) highlights the need for searching for additional morphological characters that allow distinguishing the taxa within this clade.

Oxalis purpurea is a species with wide edaphic tolerance (Haukka et al., 2013), a high level of genetic variability (Becker et al., 2022), an extremely high level of vegetative reproduction, pronounced self-compatibility, and substantial damage resistance (Zietsman et al., 2008). In disturbed habitats, *O. purpurea* often becomes a malicious weed, included in the GCW (2007). It is a winter-growing dwarf synanthous geophyte (Harrower, 2009) with immensely shortened internodes in the aboveground part of the shoot, with trifoliate leaves collected in basal rosettes, and a short rhizome-like underground part of the shoot continuing into a bulb.

Descriptions of the bulb structure of Southern African *Oxalis* differ even within the same species, as they were carried out at different ontogenetic stages (Zhila & Tymchenko, 2020). According to Moodley (1988), *O. purpurea* has one of the simplest bulb structures, the seasonal growth of which begins with the onset of winter rains and has a developmental cycle typical for all bulbous *Oxalis* species from this region.

Thus, the bulbs of Southern African *Oxalis* consist of the following structures: a basal plate, outer protective leathery scales, inner nourishing fleshy scales, and a bud that will develop in the next growing season (Salter, 1944; Moodley, 1988; Gebregziabher, 2004). A sprouted bulb with an already formed aboveground part has a similar structure. Levyns (1974), who described the annual development cycle of *O. purpurea*, reported one more type of scale that forms on the basal plate at the beginning of bulb development – thin and short-lived, disappearing before the bulb matures. When studying the morphostructure of bulbs during growth, another type of scale, membranous, is noted, located on the underground part of the shoot, often referred to as the ‘rhizome’ (Zhila & Tymchenko, 2020).

This work aimed to comprehensively analyze the features of shoot formation in the underground part of *O. purpurea* plants, including the type of bulb scales, their number, and functional purpose, as well as the activity of axillary meristems.

Material and methods

Oxalis purpurea plants were introduced into the M.M. Gryshko National Botanical Garden of the NAS of Ukraine. Observations were conducted during the 2019 and 2023–2024 growing seasons. Plants were kept in pot culture in a cool greenhouse. During the growing season, three plants were dug up once a month to establish the bulb morphostructure by sequentially removing scales. The morphostructures were described and drawn using an Lomo MBS-9 light microscope. The applied descriptive terminology follows Gebregziabher (2004) with additions of Zhila & Tymchenko (2020). Descriptions and measurements of buds formed on fleshy scales, in five replicates, were made using a Carl Zeiss Stemmi 2000 microscope at magnifications $\times 10$ to $\times 80$.

Results and discussion

The bulb in *O. purpurea* is ovoid, approximately 1 cm in diameter. The outer covering scales are blackish-brown and sticky. Leaves are petiolate (up to 5 cm long, widened at the base), leaflets are dark green, 1–3 cm long, 1–3 cm wide, sparsely hairy on the abaxial side and along the edges, without oxalate deposits. Leaflets are flat, not folded. Flowers are pentamerous, located solitary on a hairy peduncle up to 11 cm long. Sepals are up to 1 cm long, lanceolate, and hairy. Petals up to 2.5 cm long, purple but always yellow at the base. Under the test conditions, the fruits did not form.

The bulb of *O. purpurea* is imbricate, with few scales. In a state of relative dormancy, the bulb consists of a shortened section of the main shoot axis (basal plate) with scales developed on it, and a terminal bud that produces the main shoot axis (Pütz, 1994). The terminal bud of the main shoot axis has a monopodial growth pattern (Jeannoda-Robinson, 1977). After a period of relative

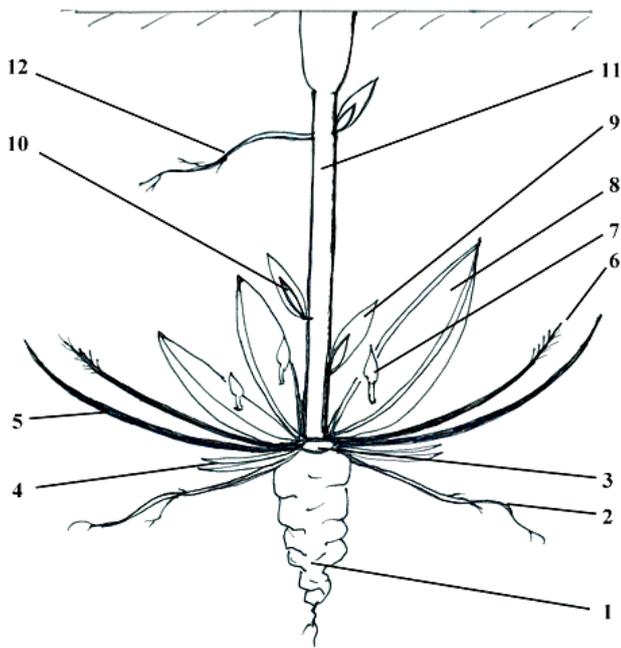


Figure 1. Schematic illustration of bulb and main shoot axis structure in *Oxalis purpurea*: 1 – rachis-like contractile basal root; 2 – basal thread-like root; 3 – basal plate; 4 – thin evanescent scales; 5 – protective membranous scales on the basal plate; 6 – leathery scale; 7 – pediculate bud on the first fleshy scale; 8 – first fleshy scale with hyaline edge; 9 – first membranous scale on the main axis of the shoot ('thread'); 10 – axillary bulb embedded under the first membranous scale; 11 – first elongated internode; 12 – thread-like adventitious root on the stem.

dormancy, thread-like roots (Fig. 1: 2) begin to grow from the mother bulb around the basal plate (Fig. 1: 3). The main shoot axis partially remains in the bulb and partially became located between the bulb and the soil surface forming so-called 'rhizome', on which thread-like roots also develop (Fig. 1: 12). The rest of the main shoot axis develops above the soil surface. Subsequently, one or two thread-like roots around the basal plate thicken and accrete with the basal plate, forming a contractile taproot-like roots (Fig. 1: 1; Zhila & Tymchenko, 2016).

The first two internodes of the main shoot axis with membranous scales at the nodes (Fig. 1: 9), in the axils of which buds (bulbils) are formed (Fig. 1: 10), are called 'threads' (Pütz, 1994). They are shortened and can elongate due to intercalary growth with simultaneous contraction of the contractile root at the end of the growing season. At the beginning of root

contraction, the scales attached to the basal plate of the bulb detach from it and remain in their original position. The internode continues to elongate further (Fig. 1: 11).

The elongation of the 'threads' and the contraction of the root can reach 30 cm in *O. pes-caprae* L. (Pütz, 1994). The buds located on the 'threads' develop into renewal bulbs and typically get the same size as the mother bulb (Pütz, 1994). Axillary buds are present at all bulb scales (Pütz, 1994; Zhila & Tymchenko, 2020) and, during the contraction of the contractile root, can be displaced to a considerable distance from the mother bulb.

Gebregziabher (2004) investigated *O. purpurea* bulbs from two localities when the plants were in the floral state. The bulbs of both specimens varied in terms of the length of the so-called 'rhizome', their diameter (a difference of 1.5 times), the length of the beak of the covering scales, the number of fleshy scales, and the presence of trichomes on different parts. Common features for both specimens were: a narrow basal part (basal plate); the presence of two types of covering scales – golden-brown membranous and honey-brown leathery; sticky secretory cells on the lower half of the outer surface of the covering scales; a beak-like apex of the bulb; the presence of a narrow membranous edge on the largest fleshy scale.

In the bulbs of the studied specimens, the presence of scales on the basal plate (Fig. 1: 3) was established in the following sequence:

- 1) Thin, short-lived scales (Fig. 1: 4).
- 2) Two protective membranous scales (Fig. 1: 5) with a smooth surface, where the inner surface is sticky. The first scale is semi-enclosing, the second is very wide, covering almost the entire bulb.
- 3) Two firm leathery scales (Fig. 1: 6) with pubescent beaks.
- 4) Three fleshy scales, different in width, almost equal in length. The first scale (up to 12.5 mm long) is the longest and has a narrow hyaline edge (Fig. 1: 8), on which pediculate buds (Fig. 1: 7) are formed.

Commonly, seed plants are hemiaxillar – their lateral shoots develop only from buds in the axils of leaves (Esau, 1977). However, some species have shoots (vegetative or generative) that appear in a supra-axillary position. Such displacement is referred to as metatopy (Endress, 2010). To date, two types of



Figure 2. Location of the axillary pediculate bud on the first fleshy scale of *Oxalis purpurea*: **A** – side view; **B** – top view.

metatopy are well known: axial displacement (concrecence) and epiphyllous displacement (recaulescence). Epiphyllous displacement (recaulescence) is the development of a lateral bud on its covering leaf (Troll, 1937). Recaulescences usually occur in flowers and inflorescences, for example, in *Bougainvillea glabra* Choisy from Nyctaginaceae (Cooper, 1932), *Phyllonoma integerrima* (Turcz.) Loes. from Phyllonomaceae (Dickinson & Sattler, 1974), and *Helwingia japonica* (Thunb.) F.Dietr. from Helwingiaceae (Dickinson & Sattler, 1975).

In studied *O. purpurea* bulbs, in all three fleshy scales, the axillary bud is located not in the axil of the scale but on the midrib of its adaxial surface, above the proximal end. Hence, an epiphyllous displacement of the lateral bud was observed (Fig. 2 A, B). The displaced pediculate buds were conical in shape, with pointed apices.

There are no known reports of metatopy in Oxalidaceae, and in bulbous plants, it has not been observed at all. Therefore, our report is the first in this regard.

Conclusions

The phenomenon of recaulescence on the fleshy scales of *O. purpurea* bulbs discovered

by us demonstrates the need for further research on the structure of *Oxalis* bulbs, which may have potential taxonomic significance. This phenomenon, previously unreported for Oxalidaceae and bulbous plants, is documented for the first time here.

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***Oxalis purpurea* L. (Oxalidaceae): морфоструктура цибулини, рекаулесценція**

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Досліджено морфоструктуру цибулин *Oxalis purpurea* упродовж вегетаційного періоду з акцентом на оцінку кількісних показників та функціональне призначення лусок. Встановлено, що у досліджуваного виду сталим є число лусок, що складається з двох захисних плівчастих лусок, двох шкірястих і трьох м'ясистих лусок. Перша м'ясиста луска має вузький гіаліновий край. Крім того, вперше описано явище метатопії у представника родини Oxalidaceae та рекаулесценції у цибулинної рослини.

Ключові слова: Oxalidaceae, *Oxalis purpurea*, цибулина, луски, метатопія, рекаулесценція