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The study of the genus *Vaucheria* (Vaucheriaceae, Xanthophyceae) in the South Caucasus: species from Georgia in the TBI Herbarium

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Summary. *Vaucheria*, a widely distributed genus, exhibits unique characteristics among Xanthophyceae, such as its siphonous coenocytic thallus and oogamous reproduction. Limited research has been conducted on *Vaucheria* species in the South Caucasus region, which includes Armenia, Azerbaijan, and Georgia, resulting in a poor understanding of their diversity and distribution. This study focused on the examination of the algal collection at the Georgian National Herbarium in the Institute of Botany, Ilia State University, Tbilisi (TBI). As a result, eight species were identified. Four species, namely *V. pseudaversa*, *V. pseudogeminata*, *V. racemosa*, and *V. taylorii*, were newly established as occurring in Georgia. Additionally, the presence of *V. bursata*, *V. canalicularis*, *V. cruciata*, and *V. frigida*, previously known from literary data, was confirmed. The morphology of these species aligned with existing taxonomic literature. The article also critically examines early records of five additional species, which cannot currently be confirmed by voucher specimens. The new records underscore the importance of further research to comprehensively understand the diversity of *Vaucheria* in this region.

Исследование рода *Vaucheria* (Vaucheriaceae, Xanthophyceae) на Южном Кавказе: виды из Грузии в Гербарии TBI

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Ключевые слова: желто-зеленые водоросли, Кавказ, коллекции водорослей, морфология, новые находки.

Аннотация. *Vaucheria* – широко распространенный род желто-зеленых водорослей (Xanthophyceae), характеризующийся уникальными признаками, такими как сифоновые ценоцитные талломы и половое размножение по типу оогамии. На Южном Кавказе, который включает Армению, Азербайджан и Грузию, по видам *Vaucheria* проводились очень ограниченные исследования, что привело к недостаточному пониманию их видового состава и распространения. В данном исследовании представлены результаты работы с коллекцией водорослей Грузинского национального гербария при Институте ботаники Государственного университета Илии в Тбилиси (TBI). В результате было выявлено восемь видов, из которых четыре вида впервые обнаружены в Грузии: *V. pseudaversa*, *V. pseudogeminata*, *V. racemosa* и *V. taylorii*. Кроме того, было подтверждено присутствие *V. bursata*, *V. canalicularis*, *V. cruciata* и *V. frigida*, ранее известных из литературных источников. Морфология этих видов соответствует описаниям в таксономической литературе. В статье также критически

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рассматриваются ранние находки еще пяти видов, которые в настоящее время не могут быть подтверждены образцами. Новые данные выявляют важность дальнейших исследований для всестороннего понимания разнообразия *Vaucheria* в этом регионе.

Introduction

Vaucheria DC. is a widely distributed genus of Xanthophyceae that can be found in both aquatic and terrestrial environments. The distinguishing characteristics of this genus are its siphonous coenocytic thallus and oogamous reproduction. While the species of *Vaucheria* can be easily observed by the naked eye as felt-like entangled masses in water or dense mats on various substrates, precise identification requires thorough microscopic observations to detect gametangia, whose morphology is species-specific. This poses a problem for research since the production of gametangia does not always coincide with vegetation. Additionally, even when well-developed gametangia are observable, a significant level of morphological variability can impede accurate identification. These factors likely contribute to the poor understanding of these algae in many regions, including the South Caucasus, which is a border region between the continents of Europe and Asia. The South Caucasus stretches between the Caspian and Black seas and includes three countries: Armenia, Azerbaijan, and Georgia.

The study of the genus *Vaucheria* in the South Caucasus started in early XX century with the beginning of expeditions of Russian botanists throughout the region, which then was a part of the Russian Empire. First data on *Vaucheria* richness and distribution were published by Woronichin (1923, 1925), who reported six species and two formae from the territories of modern Georgia and Azerbaijan. Subsequently, the research was not as intensive, and only a few studies emerged that identified new species for the region or provided new distributional records (Jibladze, 1949, 1968; Kukhaleishvili, 1969a, b; Kanchaveli, 1977; Nakhutsrishvili, 1986). Particularly, the species of *Vaucheria* were recently revealed as an important component of aquatic vegetation in large deep lakes and small rivers in Armenia (Pavlov et al., 2010). Meanwhile, our knowledge on the genus *Vaucheria* in the South Caucasus has remained extremely limited, making it impossible to create an adequate impression of its modern diversity and distribution.

This research had been planned as a collection-based with the objective of re-examining all available *Vaucheria* samples from Georgia, where, according to the published data (Nakhutsrishvili, 1986), only nine species and two formae were recorded.

Material and Methods

The search for samples was conducted across four main herbaria, including the Herbarium of the Komarov Botanical Institute, St. Petersburg (LE), the Georgian National Herbarium, Institute of Botany, Ilia State University, Tbilisi (TBI), the Herbarium of the Georgian National Museum, Tbilisi (TGM), and the Herbarium of the Batumi Botanical Garden, Batumi (BATU). Among these herbaria, *Vaucheria* samples from Georgia were found only in TBI. This herbarium holds a substantial collection of algae, with around 2500 catalogued and labelled samples, including some historically significant herbarium sheets. The samples of *Vaucheria* were identified in 61 stored samples preserved in 4 % formaldehyde solution, which were collected from various aquatic, semi-aquatic, and semi-terrestrial habitats between 1955 and 2010. However, only 47.54 % of the collected samples contained fertile specimens, which are the focus of the following discussion.

It should be noted that in the majority of cases, the confinement to certain administrative region was re-established and harmonized with modern administrative subdivision of Georgia.

Samples

Autonomous Republic of Abkhazia

1. "Gagra municipality, Bichvinta [Pitsunda], irrigation channel. 17 VI 1955. K. Kanchaveli" (TBI).

2, 3. "Gulripshi, Sakeni, along the road to sour springs, left side, t 10 °C, pH = 5.5. 17 VII 1961. K. Kanchaveli 506, 506ა" (TBI). **4**. "Gulripshi, Sakeni, along the road. 16 VII 1961. K. Kanchaveli 494" (TBI).

Imereti region

5. "Tsqaltubo municipality, the Khvamli Mountain, Lakhevi village, 1200 m, drinking spring, t 9 °C, pH = 6. 13 VIII 1980. K. Kanchaveli 0516" (TBI).

Kakheti region

6. "Dedoplistskaro municipality, Vashlovani Nature Reserve, Pantishara, spring, on wet soil. 7 IV 1990. K. Kanchaveli 0998" (TBI). **7**. "Kvareli municipality, Lake Chalis Tba, t 29 °C, pH = 6. 3 VIII 1974. K. Kanchaveli 0239" (TBI). **8, 9**. "Lagodekhi municipality, Tchiauri, bog, floodplain forest. 1 VIII 1974. K. Kanchaveli 0228, 0229" (TBI). **10-12**. "Telavi municipality, the Alazani River valley, floodplain forest, 25 VII 1958, K. Kanchaveli 106', 107', 108' " (TBI).

Kvemo Kartli region

13. "Tetritsqaro municipality, Alekseevka, the Aslanka River, right bank, in riverbed, t 13 °C. 28 VII 1966. K. Kanchaveli 855" (TBI). **14**. "Tetritsqaro, Algeti Reserve [currently National Park], Namtoriana, swampy area, mixed spruce forest, in puddle. 12 VII 2008. L. Kukhaleishvili ß57" (TBI).

Mtskheta-Mtianeti region

15. "Akhalgori municipality, Largvisi, 1550 m, the Tskhradzmula River, left bank, in spring, on sand, t 13 °C, pH = 5.5. 19 VIII 1983. K. Kanchaveli 0718" (TBI). **16, 17**. "Dusheti municipality, Chargali, the Charglura River, right bank, spring, t 13 °C, pH = 8. 23 VII 1972. K. Kanchaveli 0164, 0166" (TBI). **18**. "Dusheti, Mutoschila, psha, right bank of the river, pH = 7, t 15 °C. 14 VII 1981. K. Kanchaveli 0581" (TBI). **19**. "Dusheti, Nedikhi, the Aragvi River, right bank, psha, t 16 °C, pH = 7. 15 VII 1972. K. Kanchaveli 0149" (TBI). **20**. "Dusheti, Pshav-Khevsureti, Gulischala, from Barisakho to Rovka, the Orkhevi River, on wet rock. 15 VIII 1958. K. Kanchaveli 122' " (TBI). **21**. "Dusheti, Pshavi, Khoshary, spring on the slope near Tamargele, left bank of the Aragvi River, t 6 °C. 23 VIII 1958. K. Kanchaveli 145' " (TBI). **22, 23**. "Kazbegi municipality, Gergeti, near brook, t 20 °C, pH = 7.5. 21 VII 1971. K. Kanchaveli 0136, 0138" (TBI).

Racha-Lechkhumi and Kvemo Svaneti region

24. "Ambrolauri municipality, the Cholaga River, on stones. 8 VII 1982. K. Kanchaveli" (TBI). **25**. "Lentekhi municipality, Labrakhi Mountain, 2100 m, spring near road, t 12 °C, pH = 5. 12 VIII 1980. K. Kanchaveli 0533" (TBI). **26**. "Lentekhi, Lashkheti, Sasashi, drinking spring near Bebetsi, on rock. 21 VII 1963. K. Kanchaveli 625" (TBI). **27**. "Oni municipality, channel along the road to Oni, 26 VII 1959, K. Kanchaveli 326" (TBI). **28**. "Tsageri municipality, Lailashi, the Okronishi cold spring, on concrete wall, t 11 °C, pH = 7. 6 VIII 1980. K. Kanchaveli 0508" (TBI).

Shida Kartli region

29. "Java municipality, Edisi, the Kalasandori River, right bank, mineral spring, on wall near spring, on travertines, t 8 °C, pH = 6. 21 VII 1972. K. Kanchaveli 0172" (TBI).

Furthermore, in this study, we examined available published and library materials, such as catalogs, card indexes, and line drawings, to gather additional information on specimens or records. It should be noted that the synopsis of the Georgian algal flora (Nakhutsrishvili, 1986) is cited below in cases where it refers to unpublished data, including scientific reports and dissertation manuscripts.

For identification, the algal specimens were first cleaned of mud and storage medium using tap water in Petri dishes. The filaments were then carefully untangled using dissecting needles and examined under microscopes. To preserve the specimens for further study, a fresh portion of 4 % formaldehyde solution was added to each sample after identification.

Results and discussion

In total, eight species were identified, including four that are new to Georgia. The morphology of these species was found to be consistent with data in available taxonomic literature.

Species new to Georgia

V. pseudaversa Vishnyakov

Samples: 25 (Fig. 1a, b). Gametangia born on filaments; oogonia are bilaterally symmetrical, globose in lateral view and appressed to the filament; antheridia are tubular, creeping; oospore leaves peripheral oogonial cavity. The most distinctive characteristic of this species, the reflexed oogonial apex towards the filament, was clearly visible in the studied material.

V. pseudaversa has a semi-cosmopolitan distribution and can be found in a variety of aquatic and terrestrial environments. The nearest known locality is in the Voronezh Region of Russia, on the East European Plain (Vishnyakov, 2021b). This is the first record of this species in the Caucasus and West Asia. Other nearby localities in Asia include West Siberia (where it is known as *V. aversa* Hassall, Sviridenko et al., 2015) and the Himalayas (as *V. aversa*, Santra, Adhya, 1976).

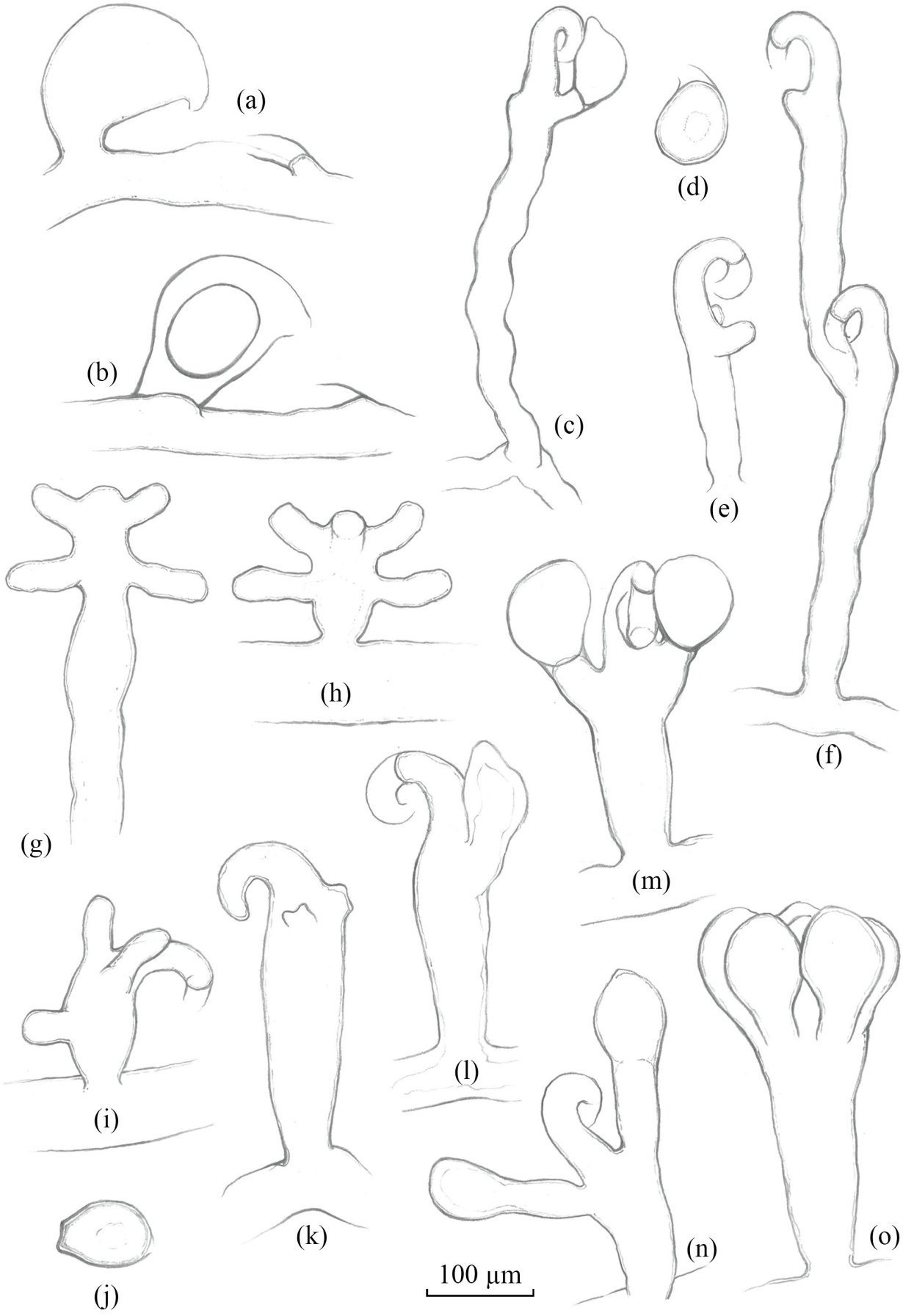

Fig. 1. Morphology of *Vaucheria* species from the TBI Herbarium: a, b – *V. pseudaversa*; c–f – *V. pseudogeminata*; g–j – *V. racemosa*; k–o – *V. taylorii*.

V. pseudogeminata Dangeard

Samples: 19 (Fig. 1c–f). Gametangia born on fruiting branches, both lateral and terminal. Fruiting branch consists of 1 circinate-cylindrical antheridium born on erect stalk and 2, rarely 1, erect oogonia. Each oogonium bears conical distal cavity, which is left by the oospore (Fig. 1d). Filaments are commonly undulate in the studied material. The similar undulate pattern had also been observed in some populations from Central and Eastern Europe (Rieth, 1980; Vishnyakov, 2015).

Vaucheria pseudogeminata has semi-cosmopolitan distribution and occurs in a variety of terrestrial and semi-terrestrial habitats, such as riverbanks. The closest records are in the Republic of Adygea in North Caucasus and the Krasnodar Territory on the Black Sea coast (Vishnyakov, 2021a). However, this species appears to be rare in West Asia and is currently only known to occur in the Caucasus.

It is worth noting that a similar species, *V. erythrospora* T. A. Christ., was reported from Iraq (Islam, 1984). Although Islam was willing to consider *V. erythrospora* and *V. pseudogeminata* as conspecific, it is supported here that these names belong to separate species. *Vaucheria erythrospora* differs from *V. pseudogeminata* in having pendent oogonia, which are usually found singly, and in habitat preferences, being abundant in various saline conditions (Christensen, 1956; Entwisle, 1988).

V. racemosa (Vaucher) DC.

Samples: 1, 8, 9 (Fig. 1g–j). Gametangia born on fruiting branches, both lateral and terminal. Fruiting branch consists of 1 circinate-cylindrical antheridium born on downcurved circinate stalk and 3–5 oogonia on relatively long stalks aroused one below the other on opposite sides of the branch. In the examined material, oogonia containing oospores were commonly observed to have fallen from the stalks (Fig. 1j); however, the specific habit of the species was still recognizable.

Vaucheria racemosa is a semi-cosmopolitan species found in both aquatic and semi-aquatic habitats, with a greater abundance in the northern hemisphere. The closest record is in the Republic of Adygea, North Caucasus (Vishnyakov, 2021a). The species seems to be rare in West Asia, being currently known from the Caucasus region.

It should be noted that the name *V. uncinata* Kütz. has been frequently misapplied to *V. racemosa*, particularly in older taxonomic literature (Blum, 1953; Christensen, 1969). Zauer (1977) formally transferred all records of *V. uncinata* from the former Soviet Union, including those from the Caucasus region, to *V. walzii* Rothert, which is now considered a later synonym of *V. racemosa* (Christensen, 1969). By that time, *V. uncinata* had been reported three times from two localities in Georgia (see below). However, none of these records can be unambiguously attributed to *V. racemosa* as described by Blum and Christensen.

A somewhat similar species, *V. verticillata* Meneghini, was reported from Iraq (Islam, 1984). The Iraqi material shares certain characteristics with both *V. racemosa* and *V. taylorii* Blum, suggesting an unusual growth form of *V. racemosa* with inflated fruiting branches and irregularly arranged oogonial stalks. Further studies are necessary to clarify the taxonomic status of *V. verticillata* from the region.

V. taylorii Blum

Samples: 2, 3, 10, 14, 24, 25 (Fig. 1k–o). Gametangia born on fruiting branches, both lateral and terminal. Fruiting branch consists of 1 circinate-cylindrical antheridium born on a relatively long erect stalk and (1)2–3(5) erect oogonia on short stalks that form a whorl.

As the material from the North Caucasus (Vishnyakov et al., 2020: plate IV: 4), the studied specimens of *V. taylorii* display weakly inflated fruiting branches and a lower number of oogonia compared to typical populations (cf. Blum, 1972). This morphology can be misleading and resemble that of *V. geminata* (Vaucher) DC., a species known for usually having two oogonia per fruiting branch (Schneider et al., 1999; Vishnyakov et al., 2020). This similarity may partially explain the relatively high number of records of *V. geminata* in Georgia (Nakhutsrishvili, 1986), as no material definitively representing *V. geminata* was found in TBI (see details below). *Vaucheria taylorii* has a semi-cosmopolitan distribution in aquatic, semi-aquatic, and semi-terrestrial habitats. The nearest documented occurrence of the species is in the Kabardino-Balkarian Republic, the North Caucasus (Vishnyakov et al., 2020). In West Asia, the species has only been found in the Caucasus region.

Confirmed species

V. bursata (O.F. Müller) C. Agardh

Samples: 4, 7, 10, 12, 20, 21, 28 (Fig. 2a–d). Gametangia born on filaments in groups of 1 or 2 oogonia and 1 antheridium. Oogonia are sessile, mostly bilaterally symmetrical; antheridia are stalked, circinate-cylindrical.

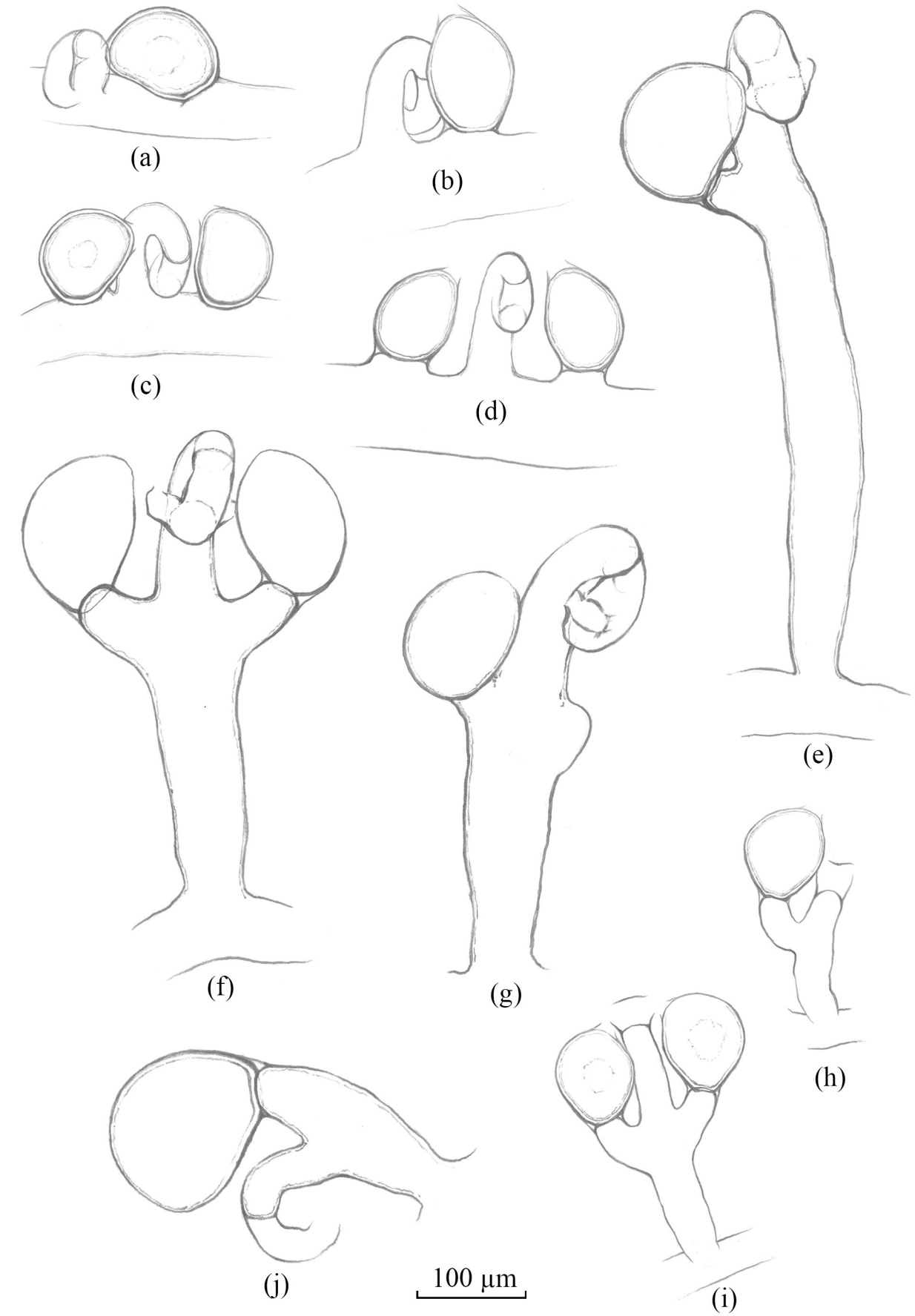

Fig. 2. Morphology of *Vaucheria* species from the TBI Herbarium: a–d – *V. bursata*; e–g – *V. canalicularis*; h, i – *V. cruciata*; j – *V. frigida*.

In this study, a broad species concept was employed, where various growth forms are not considered important at the intraspecific level (Christensen, 1973; Entwisle, 1987). Generally, two forms were observed in the examined material: one corresponds well to the "typical" form with oogonia having the pore directed upwards along the filament (Fig. 2b, d), while the other corresponds to the "repens" form, with oogonia having the pore typically directed parallel to the filament (Fig. 2a, c). However, none of the examined specimens could be identified as *V. orthocarpa* Reinsch, a similar species that has larger, nearly radially symmetrical oogonia (see: Vishnyakov, 2015).

Vaucheria bursata has a cosmopolitan distribution in various freshwater and terrestrial habitats. In Georgia, the species has been previously recorded from the Pshariskhevi River in the Aragvi River basin, Mtskheta-Mtianeti region (as *V. sessilis* (Vaucher) DC.; Nakhutsrishvili, 1986); the Tsavkisistskali River ravine in Tbilisi (as *V. sessilis* f. *genuina* Hansg. and f. *repens* (Hassall) Hansg.; Woronichin, 1925, 1927); Kazreti in Bolnisi municipality, Kvemo Kartli region (as *V. sessilis* f. *genuina*; Jibladze, 1968), Gagra municipality in Abkhazia (as *V. sessilis* f. *sessilis*; Nakhutsrishvili, 1986), and Chigo in Akhmeta municipality, Kakheti region (as *V. sessilis* f. *repens*; Jibladze, 1965). This study reports new species records for the Racha-Lechkhumi and Kvemo Svaneti region. The closest known records to Georgia are from the North Caucasus, including Krasnodar Territory, Republic of Adygea, Kabardino-Balkarian Republic, and Republic of North Ossetia-Alania (Vishnyakov et al., 2020; Vishnyakov, 2021a). In West Asia, the species has also been reported from Iraq (Islam, 1984), Turkey (Aysel, 2005), and Israel (Nevo, Wasser, 2000).

V. canalicularis (L.) T. A. Christ.

Samples: 5, 6, 10–13, 15–19, 22, 23, 26, 27, 29 (Fig. 2e–g). Gametangia born on fruiting branches, both lateral and terminal. Fruiting branch consists of 1 or 2 erect oogonia and 1 deltoid antheridium at the apex of circinate stalk; antheridium with 2 lateral pores.

Vaucheria canalicularis is a widely distributed species found in freshwater and saline waterbodies, as well as terrestrial habitats worldwide. In Georgia, it was previously known only from the Tsavkisistskali River in Tbilisi, where it was reported under the name *V. woroniniana* Heer. (Woronichin, 1925). However, during the present study, the species was identified in samples collected from various regions throughout the country, including Imereti, Kakheti, Kvemo Kartli, Mtskheta-Mtianeti, Racha-Lechkhumi and Kvemo Svaneti, and Shida Kartli. The nearest localities to Georgia are in the North Caucasus regions, including Krasnodar Territory, Republic of Adygea, Kabardino-Balkarian Republic, and Republic of North Ossetia–Alania (Vishnyakov et al., 2020; Vishnyakov, 2021a). In West Asia, the species has also been recorded in Turkey (Aysel, 2005), Iraq (Islam, 1984), and Israel (Nevo, Wasser, 2000).

Vaucheria canalicularis and *V. geminata* share a remarkable similarity in the arrangement of their fruiting branches, although these two species exhibit significant differences in terms of antheridial morphology. Particularly, the antheridium of *V. canalicularis* is typically deltoid and bears one to two pores on lateral papillae. However, this characteristic feature is often obscured by adjacent oogonia, and the papillae are not always clearly visible, leading to potential confusion between these two species. The presence of such confusion in Georgia was confirmed by two lines of evidence: the absence of typical *V. geminata* specimens in TBI, and the analysis of archived materials, including line drawings from lost samples collected in the Aragvi River valley by Kukhaleishvili in the 1960s. None of the drawings labeled as *V. geminata* exhibit the typical morphology of this species, such as short and delicate fruiting branches, circinate-cylindrical antheridium, and oogonia consistently less than 100 μm in length (cf. Christensen, 1969: fig. 6), but rather resemble *V. canalicularis*. Furthermore, one of the drawings illustrates the deltoid antheridium that is typical of *V. canalicularis* (right bank of the Charglura River, near the confluence with Pshavi Aragvi, in oxbow, coll. 9 V 1966). The study of these archival records thus indicates an even wider distribution of the species within Georgia.

V. cruciata (Vaucher) DC.

Samples: 6 (Fig. 2h, i). Gametangia born on fruiting branches, both lateral and terminal. Fruiting branch consists of 1 or 2 erect oogonia and 1 saccate antheridium arising on erect stalk; antheridium has (1)2(3) lateral pores.

Vaucheria cruciata is distributed across diverse aquatic and terrestrial habitats worldwide. In Georgia, the species was previously documented in the Aragvi River basin, Mtskheta-Mtianeti region (as *V. debaryana* Woronin; Kukhaleishvili, 1969b; Nakhutsrishvili, 1986). Despite the lack of extant material from the Aragvi basin, Kukhaleishvili's identification accuracy is supported by meticulously drawn

illustrations with accompanying measurements (left bank of the Pshavi Aragvi, vicinities of Ortskhali, in puddle, coll. 7 V 1966; vicinities of Chokhi, under the waterfall, coll. 25 V 1966), which are presently archived at TBI. This study also presents a novel occurrence of the species in the Kakheti region. The nearest locality to Georgia is in the Republic of Adygea, North Caucasus (Vishnyakov, 2021a). In West Asia, the species has been also observed in Turkey (Aysel, 2005).

V. frigida (Roth) C. Agardh

Samples: 2, 3 (Fig. 2j). Gametangia born on fruiting branches. Fruiting branch consists of 1 pendent oogonium and 1 circinate-cylindrical antheridium.

Vaucheria frigida has a cosmopolitan distribution in aquatic and terrestrial habitats. In Georgia, it was previously reported as *V. terrestris* Lyngb. from the Qeli Highland in the Mtskheta-Mtianeti region (Nakhutsrishvili, 1986) and Kochlu, Bolnisi municipality of the Kvemo Kartli region (Jibladze, 1968). This study also presents a novel occurrence of the species in Abkhazia. The nearest recorded locality is in the Republic of Adygea, North Caucasus (Vishnyakov, 2021a). In West Asia, the species is also known to exist in Turkey (Aysel, 2005).

Species need to be confirmed

There are five species in Georgia whose presence in the country cannot currently be confirmed by voucher specimens. Thorough future studies will be necessary to determine their actual presence in the country.

V. borealis Hirn

Vaucheria borealis predominantly occurs in high-latitude and mountainous regions of Europe and North America, although some of its records have been considered doubtful (Rieth, 1962; Blum, 1972; Entwisle, 1987). The species appears to be rare, and in West Asia, it has only been reported in Georgia, particularly in Bakuriani, Borjomi municipality, Samtskhe-Javakheti region (as *V. borealis* var. *minor* Woron.; Woronichin, 1923) and in the sources of tributaries of the Aragvi River, Mtskheta-Mtianeti region (Nakhutsrishvili, 1986). Although the type material of *V. borealis* var. *minor* has never been re-examined and is lost from TBI, this variety is considered currently under a broad species concept of *V. borealis* (Rieth, 1980). Unfortunately, no materials of *V. borealis* from the Aragvi basin were found in TBI, but only *V. bursata*, a somewhat similar species (in samples No. 20, 21). New species records can be expected from mountainous regions of the country.

V. dillwynii (Weber et Mohr) C. Agardh

In West Asia, the species was reported only from Georgia as *V. pachyderma* Walz: right bank of the Khrami River [as Ktsia], Bolnisi municipality, Kvemo Kartli region (Jibladze, 1968). Jibladze provided the oospore dimensions (88 × 72 μm), which are significantly smaller than those in many of typical populations (Rieth, 1980; Entwisle, 1988), which makes the record doubtful. It is probably that it belongs to *V. bursata*, which has generally smaller oogonia. *Vaucheria dillwynii* has nearly cosmopolitan, although disjunct (Entwisle, 1988), distribution with the closest records in Russia's Black Sea coast, Krasnodar Territory (Kotkova et al., 2024); because of this, the emergence of the species in Georgia is very likely.

V. geminata (Vaucher) DC.

Nearly cosmopolitan species (Rieth, 1980; Entwisle, 1988), which was frequently reported from Georgia, particularly from the Kvemo Kartli, Mtskheta-Mtianeti, Racha-Lechkhumi and Kvemo Svaneti regions, and Tbilisi (Woronichin, 1925, 1927; Jibladze, 1968; Kukhaleishvili, 1969a, b; Nakhutsrishvili, 1986). However, none of *V. geminata* specimens were found in TBI. When archived material was studied, many drawings of a *V. canalicularis*-like alga were found, which had been annotated as *V. geminata*. Both species had frequently been confused (see notes in: Vishnyakov et al., 2020). However, since the antheridial morphology cannot be clearly checked, it is impossible to interpret these with certainty. Meanwhile, the study of archived material partly explains the high number of records of *V. geminata* in old literature. Given the widespread distribution of the species (Entwisle, 1988), it seems plausible that it occurs in Georgia.

V. synandra Woronin

Marine species with a disjunct Atlantic distribution (Christensen, 1987). In Georgia, it was reported from a single locality in the Greater Caucasus: Pansheti, Kazbegi municipality, Mtskheta-Mtianeti region, in a ditch, coll. 21 VII 1971 (Kanchaveli, 1977). The more recent record for the Kazbegi protected area (Barinova et al., 2011) is apparently based on the Kanchaveli's publication. However, here are several pieces of evidence to suggest that the record is doubtful. In TBI, only two samples collected at the

same date near Pansheti were found (No. 22, 23, see above), and both actually contain *V. canalicularis*. Moreover, the subalpine conditions of the Kazbegi area are in sharp contrast with the ecological preferences of the species, which inhabits brackish water coastal areas. Although it can rarely occur in saline inland areas (Rieth, 1980), none of the known localities belong to mountainous regions. In West Asia, the reliable records of *V. synandra* are only known from southern Iraq (Islam, 1984). New species records can be expected from Georgia's Black Sea coast, even though the nearest known localities are on the western coast of the Mediterranean Sea (Vaquer, 1976).

V. uncinata Kütz.

The species is also known as *V. arrhyncha* Heidinger or *Vaucheriopsis uncinata* (Kütz.) Zauer and has a nearly cosmopolitan distribution in aquatic and terrestrial habitats (Rieth, 1980; Entwisle, 1988). In Georgia, it has been reported from two localities: Lake Lisi, Tbilisi (Woronichin, 1925; Jibladze, 1949), and the Mashavera River, Paladauri, Bolnisi municipality, Kvemo Kartli region (Jibladze, 1968). An analysis of brief morphological descriptions suggests that these belong to species with quite different habits. *Vaucheria uncinata* has 1 antheridium and 1 or 2 broadly ellipsoid oogonia without a distinctive fertilization pore on pendent stalks; the oogonia are 100–198 μm in diameter (Rieth, 1980). The description provided by Woronichin (1925) covers the morphology of specimens having 2–5 broadly ovate, mostly pendent oogonia with fertilization pores (described as "stomae"), 56–89 × 49–82.5 μm. Jibladze (1949) reported an alga having similar oogonia from the same locality (broadly ovate, 56–86 × 47–80 μm). These may, in fact, represent a species from the section *Racemosae*, *V. racemosa* or *V. verticillata* sensu Christensen (1987), non Rieth (1980). According to Jibladze (1968), the specimen from the Mashavera River has oospores of 229 × 176 μm, which, however, is extraordinary for *V. uncinata*. It is possible that, in this case, the issue was resolved through the use of asexual reproduction organs, such as aplanospores, or zoospores that had lost their mobility, of another *Vaucheria* species. Meanwhile, given the wide general distribution, it is plausible that *V. uncinata* occurs in Georgia.

Conclusions

The presented results supplemented the number of known *Vaucheria* species in Georgia by the records of 4 new species, *V. pseudaversa*, *V. pseudogeminata*, *V. racemosa*, and *V. taylorii*, and highlighted the need of extensive sampling efforts for further revision of the genus. Currently, 13 species are known for Georgia, of which only 8 are confirmed by the voucher specimens. Even though some species were not confirmed in the Georgian flora, the species richness is probably higher and may well include at least 4 additional species, which are known from adjacent regions of the Caucasus. *Vaucheria alaskana* Blum and *V. lii* Rieth were reported from the Republic of North Ossetia–Alania (Vishnyakov et al., 2020), *V. rostellata* Kütz. – from Russia's Black Sea coast, Krasnodar Territory (Vishnyakov, 2021b), and *V. dichotoma* (L.) Martius – from Azerbaijan (Woronichin, 1925) and Armenia (Pavlov et al., 2010). Georgia is the only country in the South Caucasus with access to the Black Sea, a marginal sea of the Atlantic Ocean. Although the sea is non-tidal and therefore has a low diversity of *Vaucheria*, certain species of the sections *Woroninia* and *Piloboloideae*, which are found in other parts of the sea (Kalugina-Gutnik, 1975; Tkachenko, Sardarian, 2018), can still be discovered in the coastal waters of Georgia. The study also revealed that the country's territory is unevenly studied, with no *Vaucheria* records available for three western regions: Autonomous Republic of Adjara, Guria, and Samegrelo–Zemo Svaneti. The analyzed samples were primarily sourced from underground water outputs (known as "psha" in Georgian) and riverbanks. However, true terrestrial habitats have yet to be sufficiently sampled in Georgia. These habitats could be suitable for some species that do not occur in aquatic habitats, such as *V. incurva* T. A. Christ. This particular species is known from a locality close to Georgia, the city of Sochi (Vishnyakov, 2023).

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