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REVIEW ARTICLE

## Microalgae Culture Collection of the M.G. Kholodny Institute of Botany (IBASU-A): a 65-year history

Olena V. BORYSOVA <sup>1</sup> , Olga V. BUROVA <sup>1\*</sup> , Tatiana I. MIKHAILYUK <sup>1</sup> ,  
Mariana O. KONISHCHUK <sup>1</sup> , Thomas FRIEDL <sup>2</sup> 

<sup>1</sup> M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine,

2 Tereshchenkivska Str., Kyiv 01601, Ukraine

<sup>2</sup> Experimental Phycology and Culture Collection of Algae (SAG),

Albrecht-von-Haller-Institute for Plant Sciences, Georg August University Göttingen

18 Nikolausberger Weg, Göttingen 37073, Germany

\* Author for correspondence: [olga\\_burova@yahoo.com](mailto:olga_burova@yahoo.com)

**Abstract.** This article presents the Microalgae Culture Collection of the M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine (IBASU-A), which was established by Professor Nadiya P. Massjuk in 1960. Currently, it is the largest algal collection in Ukraine and has been designated as an Ukrainian National Heritage unit since 2013. The structure, history, and development of the collection are described. It maintains 500 strains representing 186 prokaryotic and eukaryotic species from 100 genera and 10 classes, including *Cyanobacteria* (32 species), *Chlorophyta* (125), *Charophyta* (23), *Euglenophyta* (2), and *Heterokontophyta* (6). The IBASU-A holdings include halophilic, freshwater, and terrestrial algae, as well as biotechnologically significant strains, rare taxa, authentic strains (ex-type cultures, etc.), and a unique collection of bacterial associates of algae. The primary mission of IBASU-A is the isolation, preservation, management, and supply of algal strains for academic research and biotechnology. Several strains of taxa belonging to the families *Chlorellaceae*, *Scenedesmaceae*, and *Selenastraceae* have been successfully employed in various applied projects, serving as test objects for assessing the toxicity and carcinogenicity of organic substances, as well as biological agents for industrial waste treatment and high-yield biomass producers for biofuel production. A feature of the IBASU-A collection is that, along with algae cultures, strains of bacteria accompanying microalgae in nature (bacterial consortia) are deposited there: 270 strains isolated from 45 xenic cultures of green algae.

**Keywords:** authentic strains, bacterial consortia, biodiversity, biotechnology, collection, cultures, cyanobacteria, ex-type cultures, IBASU-A, microalgae, National Heritage, rare species

The Microalgae Culture Collection of Ukraine (acronym IBASU-A) marked its 65<sup>th</sup> year of continuous operation in 2025. It was established by

Professor Nadiya P. Massjuk, initially for the use of algal cultures of halophilic flagellate algae in basic and applied studies according to scientific priorities

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of the Department of Phycology at the M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine. The first strains of *Dunaliella salina* (Dunal) Teodor. were isolated in 1960 from Crimean salt waterbodies with a focus on their biological potential as producers of  $\beta$ -carotene, bioactive compounds, microalgae mass cultures, and animal and aquaculture feeds. Then, the diversity of species of *Dunaliella* Teodor. in this collection started to increase in size. Most of the halophilic flagellates were collected by Nadiya P. Massjuk from various habitats, including salt lakes, lagoons, pools, and saline soils in Ukraine as well as Azerbaijan, Kyrgyzstan, Turkmenistan, and Uzbekistan. Some samples, which were sent by colleagues from Western Siberia and Israel, enriched the diversity and scientific value of the collection (Yunger, Tere-shchuk, 1990).

During the 1960s and 1970s, the IBASU-A collection was extensively explored in research on the morphology, systematics, ecology, and biogeography of *Dunaliella* species. Such work contributed to a deeper understanding of the genus, including the description of new species and insights into their adaptation to various saline environments. Nadiya P. Massjuk is acknowledged as the author of 12 species within the genus *Dunaliella*. These include: *Dunaliella asymmetrica* Masjuk, *D. carpatica* Masjuk (a Carpathian endemic discovered in Romania and Ukraine), *D. granulata* Masjuk, *D. maritima* Masjuk (a marine species), *D. minutissima* Masjuk, *D. pseudosalina* Masjuk & M.I. Radcz., *D. terricola* Masjuk, *D. turcomanica* Masjuk (Asian endemic from Turkmenistan), *D. baas-beckingii* Masjuk, *D. gracilis* Masjuk, *D. jacobae* Masjuk, and *D. ruineniana* Masjuk (Australian endemic). Most of these species were described based on strains and specimens collected from various regions around the world, including Europe, Asia, and Australia. These taxa make up a significant portion of the 27 recognized *Dunaliella* species globally. In addition to these new species, two taxa were reclassified by Nadiya P. Massjuk as new combinations due to their transfer from other genera: *Dunaliella acidophila* (Kalina) Masjuk (previously *Spermatozopsis acidophila* Kalina), a European endemic from the Czech Republic, and *D. obliqua* (Pascher) Masjuk (formerly *Apiochloris obliqua* Pascher), with the respective strain also originating from the Czech Republic (Borowitzka, Siva, 2007; Guiry, Guiry, 2026).

Beyond their importance in fundamental scientific research, the *Dunaliella* strains were extensively investigated for their potential biotechnological applications, focusing on their ability to synthesize valuable compounds, including enzymes, proteins, and vitamins, especially  $\beta$ -carotene, a pigment of significant economic and nutritional importance. The pioneering studies conducted during this period laid the foundation for future applied research and commercial applications of the genus *Dunaliella*. In addition to their significant scientific and biotechnological value, selected strains from the genera *Dunaliella* and *Pedinomonas* Korshikov were patented (Massjuk et al., 1984; Mikhailyuk et al., 2010). These patents underscored the importance of the collection's strains not only for scientific research but also for their potential in various industrial and commercial applications, including biotechnology uses.

Throughout the 1980s, the IBASU-A collection at the M.G. Kholodny Institute of Botany, NAS of Ukraine, played a pivotal role in advancing applied scientific research using its halophilic flagellate cultures. These cultures were highly valued for their pronounced sensitivity to environmental changes, making them effective bioindicators. As bioindicators, they provided reliable data for assessing environmental conditions across various experimental procedures. Due to their unique biological characteristics, these strains proved excellent models for investigating the intricacies of algal photomovement (Massjuk et al., 2007).

In addition to their use in environmental studies, ten *Dunaliella* strains were selected for mass cultivation in space biology projects. These strains were specifically chosen for a series of space experiments, in which their distinctive biological characteristics made them exceptional models for studying the complexities of algal photomovement. Their responses to light and other environmental factors provided valuable insights into biological processes under the unique conditions encountered in space (Massjuk et al., 2007).

Moreover, some IBASU-A strains of the *Dunaliella* species were also used in ecological studies examining interactions between halophilic algae and their associated bacterial communities. These investigations explored the complex relationships within these specialized microbial consortia, shedding light on how halophilic algae interact with bacteria in their natural environments. The research

contributed valuable knowledge about the dynamics and ecological significance of these associations, enhancing the understanding of microbial consortia in saline habitats (Borisova, Tsarenko, 2004).

By 1995, the IBASU-A collection initially contained mainly representatives of halophilic algae from the family *Dunaliellaceae* (135 cultures), collected in Ukraine and some other countries, and significantly fewer species of freshwater algae from the families *Chlorellaceae* and *Scenedesmaceae* (20 cultures), obtained some algal strains from the Culture Collection of Algae and Protozoa (CCAP, UK), Culture Collection of Autotrophic Organisms (CCALA, Czech Republic), and the Culture Collection of Algae at the University of Texas at Austin (UTEX, USA). These cultures were used for bioassay testing and some experiments as model organisms in toxicological studies (Lenova, Stupina, 1990; Lenova et al., 1991). However, this composition was no longer sufficient for the Department's subsequent research objectives, which focused on the study of algal biodiversity in Ukraine. Consequently, the halophilic algal collection was downsized by removing duplicate strains and shifting the focus toward new isolates obtained by individual researchers from various water bodies across Ukraine, which were subsequently deposited into the IBASU-A collection. As a result, the collection was established in its present state.

The first catalog of the IBASU-A algae collection was published in 1990 and contained information on 138 strains of *Dunaliella*, *Asteromonas* Artari, and *Platymonas* G.S. West (= *Tetraselmis* F. Stein) (Yunger, Tereshchuk, 1990). Updated catalogs were published in 2014 and 2020 (Borysova et al., 2014, 2020), and since 2024 detailed information about the IBASU-A strains has been available on the website (<https://ibasua.kiev.ua/>). A series of articles analyzing the collection has also been published (Junger, Tereshchuk, 1990; Borisova, Tsarenko, 2003, 2004; Borysova et al., 2016; Tsarenko et al., 2020).

This article presents updated information on the structure, composition, and potential of the IBASU-A collection, which maintains strains of cyanobacteria and microalgae (i.e., organisms nomenclaturally treated as algae: see Preamble 8 and Art. 44 of the *International Code of Nomenclature for algae, fungi, and plants (ICN, Madrid Code: Turland et al., 2025)*, as well as bacterial consorts of algae.

The IBASU-A collection is continually updated with new algal strains from various regions of

Ukraine and other countries. Enrichment cultures are established from environmental samples. New strains are isolated by micropipetting individual cells under a microscope or by serial streaking onto agar-containing Petri dishes, followed by isolation of individual colonies (Algae..., 1989; Kostikov et al., 2001; Andersen, Kawachi, 2005).

The collection is maintained on both liquid and agar nutrient media, with cultures stored in test tubes, flasks, and Petri dishes. To ensure reliable preservation, each strain is kept in 2–3 replicates. Most cultures are xenic and maintained in illuminated growth chambers at 15–20 °C or in glass-door incubators at 10–15 °C. Only a small portion of the collection is axenic (21 strains), and these cultures are stored on agar media in refrigerators at 4 °C. Cultures are regularly subcultured onto fresh nutrient media (1 to 5 times per year, typically quarterly). Depending on the biological characteristics of the microalgal species, approximately nine nutrient media with different mineral compositions are used, including Artari, Bold Basal, Burrelli, Tamiya, Chu 13, BG-11, etc. (Borysova et al., 2016, 2020). For the cultivation of certain algal species, nutrient media are supplemented with vitamins B<sub>1</sub> and B<sub>12</sub>, glucose, urea, yeast autolysate, or soil extract. Microalgal cultures are regularly monitored, both visually and microscopically, for viability and the absence of contaminants (such as fungi, protists, or other algae). Additionally, subculturing onto organic-rich agar media is used to detect and exclude fungal contamination. In the event of contamination, strains are purified by subculturing onto agar media and subsequently isolating non-contaminated algal colonies.

Strains of bacterial consorts are cultivated on meat-peptone agar with 1.0% starch and are maintained under refrigeration at 4 °C. Subculturing is performed 3–4 times a year. The work in the IBASU-A as well as images of culture collection facilities and algal cultures are presented on Fig. 1.

At present, IBASU-A is the largest algal collection in Ukraine. Since 2013, it has been designated as a Ukrainian National Heritage unit (Resolution..., 2013). Due to its significant size and unique taxonomic composition, the collection is recognized as a world-class biological resource. It is registered in the World Federation for Culture Collection with registration number WDCM1282. In 2024, a website for the collection was launched (<https://ibasua.kiev.ua/>), providing general information, contact



**Fig. 1.** The work in the IBASU-A and images of culture collection facilities and algal cultures. A: transferring algae on fresh media, work with the laminar flow (Dr. O. Borysova); B: investigation of algal strains with molecular phylogenetic methods (Dr. T. Mikhailiuk); C: preparation of nutrient media, work with the steam sterilizer (M. Konishchuk); D: microscopy of algal strains (Dr. O. Burova); E-G: flasks and tubes with algal cultures in the cultivation chamber (E) and on shelves in the culture rooms (F, G)

Table 1. Taxonomic structure of IBASU-A collection

Phylum	Number of			
	Classes	Genera	Species / infraspecific taxa	Strains
<i>Cyanobacteria</i>	1	23	32	50
<i>Euglenophyta</i>	1	1	2	2
<i>Heterokontophyta</i>	2	6	6	7
<i>Chlorophyta</i>	3	63	124/125	403
<i>Charophyta</i>	3	7	22/23	38
<b>Total</b>	<b>10</b>	<b>100</b>	<b>186/188</b>	<b>500</b>

details, and an online catalog of the IBASU-A algal strains.

IBASU-A includes 500 strains of 186 prokaryotic and eukaryotic species, including their varieties, which belong to 100 genera, 10 classes, and represent *Cyanobacteria* (32), *Chlorophyta* (125), *Charophyta* (23), *Euglenophyta* (2), and *Heterokontophyta* (6 species) (Table 1).

The main part of the collection (403 strains) consists of green algae (*Chlorophyta*), the leading taxonomic group in the Ukrainian algal flora (Algae of Ukraine..., 2011; Tsarenko et al., 2024), followed by *Cyanobacteria* (50), *Charophyta* (38), *Heterokontophyta* (7), and *Euglenophyta* (2).

The genera with the greatest number of algal species and strains are *Chlamydomonas* Ehrenb. (eight species and 27 strains), *Chlorella* Beij. (two species, 20 strains), *Coelastrum* Nägeli (four species and 11 strains), *Desmodesmus* (Chodat) An, Friedl & E. Hegewald (17 species, 18 infraspecific taxa and 73 strains), *Dunaliella* (six species and 38 strains), *Oocystis* Nägeli ex A. Braun (four species and 13 strains), *Tetrademus* G.M. Sm. (five species and 34 strains), *Stichococcus* Nägeli (four species and 17 strains), and *Klebsormidium* P.C. Silva, Mattox & W.H. Blackw. (12 species, 13 infraspecific taxa and 25 strains).

The funds of IBASU-A include cultures of halophilic, freshwater, and terrestrial algae; collections of algal strains with valuable biotechnological properties; strains of rare species; authentic strains (ex-type and other nomenclaturally important cultures); and bacterial strains isolated from algal xenic cultures (Borysova et al., 2016, 2020). The basis of the collection are the strains isolated from freshwater and terrestrial habitats across various Ukrainian regions and in some countries of Europe (the Czech Republic, Germany, Slovakia, UK, France, Russian Federation), Asia (Georgia, Israel, Iran), Africa (Egypt, South Africa), and North and South

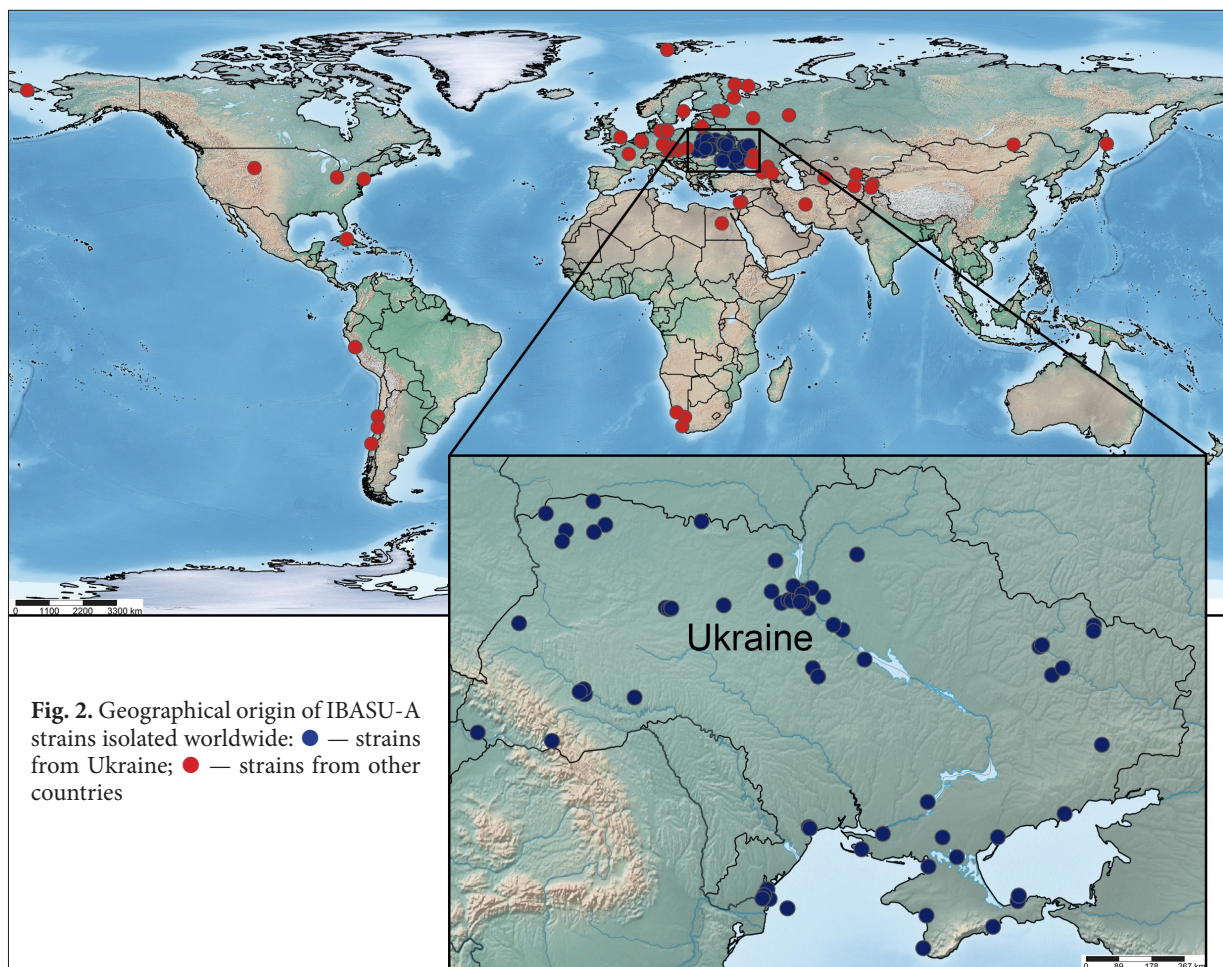
America (the USA, Chile, Peru, Cuba), as well as the island of Svalbard (Fig. 2).

The halophilic algae (40 strains) from the collection of Nadiya P. Massjuk are represented by species of *Asteromonas* and *Dunaliella* (*Chlorophyta*) isolated from halophilic habitats in southern Ukraine, Azerbaijan, Kyrgyzstan, and Turkmenistan.

The collection of freshwater and terrestrial algae (403 strains) constitutes the largest component of IBASU-A. It comprises strains isolated from environmental samples collected by Ukrainian phycologists during investigations of algal diversity in freshwater and terrestrial habitats across Ukraine and several other countries (Borysova et al., 2020). Most strains were gathered in the 1990–2010s during numerous expeditions in physiographic regions of Ukrainian Polissia (Volyn, Zhytomyr, Rivne, Kyiv, Chernihiv regions), Forest-Steppe (Vinnytsia, Lviv, Khmelnytsky, Cherkasy regions), Steppe (Donetsk, Zaporizhzhia, Mykolaiv, Odesa, Kharkiv, Kherson regions), the Ukrainian Carpathians (Transcarpathian, Chernivtsi regions), and the Crimean Peninsula. Moreover, a substantial portion of the cultures was deposited from personal collections, including collection of *Scenedesmaceae* (107 strains) isolated by Petro M. Tsarenko while studying the algal diversity of Shatsk Lakes (Volyn Region) and other regions of Ukraine, Mecklenburg Lake District (Germany), Hula Valley (Israel), and algal growth on technogenic materials in Georgia (Tsarenko et al., 1996, 1997, 2005; Borysova et al., 2020, 2024).

From taxonomic and biodiversity perspectives, the strains from Tatyana M. Darienko's collection (28 strains) are of particular interest. These primarily include *Volvocales* species isolated from soils in the Trakhtemyriv Regional Landscape Park (Kyiv Region) and on Zmiinyi (Snake) Island (Odesa Region, Ukraine).

Significant contributions to the collection's development have been made by Tatiana I.



**Fig. 2.** Geographical origin of IBASU-A strains isolated worldwide: ● — strains from Ukraine; ● — strains from other countries

Mikhailyuk and Eduard M. Demchenko, who isolated 111 strains from terrestrial habitats across various regions of Ukraine. These include protected areas in the Kyiv, Cherkasy, Ivano-Frankivsk, Kharkiv, Kherson, Zhytomyr, and Odesa regions, as well as Crimea (Mikhailyuk et al., 2018b, 2021, 2025), and from Germany, Iran, and some other countries (Mikhailyuk et al., 2019a). The majority of strains were isolated as part of a targeted investigation of algae and cyanobacteria from biological soil crusts. During this investigation, taxonomic revisions of algal and cyanobacterial taxa in the genera *Timaviella* Sciuto & Moro, *Oculatella* Zammit, Billi & Albertano, *Interfilum* Chodat, *Klebsormidium*, and others were conducted. New species and genera (*Carminoleptolyngbya* Mikhailyuk & Vynogradova, *Kondratevia* Mikhailyuk & Vynogradova, *Streptofilum* Mikhailyuk & Lukešová, *Streptosarcina* Mikhailyuk & Lukešová) have been described, and some strains were proposed as epitypes of known

taxa. Additionally, Tatiana I. Mikhailyuk has deposited in IBASU-A a series of strains obtained from other culture collections or individual scientists, e.g., from the culture collections of Rostock University, Germany, and the Institute of Soil Biology at České Budejovice, Czech Republic.

Overall, the freshwater algae collection comprises 48 species, primarily from the families *Scenedesmaceae* (12 genera, 37 species), *Chlorellaceae* (4 genera, 5 species), and *Selenastraceae* (3 genera, 6 species). The use of IBASU-A strains in basic and applied research has clarified the roles of algae and their associated bacteria in the bioremediation of industrial wastewater. Specifically, studies have examined the removal of chemical by-products and mineral fertilizers, as well as the species-specific transformation of carcinogenic nitrosamines and other organic compounds in aquatic ecosystems (Lenova, Stupina, 1990; Lenova et al., 1991; Stupina, Borisova, 2002; Borysova et al., 2020). The potential

of algal-bacterial complexes as model systems in aquatic toxicology experiments was demonstrated (Borisova et al., 2000, 2020). Additionally, IBASU-A strains were screened to identify promising candidates for biodiesel production. Selection was based on key criteria, including rapid biomass growth, stress tolerance, resistance to contamination, and significant lipid accumulation. The data were compared with those of known high-biomass producers. Consequently, a new sub-collection of promising strains for bioenergy production was established. It comprises 33 strains of 18 species from the following genera: *Botryococcus* Kütz. (four), *Chlorella* (nine), *Chloroidium* Nadson (two), *Desmodesmus* (seven), *Monoraphidium* Komárk.-Legn. (three), *Parachlorella* Krienitz & al. (three), *Raphidocelis* Hindák (one), and *Tetrademus* (three) (Borysova, Tsarenko, 2021). Overall, IBASU-A comprises 80 strains with valuable biotechnological properties, including the aforementioned specialized bioenergy collection. These consist of both well-known

industrial cultures and unique Ukrainian isolates (Tsarenko et al., 2012, 2016, 2020) (Table 2, Fig. 3).

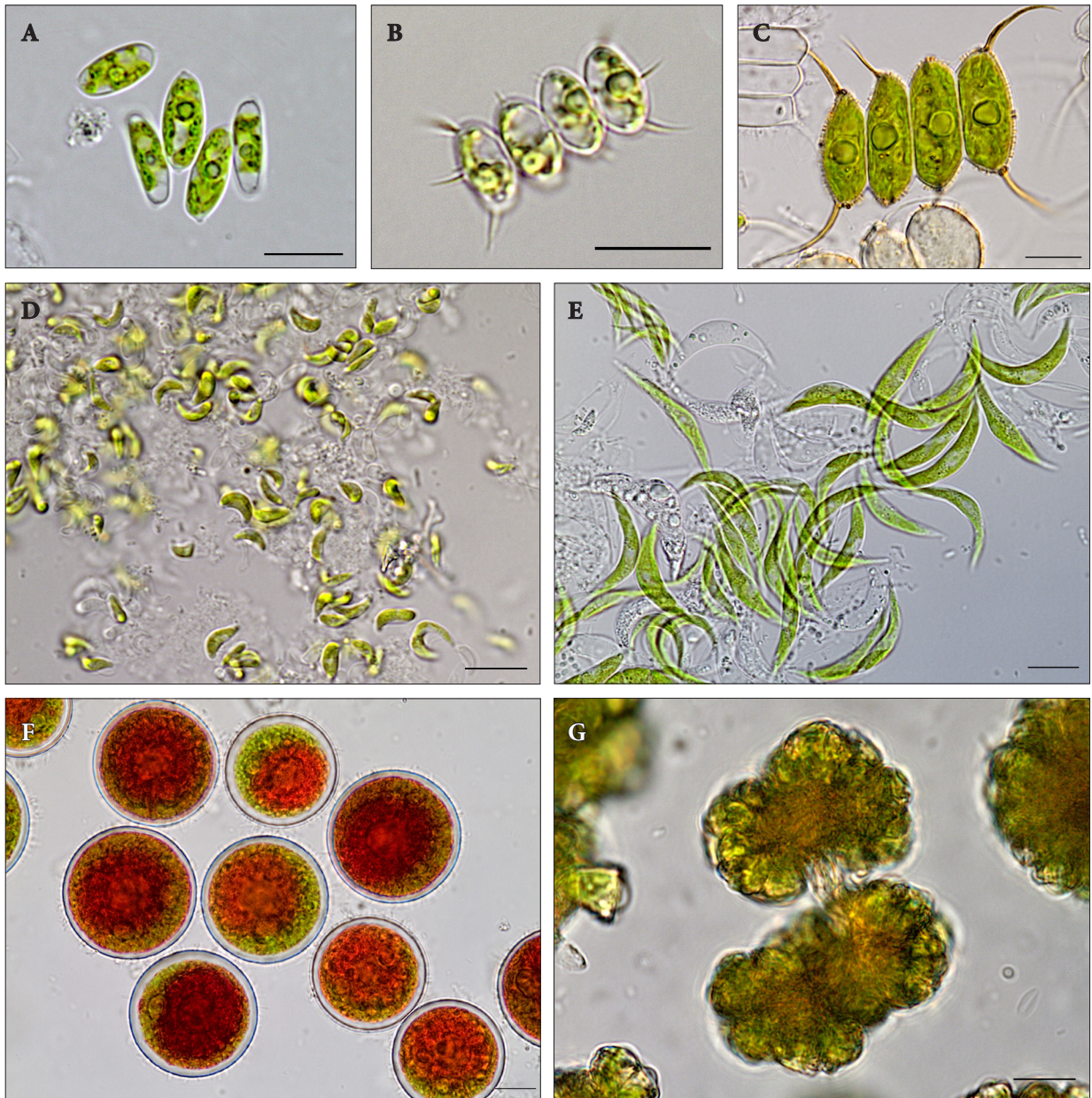
The collection of rare species and authentic strains comprises mostly species and varieties described as new to science by Ukrainian and other authors from Ukraine and some other countries (Table 3, Figs 4, 5). In preserving authentic strains (ex-type and other nomenclaturally significant cultures), we follow the provisions of the *International Code of Nomenclature for algae, fungi, and plants (ICN, Madrid Code: Turland et al., 2025)*, specifically its Recommendation 8B.1 (“Whenever practicable a living culture should be prepared from the holotype material of the name of a newly described taxon of algae or fungi and deposited in at least two institutional culture or genetic resource collections”). Species rare for the algal flora of Ukraine were found in Turske Lake (Volyn Region): *Desmodesmus curvatocornis* (Proshk.-Lavr.) E. Hegewald, *D. histrix* (Lagerh.) E. Hegewald, *D. multivariabilis* var. *turskensis* P.M. Tsarenko & E.

Table 2. IBASU-A algae strains with biotechnological importance

Species	IBASU-A strain number	Origin	Field of usage
<b>CYANOBACTERIA</b>			
<i>Oscillatoriales, Microcoleaceae</i>			
<i>Limnospira platensis</i> (Gomont) K.R.S. Santos & Hentschke	700	unknown	Food, pharmaceutical, medical
<i>Nostocales, Aphanizomenonaceae</i>			
<i>Anabaena cylindrica</i> Lemmerm.	816	UK	Food, pharmaceutical, medical
<b>CHLOROPHYTA</b>			
<b>CHLOROPHYCEAE</b>			
<i>Chlamydomonadales, Asteromonadaceae</i>			
<i>Asteromonas gracilis</i> Artari	65, 66	Ukraine, Kherson Region; Russian Federation	Food, pharmaceutical, medical, aquaculture
<i>Chlamydomonadales, Dunaliellaceae</i>			
<i>Dunaliella salina</i> (Dunal) Teodor.	2–4, 6, 10–12, 16, 20	Ukraine, Odesa, Kherson regions, Crimea	Food, pharmaceutical, medical
<i>D. viridis</i> Teodor.	22, 24, 42, 56	Ukraine, Kherson, Zaporizhzhia regions, Crimea	Aquaculture
<i>Chlamydomonadales, Haematococcaceae</i>			
<i>Haematococcus lacustris</i> (Gir.-Chantr.) Rostaf.	219, 461, 462, 464	Ukraine, Kyiv Region, Crimea; Russian Federation, Caucasus	Bioenergetics, food, pharmaceutical, medical
<i>Sphaeropleales, Selenastraceae</i>			
<i>Messastrum gracile</i> (Reinsch) T.S. Garcia	316–318, 580	Ukraine, Kyiv; Germany	Bioenergetics
<i>Monoraphidium griffithii</i> (Berk.) Komárk.-Legn.	493, 494	Ukraine, Kyiv Region	Bioenergetics, bioremediation

Table 2 (continued)

Species	IBASU-A strain number	Origin	Field of usage
<i>M. saxatile</i> Komárk.-Legn.	364	Ukraine, Volyn Region	Bioenergetics, bioremediation
<i>Monoraphidium</i> sp.	166, 378, 379, 572–574	Ukraine, Kyiv, Kharkiv regions	Bioenergetics, food, pharmaceutical, medical
<i>Raphidocelis subcapitata</i> (Korshikov) Nygaard & al.	358, 360, 363	Ukraine, Donetsk, Volyn regions	Bioenergetics, bioremediation
<b>Sphaeropleales, Scenedesmaceae</b>			
<i>Desmodesmus armatus</i> (Chodat) E. Hegewald	263, 270, 337	Ukraine, Kyiv Region	Bioenergetics, bioremediation
<i>D. curvatocornis</i> (Proshk.-Lavr.) E. Hegewald	384	Ukraine, Volyn region	Bioenergetics
<i>D. magnus</i> (Meyen) P.M. Tsarenko	401, 402	Russian Federation, Sakhalin	Bioenergetics
<i>D. multivariabilis</i> var. <i>turskensis</i> P.M. Tsarenko & E. Hegewald	398	Ukraine, Volyn Region	Bioenergetics
<i>D. pannonicus</i> (Hortob.) E. Hegewald	381, 382	Germany	Bioenergetics
<i>D. subspicatus</i> (Chodat) E. Hegewald & A.W.F. Schmidt	408, 701	Ukraine, Kharkiv, Transcarpathian regions	Bioenergetics
<i>Scenedesmus obtusus</i> Meyen	297	Germany	Bioenergetics, bioremediation
<i>Tetradesmus arenicola</i> Mikhailyuk & P.M. Tsarenko	522, 523	Ukraine, Odesa Region; Germany	Food, pharmaceutical, medical
<i>T. dimorphus</i> (Turpin) M.J. Wynne	251, 255, 258, 259	Ukraine, Cherkasy, Khmelnytskyi, Kyiv, Transcarpathian regions	Food, pharmaceutical, medical, agriculture, bioenergetics, bioremediation
<i>T. obliquus</i> (Turpin) M.J. Wynne	473, 529	Peru	Bioenergetics, bioremediation
<i>Coelastrella</i> sp.	527, 528	Ukraine, Kyiv, Khmelnytskyi regions	Bioenergetics
<b>TREBOUXIOPHYCEAE</b>			
<b>Trebouxiales, Botryococcaceae</b>			
<i>Botryococcus braunii</i> Kütz.	428, 429, 432, 433, 434, 435, 437	Ukraine, Kyiv, Chernihiv, Transcarpathian, Volyn, Zhytomyr regions	Bioenergetics
<b>Chlorellales, Chlorellaceae</b>			
<i>Chlorella vulgaris</i> Beij.	189–192, 452, 472; 453, 715–717	Russian Federation, Caucasus, Chukotka; Ukraine, Kharkiv Region	Food, pharmaceutical, medical, agriculture, bioenergetics, bioindication, bioremediation
<i>Parachlorella kessleri</i> (Fott & Nováková) Krienitz & al.	197–200, 444	Ukraine, Kyiv Region; Russian Federation, Saint Petersburg; USA, Pennsylvania	Food, pharmaceutical, medical, bioenergetics
<b>Watanabeales, Watanabeaceae</b>			
<i>Chloroidium saccharophilum</i> (W. Krüger) Darienko & al.	187, 481	Ukraine, Kyiv; Germany	Bioenergetics, bioindication, bioremediation



**Fig. 3.** Some biotechnologically valuable strains of *Chlorophyta* in the collection. A: IBASU-A-297 *Scenedesmus obtusus*; B: IBASU-A-396 *Desmodesmus subspicatus*; C: IBASU-A-385 *D. magnus*; D: IBASU-A-572 *Monoraphidium* sp.; E: IBASU-A-318 *Messastrum gracile*; F: IBASU-A-464 *Haematococcus lacustris*; G: IBASU-A-434 *Botryococcus braunii*. Scale bars: 10  $\mu$ m

Hegewald, *D. perforatus* var. *iberaënsis* (Tell) E. Hegewald & S.L. Jeon, and *D. serratus* (Corda) S.S. An, Friedl & E. Hegewald (Tsarenko et al., 2005). Several authentic strains of cyanobacteria and green algae in the collection were investigated during studies of biological soil crusts or other terrestrial habitats in Ukraine, Germany, the Czech Republic,

Slovakia, South Africa, Chile, and Svalbard. More detailed information is provided in Table 3.

Moreover, IBASU-A is the only collection in Europe where, along with cultures of halophilic, freshwater, terrestrial and soil algae, the strains of bacteria accompanying microalgae in nature (bacterial consorts) are stored. 270 strains of bacterial

Table 3. Authentic strains in IBASU-A collection

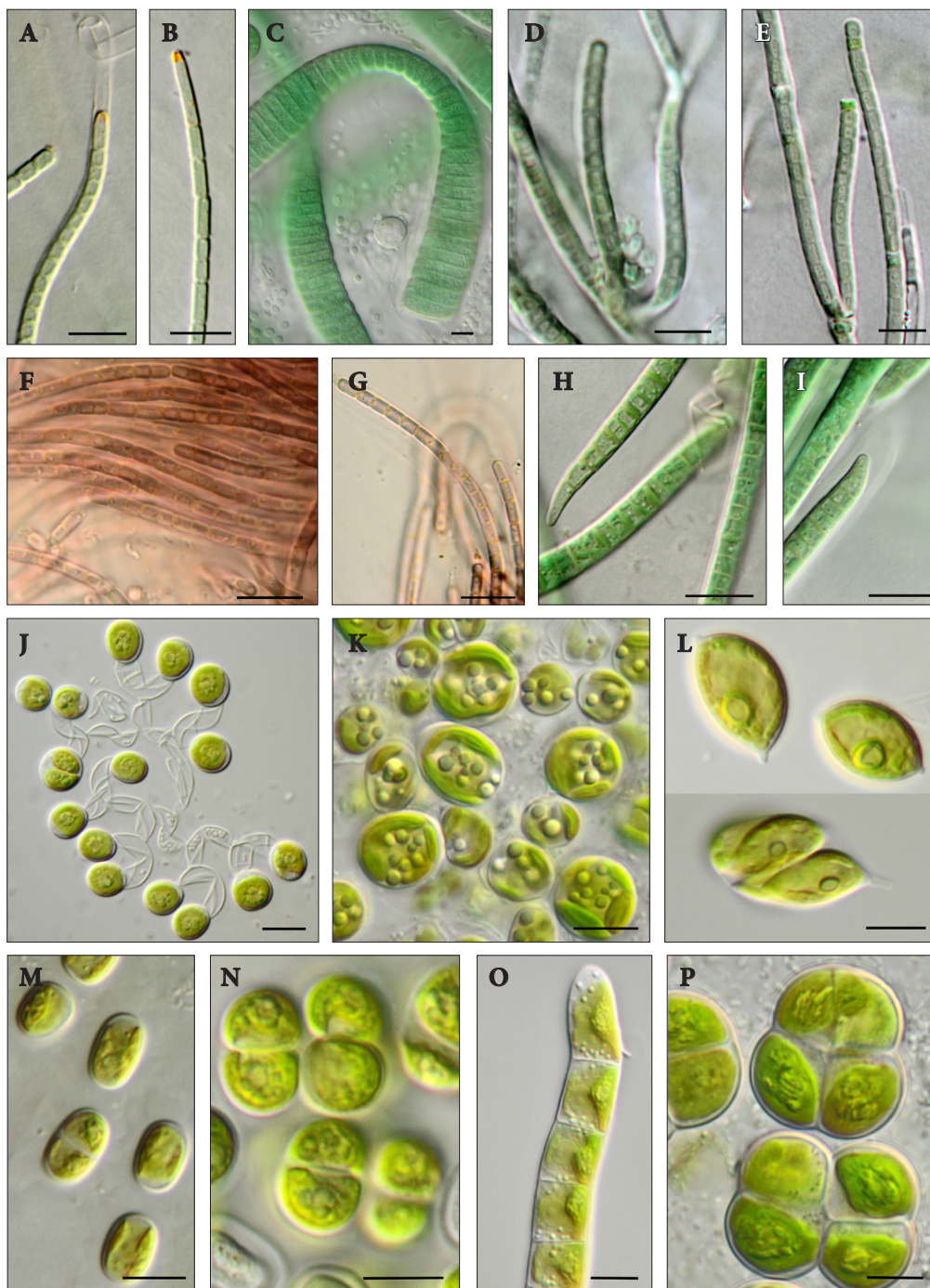
Species	IBASU-A strain number	Isolated by	Locality	References
<b>CYANOBACTERIA</b>				
<b>Leptolyngbyales</b>				
<i>Carminoleptolyngbya arenaria</i> Mikhailyuk & Vynogradova	750	Mikhailyuk T.I., 2013	Germany, Mecklenburg-Vorpommern, Warnemünde, the coast of the Baltic Sea, sand dunes, soil biocrust	Mikhailyuk et al., 2026
<b>Oculatellales</b>				
<i>Oculatella kazantypica</i> Vynogradova & Mikhailyuk	853	Mikhailyuk T.I., 2012	Ukraine, Crimea, Kazantyp Nature Reserve, Shyroka Bay, coast of the Sea of Azov, shell sand, soil biocrust	Vynogradova et al., 2017
<i>O. ucrainica</i> Vynogradova & Mikhailyuk	762	Mikhailyuk T.I., 2012	Ukraine, Crimea, vicinity of the Kazantyp Nature Reserve, spit of Aqtas Lake, coast of the Sea of Azov, shell sand, soil biocrust	Vynogradova et al., 2017
<i>Timaviella dunensis</i> Mikhailyuk & Vynogradova	754	Mikhailyuk T.I., 2013	Germany, Mecklenburg-Vorpommern, Usdom Island, vicinity of Zempin, coast of the Baltic Sea, sand dunes, soil biocrust	Mikhailyuk et al., 2022
<i>T. edaphica</i> (Elenkin) Vynogradova & Mikhailyuk	751	Mikhailyuk T.I., 2012	Ukraine, Crimea, vicinity of the Kazantyp Nature Reserve, spit of Aqtas Lake, coast of the Sea of Azov, shell sand, soil biocrust	Vynogradova, Mikhailyuk, 2018; Mikhailyuk et al., 2022
<b>Oscillatoriales</b>				
<i>Kondratevia charkoviensis</i> Vynogradova & Mikhailyuk	845	Demchenko E.M., 2014	Ukraine, Kharkiv Region, Kupiansk District, vicinity of village Kamianka, the slope of the right bank of the Oskil River, cretaceous outcrops, cyanobacterial biofilm on the moss curtain	Mikhailyuk et al., 2026
<b>Gomontiellales</b>				
<i>Crinalium magnum</i> F.E. Fritsch & R.P. John	693	Mikhailyuk T.I., 2013	Germany, Mecklenburg-Vorpommern, Heiligendamm, coast of the Baltic Sea, sand dunes, soil biocrust	Mikhailyuk et al., 2019b
<b>CHLOROPHYTA</b>				
<b>CHLOROPHYCEAE</b>				
<b>Sphaeropleales</b>				
<i>Tetrademus arenicola</i> Mikhailyuk & P.M. Tsarenko	522	Mikhailyuk T.I., 2013	Ukraine, Odesa Region, Izmail District, Danube Biosphere Reserve, coast of the Black Sea, sand dunes, soil biocrust	Mikhailyuk et al., 2019a
<b>TREBOUXIOPHYCEAE</b>				
<b>Trebouxiales</b>				
<i>Neochloris fusispora</i> Arce & H.C. Bold (= <i>Ettlia fusispora</i> (Arce & H.C. Bold) H. Ettl & G. Gärtner)	490	Bold H.C., Arce G., 1958	Cuba, Villa Clara Province, Ranchuelo, field of sugar cane, soil	Arce, Bold, 1958
<b>TREBOUXIOPHYCEAE ordo incertae sedis</b>				
<i>Leptochlorella arboricola</i> Mikhailyuk	812	Mikhailyuk T.I., 2012	Ukraine, Kyiv, Holiiv National Nature Park, Holiiv Forest, algal biofilm growing on the bark of <i>Pinus sylvestris</i>	Mikhailyuk et al., 2025

Table 3 (continued)

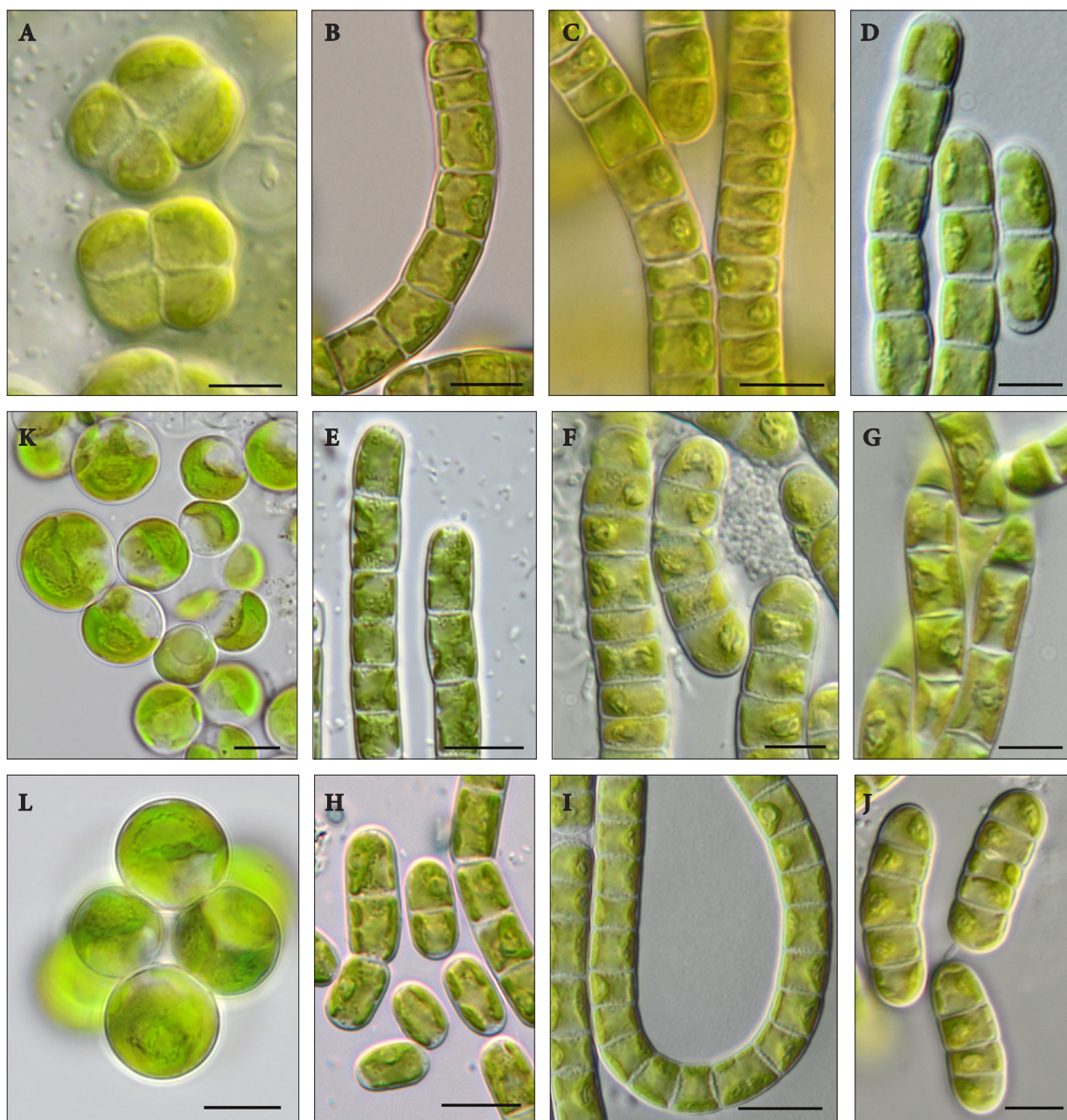
Species	IBASU-A strain number	Isolated by	Locality	References
<i>Xerochlorella dichotoma</i> (H.P. Ling & Seppelt) Mikhailyuk & P.M. Tsarenko	764	Mikhailyuk T.I., 2013	Germany, Mecklenburg-Vorpommern, Heiligendamm, coast of the Baltic Sea, sand dunes, soil biocrust	Mikhailyuk et al., 2020
<b>CHAROPHYTA</b>				
<i>KLEBSORMIDIOPHYCEAE</i>				
<i>Klebsormidiales</i>				
<i>Interfilum massjukiae</i> Mikhailyuk & al.	767	Demchenko E.M., 2005	Ukraine, Crimea, Karadag Nature Reserve, Mountain range "Karagach", surface of pyroclastic outcrops	Mikhailyuk et al., 2008
<i>Klebsormidium africanum</i> Mikhailyuk	771	Dojani S., 2005	Republic of South Africa, Grootderm, Karoo Namib, Succulent Karoo, semi-desert, soil biocrust	Samolov et al., 2019
<i>K. chilense</i> Mikhailyuk & Samolov	949	Samolov E., 2017	Chile, La Campana National Park, deciduous Mediterranean vegetation, soil biocrust	Samolov et al., 2019
<i>K. delicatum</i> Mikhailyuk & Lukešová	772	Lukešová A., 1997	Czech Republic, Slavkovský Forest, peat bog Krásno, soil	Samolov et al., 2019
<i>K. delicatum</i> var. <i>deserticum</i> Mikhailyuk & Samolov	774	Samolov E., 2017	Chile, Santa Gracia Nature Reserve, semi-arid shrubland vegetation, soil biocrust	Samolov et al., 2019
<i>K. karoense</i> Mikhailyuk	776	Dojani S., 2005	Republic of South Africa, Grootderm, Karoo Namib, Succulent Karoo, semi-desert, soil biocrust	Samolov et al., 2019
<i>K. sylvaticum</i> Mikhailyuk & Samolov	778	Samolov E., 2017	Chile, Nahuelbuta National Park, Araucaria temperate forest, soil biocrust	Samolov et al., 2019
<i>K. vermiculatum</i> Mikhailyuk	779	Dojani S., 2005	Republic of South Africa, Roscherpan Nature Reserve, Fynbos, soil biocrust along dripping zone of shrubs	Samolov et al., 2019
<i>Hormidiellales</i>				
<i>Hormidiella parvula</i> M.O.P. Iyengar & Kanth. emend. Mikhailyuk & Lukešová	815	Lukešová A., 2008	USA, Wyoming, Belle Ayr Mine near Gillette, natural prairie, soil	Mikhailyuk et al., 2018a
<i>Streptosarcina arenaria</i> Mikhailyuk & Lukešová	475	Lukešová A., 1993	Slovakia, Bratislava Region, Malacky District, Lozorno Village, burnt forest, sandy soil with ash	Mikhailyuk et al., 2018a
<b>CHAROPHYTA, class incertae sedis</b>				
<i>Streptofilum arcticum</i> Mikhailyuk, Glaser, Holzinger & U. Karst.	781	Mikhailyuk T.I., 2019	Svalbard (Norway), vicinities of the Ny-Alesund Research Station, Ossian-Sarsfjellet, tundra top soil, soil biocrust	Glaser et al., 2025
<i>S. capillatum</i> Mikhailyuk & Lukešová	521	Lukešová A., 2002	Czech Republic, near Kamenice nad Lipou, Benešov, arable field, sandy soil	Mikhailyuk et al., 2018a

consorts have been isolated from 45 xenic cultures of algae belonging to the green algal genera *Chlorella*, *Desmodesmus*, *Klebsormidium*, *Messastrum* T.S. Garcia, *Monoraphidium*, *Oocystis*, *Raphidocelis*, *Tetrademus* genera (Borysova et al., 2016, 2020; Borysova, 2022, see Table 4).

Maintaining the collection has faced significant challenges in recent years. During 2020–2021, the COVID-19 pandemic led to strict lockdowns, including stay-at-home orders and disruptions to public transportation. Consequently, essential maintenance tasks — such as preparing fresh media



**Fig. 4.** Some authentic strains of cyanobacteria and green algae (*Chlorophyta* and *Charophyta*) of the collection. A–I: Filamentous *Cyanobacteria*. A: IBASU-A-762 *Oculatella ucrainica*; B: IBASU-A-853 *O. kazantipica*; C: IBASU-A-693 *Crinalium magnum*; D: IBASU-A-751 *Timaviella edaphica*; E: IBASU-A-754 *T. dunensis*; F, G: IBASU-A-750 *Carminoleptolyngbya arenaria*; H, I: IBASU-A-845 *Kondratevia charkoviensis*. J–L: *Chlorophyta*. J: IBASU-A-764 *Xerochlorella dichotoma*; K: IBASU-A-812 *Leptochlorella arboricola*; L: IBASU-A-522 *Tetradesmus arenicola*; M–P: *Charophyta*. M: IBASU-A-521 *Streptofilum capillatum*; N: IBASU-A-781 *Streptofilum arcticum*; O: IBASU-A-815 *Hormidiella parvula*; P: IBASU-A-475 *Streptosarcina arenaria*. Scale bars: 10 µm



**Fig. 5.** Some authentic strains of green algae (*Charophyta* and *Chlorophyta*) of the collection. A–J: *Charophyta*. A: IBASU-A-767 *Interfilum massjukiae*; B: IBASU-A-776 *Klebsormidium karoense*; C: IBASU-A-771 *K. africanum*; D, G: IBASU-A-950 *K. chilense*; E, H: IBASU-A-772 *K. delicatum*; F: IBASU-A-774 *K. delicatum* var. *deserticum*; I: IBASU-A-778 *K. sylvaticum*; J: IBASU-A-779 *K. vermiculatum*. K, L: *Chlorophyta*. K, L: IBASU-A-490 *Neochloris fusispora*. Scale bars: 10  $\mu$ m

and timely subculturing — were delayed, negatively affecting the viability of certain strains. Since the full-scale invasion by Russia began in February 2022, the collection's staff has faced unprecedented challenges. In spring 2022, access to the Institute

was severely restricted by disrupted public transportation and frequent air raid alerts. In October 2022, missile explosions damaged numerous windows and some other external structures of the Institute (see Mosyakin, Shiyan, 2022); fortunately,

Table 4. Strains of bacterial consort in IBASU-A collection

Taxon or bacterial groups by phenotypic characteristics	Number of strains	Isolated from cultures of algae (genus/species)	Taxonomy
<i>Acinetobacter</i> sp.	10	<i>Comasiella arcuata</i> (Lemmerm.) E. Hegewald var. <i>platydisca</i> (G.M. Sm.) E. Hegewald & M. Wolf, <i>Tetrademus dimorphus</i> (Turpin) M.J. Wynne	<i>Pseudomonadales</i> , <i>Moraxellaceae</i>
<i>Curtobacterium</i> sp.	30	<i>Desmodesmus</i> spp., <i>Enallax costatus</i> (Schmidle) Pascher, <i>Scenedesmus</i> spp., <i>Tetrademus</i> spp.	<i>Actinomycetales</i> , <i>Microbacteriaceae</i>
<i>Flavobacterium</i> sp.	13	<i>Chlorella vulgaris</i> Beij., <i>Tetrademus dimorphus</i> (Turpin) M.J. Wynne	<i>Flavobacteriales</i> , <i>Flavobacteriaceae</i>
<i>Microbacterium imperiale</i> (Steinhaus) Collins et al.	5	<i>Tetrademus dimorphus</i> (Turpin) M.J. Wynne	<i>Actinomycetales</i> , <i>Microbacteriaceae</i>
<i>Micrococcus</i> sp.	12	<i>Dunaliella</i> spp.	<i>Actinomycetales</i> , <i>Micrococcaceae</i>
<i>Pseudomonas aeruginosa</i> (Schroeter) Migula	3	<i>Klebsormidium flaccidum</i> (Kütz.) P.C. Silva, Mattox & W.H. Blackw.	<i>Pseudomonadales</i> , <i>Pseudomonadaceae</i>
<i>Pseudomonas chlororaphis</i> subsp. <i>aureofaciens</i> (Kluyver) Peix et al. (= <i>Pseudomonas aureofaciens</i> Kluyver)	8	<i>Coelastrum rugosum</i> (Rich) P.M. Tsarenko	<i>Pseudomonadales</i> , <i>Pseudomonadaceae</i>
<i>Pseudomonas mendocina</i> Palleroni	12	<i>Dunaliella</i> spp.	<i>Pseudomonadales</i> , <i>Pseudomonadaceae</i>
<i>Pseudomonas</i> sp.	25	<i>Dunaliella</i> spp., <i>Chlorella vulgaris</i> Beij., <i>Coelastrum rugosum</i> (Rich) P.M. Tsarenko, <i>Klebsormidium</i> spp.	<i>Pseudomonadales</i> , <i>Pseudomonadaceae</i>
<i>Rhodococcus erythropolis</i> (Gray & Thornton) Goodfellow & Alderson	40	<i>Chlorella vulgaris</i> Beij., <i>Desmodesmus</i> spp., <i>Klebsormidium</i> spp., <i>Scenedesmus</i> spp., <i>Tetrademus</i> spp.	<i>Mycobacteriales</i> , <i>Mycobacteriaceae</i>
<i>Rhodococcus fascians</i> (Tilford) Goodfellow	30	<i>Chlorella vulgaris</i> Beij., <i>Desmodesmus</i> spp., <i>Scenedesmus</i> spp., <i>Tetrademus</i> spp.	<i>Mycobacteriales</i> , <i>Mycobacteriaceae</i>
Unidentified Gram (+) colorless bacteria	13	<i>Messastrum gracile</i> (Reinsch) T.S. Garcia, <i>Monoraphidium</i> spp., <i>Raphidocelis</i> spp.	–
Unidentified Gram (+) pigmented bacteria (yellow, orange, red, pink colonies)	49	<i>Messastrum gracile</i> (Reinsch) T.S. Garcia, <i>Monoraphidium</i> spp., <i>Raphidocelis</i> spp.	–
Unidentified Gram (–) colorless bacteria	10	<i>Messastrum gracile</i> (Reinsch) T.S. Garcia, <i>Monoraphidium</i> spp., <i>Oocystis</i> spp., <i>Raphidocelis</i> spp.	–
Unidentified Gram (–) pigmented bacteria (yellow, orange, red colonies)	10	<i>Messastrum gracile</i> (Reinsch) T.S. Garcia, <i>Monoraphidium</i> spp., <i>Raphidocelis</i> spp.	–
<b>Total:</b>	<b>270</b>		

the algal collection has not been affected. Subsequently, repeated attacks on Ukraine's energy infrastructure led to frequent power outages (see UN Human Rights Monitoring Mission in Ukraine, 2024). These conditions were particularly severe in summer 2024, making it impossible to maintain stable light and temperature conditions or to operate laboratory equipment with long cycles, such as autoclaves. Similar difficulties persisted through the winter of 2025–2026, when unpredictable blackouts

combined with severe frosts caused indoor temperatures in the storage rooms to drop below 13 °C. However, through the tireless dedication of the staff, significant losses to the collection were avoided. Despite the ongoing war, the IBASU-A holdings are regularly expanded with new isolates. However, the growth of the collection is constrained by limited personnel, storage equipment, and available laboratory space (Borysova et al., 2016). Consequently, a strategic optimization of the holdings is underway,

with strains that are both highly resource-intensive to maintain and of limited scientific value being gradually phased out, especially if they show poor resilience to suboptimal storage conditions.

The expansion and use of the collection are closely aligned with the research interests and scientific programs and projects of the Department of Phycology, Lichenology, and Bryology at the M.G. Kholodny Institute of Botany. Furthermore, IBASU-A serves as a resource for wider scientific collaboration. In recent years, strains have been provided to researchers from the D.K. Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine, V.N. Karazin Kharkiv National University, Ternopil Volodymyr Hnatiuk National Pedagogical University, M.M. Gryshko National Botanical Garden of the NAS of Ukraine, among others. Beyond its research functions, the collection provides algal strains for educational purposes and science outreach. Additionally, the collection's facilities host guided tours for students to promote phycological knowledge. The collection is used for practical classes and for the preparing diploma theses by students of the Taras Shevchenko National University of Kyiv, National University of Kyiv-Mohyla Academy, National Technical University "Igor Sikorsky Kyiv Polytechnic Institute", among others.

An important step in the development of the IBASU-A collection was the EURIZON project, carried out in collaboration with colleagues from the Taras Shevchenko National University of Kyiv. Since May 2024 to April 2025, additional funding from the project enabled a revision of the culture collection, improvements in culture storage conditions, procurement of necessary materials and equipment, and development of a website for the collection. During the project, new connections were established with European partners, e.g., the Culture Collection at Göttingen University (SAG, Germany). These connections enabled IBASU-A employees to visit other algae culture collections to exchange experiences in the maintenance and investigation of algal strains.

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## Conclusions

Over its 65-year history, IBASU-A has evolved into an internationally recognized resource for cultured algae and cyanobacteria and became a unit of the National Heritage of Ukraine. The collection maintains over 500 strains, organized into specialized holdings of halophilic, freshwater, and terrestrial species, as well as biotechnologically significant strains, rare taxa, and ex-type and other nomenclaturally significant strains most important for taxonomic research. A unique feature of the collection is the inclusion of bacterial associates isolated from xenic algal cultures. Furthermore, the collection's primary strength lies in its indigenous isolates from diverse aquatic and terrestrial habitats across Ukraine. Despite current challenges, IBASU-A continues to develop. Future priorities include enhancing preservation methods for rare and endangered species and expanding the study of resource-valuable strains, such as producers of biomass, lipids, vitamins, and bioactive compounds, to ensure the sustainable conservation of autotrophic diversity.

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## ETHICS DECLARATION

The authors declare no conflict of interest.

## ORCID

- O.V. Borysova  <https://orcid.org/0000-0002-0941-5099>  
 O.V. Burova  <https://orcid.org/0000-0002-4300-8075>  
 T.I. Mikhailiuk  <https://orcid.org/0000-0002-7769-2848>  
 M.O. Konishchuk  <https://orcid.org/0000-0002-6334-5036>  
 T. Friedl  <https://orcid.org/0000-0002-4070-776X>

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### Колекція культур мікрводоростей Інституту ботаніки ім. М. Г. Холодного (IBASU-A): 65 років історії

О.В. БОРИСОВА<sup>1</sup>, О.В. БУРОВА<sup>1</sup>, Т.І. МИХАЙЛЮК<sup>1</sup>, М.О. КОНІЩУК<sup>1</sup>, Т. ФРІДЛ<sup>2</sup>

<sup>1</sup> Інститут ботаніки ім. М.Г. Холодного НАН України, Україна

<sup>2</sup> Відділ експериментальної альгології та Колекція культур водоростей (SAG), Інститут рослинництва імені Альбрехта фон Галлера, університет Геттінгена, Геттінген, Німеччина

**Реферат.** Колекція культур мікрводоростей Інституту ботаніки ім. М.Г. Холодного НАН України (IBASU-A) створена в 1960-х роках. Сьогодні це одна з найбільших колекцій водоростей в Україні, яка з 2013 року визнана Національним надбанням України. Вона включає 500 штамів 186 прокаріотичних і еукаріотичних видів водоростей, що належать до 100 родів, 10 класів, представників *Cyanobacteria* (32), *Chlorophyta* (125), *Charophyta* (23), *Euglenophyta* (2), *Heterokontophyta* (6 видів). Основну частину колекції становлять зелені водорості (*Chlorophyta*) — провідна таксономічна група водоростевої флори України. Більшість штамів (403 штами) виділено з різних регіонів України. Фонди IBASU-A включають культури галофільних, прісноводних і наземних водоростей, колекції цінних для біотехнології штамів водоростей, а також рідкісних видів і автентичних штамів. Основною метою колекції культур IBASU-A є виділення, зберігання та постачання штамів водоростей для використання в дослідженнях і біотехнології. Штами видів IBASU-A родин *Chlorellaceae*, *Scenedesmaceae* та *Selenastraceae*, виділені з різних регіонів України та інших країн Європи, використовувалися в різних прикладних проектах як тест-об'єкти для оцінки токсичності та канцерогенності синтетичних органічних речовин або біологічних агентів при взаємодії з різними видами промислових відходів. Ці самі штами, як активні виробники біомаси, були успішно використані в окремому проєкті для виробництва біопалива. Особливістю колекції IBASU-A є те, що поряд із культурами водоростей, зберігаються штами бактерій, що супроводжують мікрводорості в природі (бактеріальні консорти); загалом 270 штамів, які були виділені з 45 ксенічних культур зелених водоростей.

**Ключові слова:** IBASU-A, автентичні штами, бактеріальні консорти, біорізноманіття, біотехнологія, колекція, культури, мікрводорості, національне надбання, рідкісні види, ціанобактерії