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Digitization of the oldest botanical collection in Ukraine (LW Herbarium): a case study

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Abstract. Digitization of natural collections has become very important among all other preservation tasks. One of the ways of non-destructive examination of herbarium specimens is the study of their scanned digital images or photocopies, which makes it possible to reduce mechanical and other influences on specimens. Reconsidering the importance of collections' digitization became particularly relevant on 24 February 2022, with the start of the last Russian invasion and due to the destruction or severe damage of many of them in the occupied territories. There was concern about the need and urgency to preserve, at least virtually, the most valuable assets of the LW Herbarium of Ivan Franko National University of Lviv. Currently, the digitization process includes 2 collections from the 19th century: (1) the most complete of all existing herbaria of vascular plants from the Southern Carpathians and Transylvania, collected by Dr Ferdinand Schur – an Austrian pharmacist and botanist; and (2) collection of one of the first researchers of bryophytes in South Africa – Antoni Rehman, then Professor of Jan Kazimierz University in Lwów (now Lviv). Both collections contain many nomenclatural types. Out of 7633 herbarium sheets from F. Schur's collection, more than 2700 have been digitized, and 380 representatives of the family Labiatae are published in volume I of the Atlas of his collection. The digitization of the South African mosses collected by A. Rehman began in 2023. So far, 584 packets have been digitized.

Key words: digitization, herbarium, LW, historical collections, Lviv, Ukraine

1. Introduction

Nature collections are the most important sources of information about our planet's present and past biodiversity, as well as a vital component of scientific infrastructure around the world. "They contribute to scientific discoveries and innovations, enrich education, connect communities with nature and science, and protect the Earth's biological heritage. Preserving invaluable biological collections is essential if we continue to address the world-class scientific questions that depend on these collections, foster innovation, and support educational needs, both now and in the future" (National … 2020). In recent decades, digitization of collections has become increasingly significant among all preservation tasks of the valuable past, as it provides the opportunity for additional open access to images and specimen data to solve many problems (Ong *et al*. 2023) and is of great interest to researchers around the world (Tulig *et al.* 2012; Thiers *et al.* 2016; Funk 2018; Mitka *et al.* 2018; Soltis *et al.* 2018; De Gasper *et al.* 2021; Roma-Marzio *et al.* 2023) as well in Ukraine (Novikov *et al.* 2023; Tasenkevich *et al.* 2023).

Reconsidering the importance of collections' digitization became particularly relevant for Ukraine on 24 February 2022, because the Russian-Ukrainian war caused enormous damage to collections in Ukraine, and even their losses. Thus all scientific materials collected and stored in the administrations of reserves (in diaries, herbaria, and collections) and now located in temporarily occupied territories became unavailable in Ukraine. The same applies to untransportable collections stored in universities and museums of occupied cities. Scientists have put in the maximum effort to preserve scientific collections and records, but the conditions they will be in until complete de-occupation are unknown. The

threat remains for scientific funds of cities that were not occupied. For example, from the first days of the invasion of rushists (term used e.g. by Snyder 2022), a team from the Natural History Museum of Kharkiv National University protected the collections, hiding with them in a bomb shelter during the bombings. In Kharkiv, part of the National Center for Plant Genetic Resources was also destroyed. One of the most striking examples of the loss of funds and works of botanical institutions was the burning of scientific herbaria by the Russian military forces in the city of Trostyanets, Sumy Oblast, together with the local museum and the Forest Research Station, where they were stored (Parkhomenko & Vasyliuk 2022). In Kyiv, on 10 November 2022, the premises of the Institute of Botany of the National Academy of Sciences (NAS) of Ukraine and the National Herbarium of Ukraine (KW) were damaged (Mosyakin & Shiyan 2022) by the rushists' rocket.

The Russian invasion caused enormous damage to collections in Ukraine and is a grim reminder to the entire world that the destruction of scientific collections should be qualified as another type of war crime. In general, discussions often arise among researchers regarding methods and the necessary material base for digitizing herbarium specimens. There is an increasing amount of publications discussing the problems due to time and equipment constraints and methods of solving them, which herbaria encountered when digitizing their collections (Harris & Marsico 2017; De Gasper *et al.* 2021; Jackowiak *et al.* 2022; Ong *et al.* 2023). In the proposed paper, we describe our experience of digitizing the collection of the Herbarium of the Ivan Franko National University of Lviv (LW).

2. Historical botanical collections of the University of Lviv

The Herbarium of this University was founded in 1783, so it is the oldest and most valuable historical botanical collection of Ukraine and one of the 30 oldest herbaria in the world. It is included in the world herbarium directory *Index Herbariorum* with the acronym LW (Holmgren *et al.* 1990; Thiers 2022). As a significant value for Ukrainian and world science, the Herbarium was added to the list of National Heritage Objects in 2002. About 300,000 specimens of vascular plants, slime molds, fungi, lichens, and bryophytes are deposited in LW.

Historical collections of outstanding scientists are of particular value in any herbarium (Tasenkevich *et al.* 2014). In LW, about 20 historical collections (approximately 25,000 herbarium specimens) were mainly formed in the 19th and 20th centuries, by Philipp Johann Ferdinand Schur (widely known as Dr. Ferdinand Schur), and Antoni Rehman (2 collections), Józef Krupa, Tytus Chałubiński, Tadeusz Wilczyński (2 collections + archive), Antoni Józef Żmuda, Rudolf Wilczek, Stanisław Kulczyński, Bronislaw Szafran, Gottlob Rabenhorst, Karl Krieger, Hans Sydow, Józef Kochman, Helena Krzemieniewska, Marian Raciborski (2 collections), and Otto Jaap (2 collections), listed by Tasenkevich *et al.* (2014, 2023). The LW Herbarium also houses many interesting specimens collected by other prominent Polish, Austrian, and Ukrainian botanists: Bronisław Błocki, Teofil Ciesielski, Franciszek Herbich, Feliks Krawiec, Józef Lagowski, Hiacynt Łobarzewski, Józef Mądalski, Józef Motyka, Józef Paczoski, Kazimierz Rouppert, Adolf Weiss, Tadeusz Wiśniewski, Eustachy Wołoszczak, and Aleksander Zawadzki (Volgin *et al.* 2011). The most valuable materials stored in LW include the collections of the Austrian pharmacist and botanist Philipp Johann Ferdinand Schur (vascular plants from Transylvania in the East and South Carpathians, 1844-1854) and Antoni Rehman, who was Professor of Jan Kazimierz University in Lwów, now Lviv (vascular plants of the genus *Hieracium* L. – several thousand specimens – and one of the first moss collections from South Africa: 650 specimens collected during his expeditions to South Africa in 1875-1877 and 1879-1880) (Khmil *et al.* 2013; Tasenkevich *et al.* 2014, 2023). About 2000 nomenclatural type specimens are also stored in LW.

3. The workflow and results of the digitization of herbarium specimens in LW

The preservation and preparation of voucher specimens for digitization were carried out according to generally accepted methods (Kobuski *et al.* 1958; Nevling 1973; Forman & Bridson 1989; Drobnik 2007; Popławska & Zając 2018; De Gasper *et al.* 2021). Digitization was done using HerbScan with a resolution of 600 DPI and saved in TIFF format according to methodological recommendations (JSTOR 2018), as well as using photographic equipment with a resolution of 300 DPI and saved in JPEG format.

One of the first questions that arose before the digitization of specimens, was the preservation of the material and its preparation. An important step was its correct cryoprocessing (-18°C, dry freezing), so the specimen may be suitable for potential molecular-genetic analysis. To solve this issue, LW purchased a freezer that holds 32 herbarium packs, which allows us to perform cryoprocessing of one cabinet at a time (each voucher specimen undergoes cryoprocessing annually).

The next problem to solve was the preparation of the specimens for digitization. Considering that the age of LW is over 240 years, and the average age of the main part of the herbarium specimens is more than 100 years, the preparation of this material is quite time-consuming.

It should be also noted that the economic situation and material base of LW depends on the situation in the state, and some years were difficult in this matter, so the maintenance was conducted irregularly. To cope with this problem, an algorithm was developed: valuable historical collections were mounted, numbered, and stamped, fragments of plant parts were placed in paper bags, and a barcode was created (for the register of the herbarium specimen in the electronic database) on the Zebra TLP 2824 Plus. In contrast, specimens from the general part of the herbarium were digitized without mounting and barcoding. Digitized material was processed using Adobe Photoshop CS2 software.

The process of digitization of the collections of LW began about 10 years ago, thanks to the cooperation agreement between the Lviv University and the Andrew Mellon W. Foundation (USA) as well as the HerbScan received as a gift from the Royal Botanic Gardens (Kew, UK) (Fig. 1A). At LW (throughout the implementation of the project), a regional center for "Digitization of type specimens from the herbaria of western Ukraine" was formed. The herbaria of the State Museum of Natural History the National Academy of Sciences of Ukraine, Yuriy Fedkovich Chernivtsi National University, and the Institute of Ecology of the Carpathians, also participated in the work. As a result of the implementation of the project, 1100 type specimens have been scanned.

The cheaper and faster digitization of herbarium material with photographic equipment has recently been increasingly discussed (Harris & Marsico 2017; Novikov & Sup-Novikova 2021). However, a phone with a good or cheap camera is not enough to digitize museum objects. Quality software, hardware, and accessories (tripods, interchangeable lenses, additional lighting, etc.) are necessary. Especially when it comes to botanical and zoological collections, such as herbaria or insect collections (Kunsht 2022). So, to speed up the digitization of the LW collections, with the support of the Ministry of Education and Science of Ukraine, a set of photographic equipment was purchased: a Canon EOS 80D kit EF-S 18-135mm IS USM camera, a Canon EF 16-35mm f/4L IS USM lens, a Canon EF 100 mm f/2.8L Macro IS USM macro lens, a Manfrotto 055XPROB tripod with 804RC2 head (KIT), and LED panel BOLING BL-2280P 120W CRI 95+ (Fig. 1B).

Currently, the digitization of the LW collections is being done using the developed algorithm. With photographic equipment, materials from the general part of the herbarium are digitized (especially species listed in the Red Book of Ukraine) and electronic requests from

Fig. 1. Equipment for digitization of the LW Herbarium collection
Explanations: A – HerbScan, B – photographic station

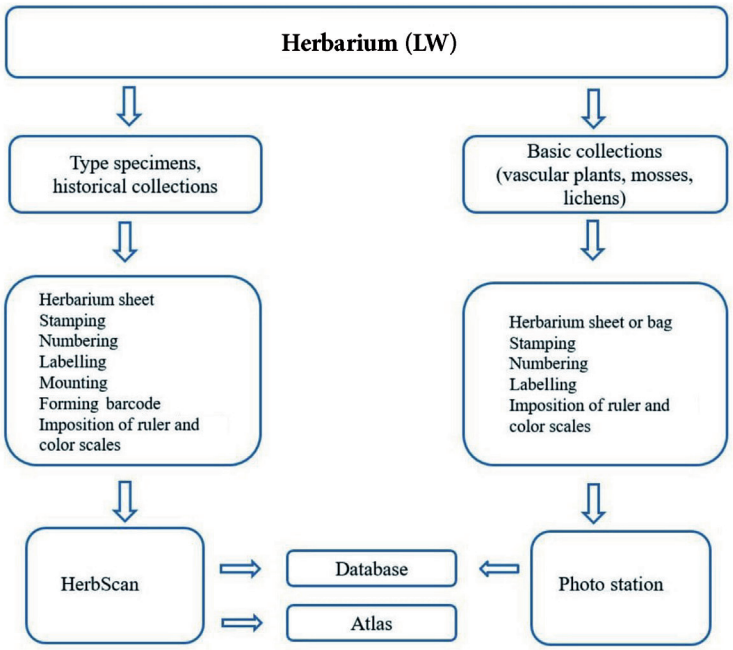

Fig. 2. A workflow for the digitization of herbarium specimens in LW

foreign and Ukrainian specialists are processed. In contrast, HerbScan is used for type specimens needing critical analysis and for F. Schur's historical collection (Fig. 2).

These approaches have given us a solution to the problem of digitizing the herbarium of vascular plants. However, LW houses several valuable collections of mosses, lichens, and fungi that require volume scanning and microscopy.

When analyzing the obtained images, it can be concluded that the digitized samples with a high-quality configured camera and a specialized scanner are significantly different. Photographs allow us to examine labels and plant morphology, and reduce the negative impact on specimens during chorological studies. Still, they are not sufficient for critical systematic examination. In comparison, the scanned material has several advantages: it is a high-quality, clear image that shows diagnostic features and enables a detailed study of the specimen, and together with the results of molecular-genetic analysis, it can preserve complete information about the taxon (Fig. 3A-B). However, the scanned images have disadvantages, too: the size of the digitized sample is quite large, which can be an obstacle to the publication of this material, as it requires a server with a large memory drive.

The first experience in publishing digitized material was obtained during A. Mellon's grant implementation, when scanned type specimens were deposited in JSTOR Global Plants, the world's largest plant database (JSTOR Global Plants 2023), and partly in Virtual Herbaria JACQ. Several academic institutions place digitized material on free platforms of various databases (Telenius 2011; Ball-Damerow *et al.* 2019; Jackowiak *et al.* 2022). In 2021, the Administration of the University of Lviv decided to place a database on its servers. Unfortunately, for the time being, the process has been suspended, partly due to the war.

Nevertheless, LW continued digitizing one of its most valuable and largest collections, namely Dr Schur's herbarium. The plant collection of the Austrian botanist Philipp Johann Ferdinand Schur (1799-1878), from Transylvania, is deposited in LW in its original form. In 76 herbarium packs, there are representatives of 157 families, 733 genera, and 3671 species, in a total of 7663 herbarium sheets (Fig. 4). According to published data, individual specimens collected by him are stored in 17 herbaria of the world. His largest (or main) collections are in herbaria in Paris and Vienna, and a collection of doublets is housed in Japan. However, the majority of researchers come to the same conclusion: the most representative, both in terms of the number and availability of type material, is the personal collection of Dr F. Schur deposited in LW (Stafleu & Cowan 1985; Speta 1994). He kept this collection for the longest time for himself, obviously because it contains authentic materials that served as the basis for writing his most important work *Enumeratio Plantarum Transsilvaniae* (Schur 1866).

In 2023, the LW team prepared an electronic layout of the book, and a few paper copies of the first volume of scanned images of plants of the family Labiatae Juss. from his collection were published as the "Atlas of the Collection of Ferdinand Schur in the Herbarium of the

Fig. 3. Samples digitized by a photographic camera (A) and by HerbScan (B)

Ivan Franko National University of Lviv. I. Labiatae Juss." (Tasenkevich *et al.* 2023) (Fig. 5). The order of the images corresponds to the order of listing the relevant taxa in F. Schur's "Enumeratio..." (Schur 1866). In the captions to the images, without reference to modern taxonomy, the nomenclature and spelling of taxa names used by F. Schur on the labels and in "Enumeratio..." (l.c.) are preserved and labels are enlarged for ease

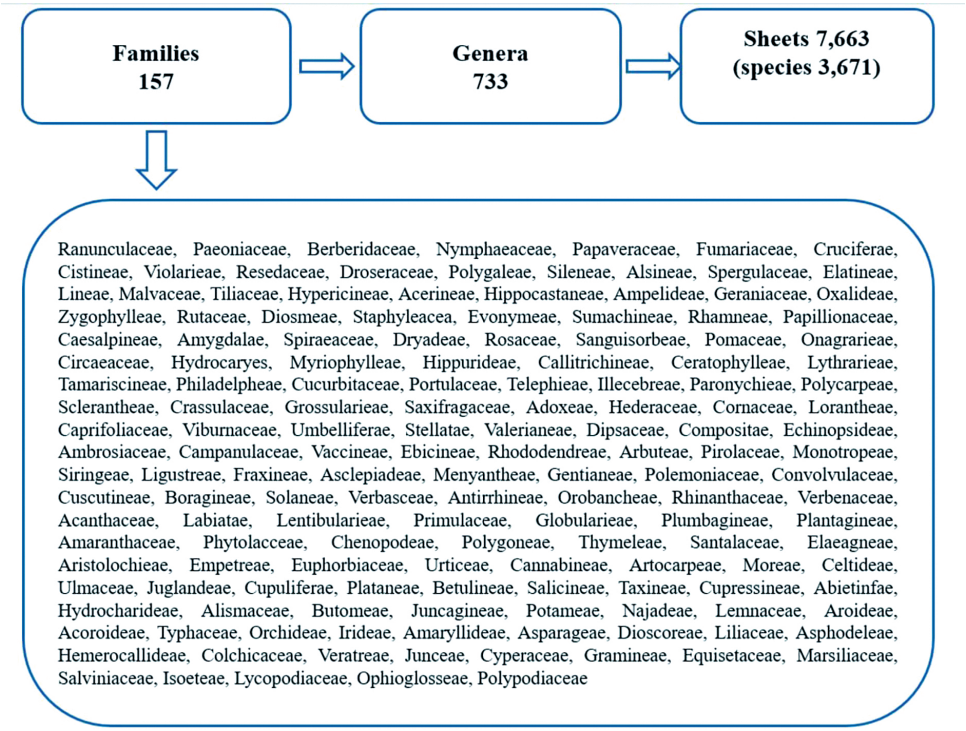

Fig. 4. Family composition of the F. Schur's collection families names are given according to F. Schur's Enumeratio ... (1866)

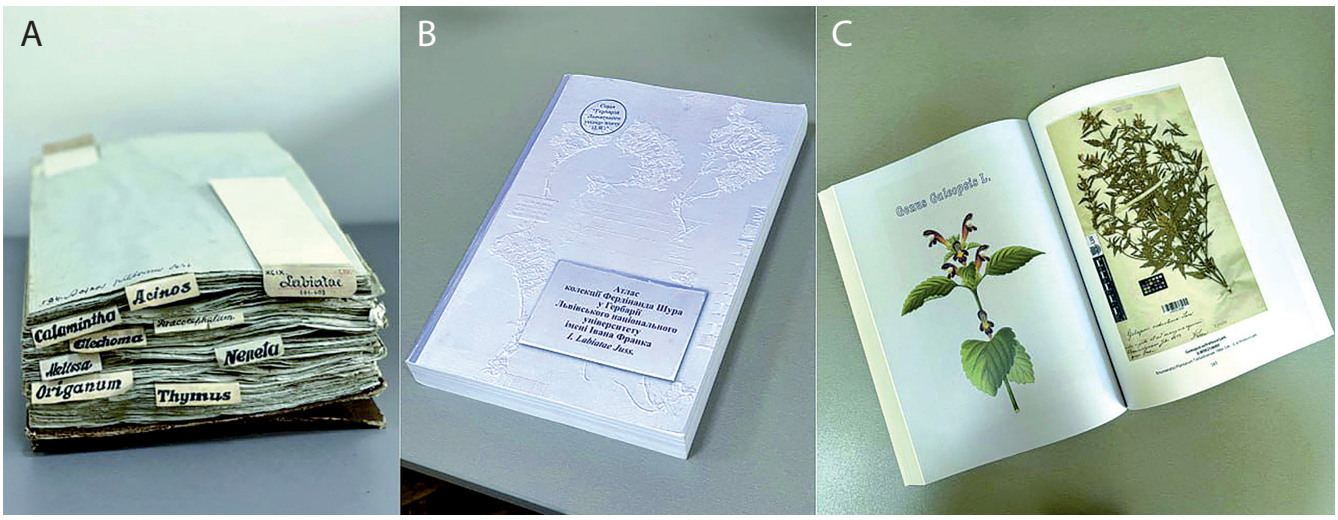

Fig. 5. Original folder with plants of the family Labiatae Juss. from the historical collection of Dr Ferdinand Schur (LW) (A). The first volume of the Atlas with scanned images (family Labiatae Juss.) (B). An example of pages from the Atlas (C)

of reading the inscriptions, and the names of taxa of various ranks adopted by the author in "Enumeratio..." (l.c.) are cited as well. The Atlas also lists specimens available in the herbarium, which were not mentioned in "Enumeratio..." (l.c.).

Out of more than 2700 samples scanned to date, all 380 members of the Labiatae from Schur's collection are contained in this volume. They represent 8 tribes (according to the nomenclature applied by F. Schur) (*Ajugoideae* Benth., *Melissineae* Benth., *Menthoideae* Benth., *Monardeae* Benth., *Nepeteae* Benth., *Ocymoideae* Benth., *Satureineae* Benth., *Scutellarineae* Benth., *Stachydeae* Benth.) and 37 genera (*Acinos* Mönch., *Ajuga* L., *Ballota* L., *Betonica* L., *Calamintha* Mönch., *Chaiturus* Host., *Chamaepitys* Tournef., *Clinopodium* L., *Dracocephalum* L., *Galeopsis* L., *Glechoma* L., *Hyssopus* L., *Lamium* L., *Lavandula* L., *Leonurus* L., *Lycopus* L., *Majorana* Wett., *Marrubium* L., *Melissa* L., *Mentha* L., *Micromeria* Benth., *Nepeta* L., *Ocymum* L., *Origanum* L., *Polium* Schur, *Phlomis* L., *Phleboanthe* Tausch, *Prunella* L., *Pulegium* Mill., *Salvia* L., *Satureja* L., *Scorodonia* Mönch., *Scutellaria* L., *Sideritis* L., *Stachys* L., *Teucrium* L., and *Thymus* L.).

Besides F. Schur's herbarium, since 2023, 584 packets of South African mosses collected by A. Rehman have been digitized. It is worth noting that each packet may contain representatives of different genera, which greatly complicates the process of further creation of the database, as it requires detailed systematic research. An example of the importance and value of continuing such research is the special investigation of LW specimens of *Fissidens eustichium* Rehman nom. nud., which since 1900 has been included in the genus *Eustichia* (Brid.) Brid., as *E. africana* (Müll. Hal.) Par. (Paris 1900). The LW specimens confirm that this species is endemic to South Africa and is different from the widespread species *E. longirostris* (Brid.) Brid., in which it was included as a synonym in 1923 (Khmil *et al*. 2022). Thus the name and the accepted status of the species *Eustichia africana* have been resurrected.

4. Conclusions

Out of over 300 000 specimens deposited in LW, the most valuable assets – from the point of view of the history of botany, taxonomy, protection of phytodiversity, cultural studies, and other related scientific disciplines – are about 20 historical collections, mostly dated to the 19th century. These include vascular plants collected by the Austrian pharmacist and botanist Dr Ferdinand Schur (7633 specimens, 2700 scanned, 380 published) and mosses from South Africa collected by Prof. Antoni Rehman, digitized since 2023 (584 packets photographed, labels entered into the database). The digital inventory of the final taxonomic and quantitative composition of Dr F. Schur and Prof. A. Rehman's collections is ongoing. New technologies have advanced our ability to solve the complex problems of studying and conserving plant diversity and expanded our scientific capabilities, as herbaria provide the basis for this important work.

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Research concept and design: L. Tasenkevich, K. Skrypets, M. Seniv
Collection and/or assembly of data: L. Tasenkevich, K. Skrypets, M. Seniv, T. Khmil
Data analysis and interpretation: L. Tasenkevich, K. Skrypets, M. Seniv
Writing the article: L. Tasenkevich, K. Skrypets, M. Seniv
Critical revision of the article: L. Tasenkevich, K. Skrypets, M. Seniv
Final approval of article: L. Tasenkevich

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