# Preserving and Promoting the Herbarium of the University of Milan through Digital Technologies

IOP Conf. Series: Materials Science and Engineering **949** (2020) 012066 doi:10.1088/1757-899X/949/1/012066

# Preserving and Promoting the Herbarium of the University of Milan through Digital Technologies

**Adriano Baratè[1], Marco Caccianiga[2], Elisabetta Caporali[2], Luca A. Ludovico[1], Silvia Pinto[2], Giorgio Presti[1], Enrico Sala[2], Antonella Testa[2]**

[1] Dipartimento di Informatica "Giovanni Degli Antoni", Università degli Studi di Milano, via G. Celoria 18, 20133 Milano, Italia
[2] Dipartimento di Bioscienze, Università degli Studi di Milano, via G. Celoria 26, 20133 Milano, Italia

E-mail: `name.surname@unimi.it`

**Abstract.** This paper deals with the application of digital technologies to the preservation and exploitation of the heterogeneous documents of the *Herbarium Universitatis Mediolanensis* of the University of Milan. The collection, dating back to the 19$^{th}$ and 20$^{th}$ Century, is mainly constituted by *exsiccata*, i.e. specimens (whole plants or plant parts) in dried form mounted on paper sheets; the archive also includes large botanical lithographs originally used in schools as educational tools. The long-term goal of the project is to complete the digitization campaign and make all these documents publicly available via a Web portal; currently, all metadata (23000 files approx.) and about 6000 digital objects are online. In this work, the whole process will be discussed, from digitization to the implementation of the Web portal based on a multimedia relational database.

## 1. Introduction

From science to technology, from medicine to humanities, the University of Milan (*Università degli Studi di Milano*) shows the evolution of a multidisciplinary knowledge. Founded in 1924, such an institution has a relatively short history, but it inherited a longer tradition of advanced studies and education in different fields, carried out by former scientific bodies. This is also why it possesses several collections of specimens, documents and books, models, instruments with a special historical and documentary value.

In particular, this paper deals with a project of preservation and valorization through digital technologies, of some of the collections that are nowadays part of the *Herbarium Universitatis Mediolanensis* (from here on, called HbMI). It is a rich heritage mainly composed of exsiccated specimen collections from 19$^{th}$ and 20$^{th}$ Century, that also includes other historical collections, i.e. wall charts and xylotheques dating around the same period and more recent specialized herbaria. It consists of tens of thousands of objects that show research and educational practices in over time.

During the past decades, the changes in training methodologies and research approaches provided a loss of interest towards the historical collections that have risked to be dispersed, also due to inappropriate conditions of preservation. Since 2017, the University of Milan carried on several projects of restoration and valorization of its heritage, which can still play an important

role as a useful scientific instrument of research and education in plant systematics and plant anatomy for botanists, but also for historians of botany, historians of education, and conservation scientists working on the preservation and promotion of cultural heritage.

Scientific literature has demonstrated that the importance of digitization in this field goes far beyond the preservation of historical heritage, including, e.g., automatically extracting specimens' characteristics [1], providing a ground base for automatic classification tasks [2], also using neural networks approaches [3], assessing commonalities and differences in herbarium sampling biases [4], and mapping plant diversity in specific geographical areas [5, 6, 7]. From this point of view, the availability of specimens in a digital format can pave the way to novel research applications.

Moreover, these collections are relevant also from an artistic point of view. In particular, botanical wall charts combine a distinguished artistic reproduction with scientific accuracy. Some exhibitions organized by the University of Milan have been greatly appreciated from the general public, also promoting the knowledge and sensitivity towards scientific historical heritage.

The rest of the paper is structured as follows: Section 2 will provide details about the heterogeneous cultural heritage preserved at the HbMI, Section 3 will describe the technologies adopted to digitize such materials, Section 4 will present the Web portal implemented in order to promote and disseminate the contents and activities of the HbMI, and, finally, Section 5 will draw conclusions.

## 2. The Herbarium Universitatis Mediolanensis

The herbaria belonging to HbMI are collections of preserved plant specimens, or parts of plants specimens, together with their label documentary information. Collected in wild and identified by experts, the plants were then pressed, dried, and properly mounted on sheets by metal pins in order to show reproductive and vegetative organs critical to identification. Each specimen was accompanied by a label with his scientific name and other information such as the family, the names of *legit* and *determinavit*, the place where it grows, the habitat and the harvest date. Plant specimens of the same species are placed, in alphabetical order, within a single, labeled "genus" folder. The organization of collections is based on Dalla Torre and Harms register: genera are arranged according to a numbering system which is based on the Engler classification system [8]. Folders are stored and protected in a herbarium cabinet. Moreover, in order to protect the specimens from insect damages, the herbarium and associated rooms are fumigated once a year; insects that could affect the specimens include silverfish or beetles (genus *Lasioderma* and *Stegobium*). Possible contaminated specimens are treated by freezing procedure.

The HbMI is based at the Department of Biosciences (formerly Department of Biology) of the University of Milan, and it constitutes the non-living heritage of the *Botanical Garden Città Studi* (*Orto Botanico Città Studi*) of the department. This affiliation is the last of a number of institutional changes that are part of the history of the collections. The main core of the historical collections arises, in fact, from the activity of the *High School of Agriculture* (*Regia Scuola di Agricoltura*), founded in 1870 by the at-the-time Ministry of Education. In 1935, the School was absorbed by the University of Milan, together with the *Brera Botanical Garden* (*Orto Botanico di Brera*), which already had a chair of botany since its foundation as a scientific institute, in 1774, mainly devoted to the advanced training of physicians and pharmacists, and to the study of local flora and useful plants. Both institutions became part of the *Institute of Botany* (*Istituto di Scienze Botaniche*) of the University that was then added to the Department of Biology, founded in 1982. This rich and articulated history is reflected by the features of the HbMI's heritage.

### *2.1. Exsiccata*

The herbaria of vascular plants preserved at the HbMI contain tens of thousands of exsiccata. Most specimens belong to Northern Italy flora, a common subject of interest for collectors and cataloguers.

Among the historical herbaria, usually named after the name of their collector/cataloguer, it is worth mentioning: Francesco Ardissone (≈ 2000 exsiccata, collected in the period 1830-1857, mainly in the Liguria region); Roberto Cobau (721 exsiccata, 1850-1870, mainly in the Lombardy region); Egidio Corti (≈ 2500 exsiccata, 1850-1870, in Milan and Origgio); Attilio Lenticchia (≈ 1000 exsiccata, 1880-1890, in the Swiss Canton of Ticino); Angelo Mazza (≈ 1300 exsiccata, 1870-1895, in Milan and its province, Naples and other Campania provinces); Mathias Schreiber (6871 exsiccata, 1840-1910, in Austria and Southern Tyrol regions); Ferdinando Sordelli (≈ 5600 exsiccata, 1851-1911, in Milan and its province and Como lowland). Moreover, there are collections made up of a relatively low number of samples: Michele Abbado Herbarium (≈ 300 exsiccata, 1893-1899); Karl Gabriel Baenitz (≈ 300 exsiccata, 1868-1901); Paul Constantin Billot (≈ 200 exsiccata, 1846-1878); Antonio Borzì (≈ 300 exsiccata, about 1880); Ludovico Caldesi (≈ 100 exsiccata, about 1860); Vincenzo Cesati (≈ 100 exsiccata, about 1870); Orazio Gavioli (≈ 200 exsiccata, 1906-1923); L.P. Haguèron (≈ 300 exsiccata, 1853-1860); Massimo Longa (≈ 200 exsiccata, 1896-1907); Luigi Micheletti (≈ 200 exsiccata, 1861-1891); Venance Payot (≈ 100 exsiccata, 1846); Lajos Richter (≈ 100 exsiccata, about 1876); Lino Vaccari (≈ 300 exsiccata, 1907-1910).

Despite a constantly ongoing process of review, the states of preservation and archiving of the original material are heterogeneous, ranging from collections reasonably ordered, with printed labels and placed in appropriate containers, to others made up of free paper sheets, each containing a specimen with autograph notes, collected into specific jackets. For example, concerning the cryptogamic collection, whose main nucleus is constituted by the *Italian Cryptogamic Herbarium*, most items have not been reorganized yet.

### *2.2. Wall Charts and Xylotheques*

The HbMI also preserves other materials presenting a high educational purpose and a relevance in terms of cultural heritage, like the wall chart collections and the historical xylotheques.

Specifically, the wall chart is a training tool that appeared in Germany in the 1820s and spread in the second half of the $19^{\text{th}}$ Century, mainly dealing with scientific subjects. Wall charts have two peculiarities: on one side they have a format large enough for easy viewing across a large classroom; on the other, the depiction of an organism in its entirety is so effective and detailed that the chart, at its time, could replace dissection labs and microscope observations. Their scientific accuracy is often accompanied by a refined aesthetic care to make scientific subjects accessible, relevant and memorable, thus representing a harmonious synthesis of art and science.

The HbMI's wall chart heritage is composed by large cromolithographs, realized between 1870 and 1920, depicting animal and plant species. Wall charts are organized in 16 sets that contain a total amount of 497 items, including the whole Dodel-Port Atlas, a collection of 42 charts (1883).

The xylotheques are documented collections of thin sections of wood of different plant species. They identify the species to which the samples belong and highlight specific properties of woods, such as porosity, grains, typical colors. Xylotheques were used to train students to recognize the various botanical species on the basis of the anatomical characteristics of the stem and trunk sections. The most relevant collection is the one made by Hermann Nördlinger, professor of Silviculture, who collected wood of about 1100 both European and exotic species between 1853 and 1888.

## 3. Digitization

This section provides some details about the digitization campaign, focusing on the technologies employed. Please note that digitization is a work in progress, consequently the description can be considered up to date at the moment of writing.

The number of materials to be digitized is small with respect to some huge collections, such as the *New York Botanical Garden Herbarium* [9], that require industrial scale digitization [10] and automated solutions [11, 12, 13]. Another relevant initiative currently under development in Italy is the *CoRIMBo* project, aiming to federate many herbaria under a common umbrella [14].

The advantage of dealing with a small herbarium is the possibility to conduct a comprehensive digitization campaign with a relatively limited budget, as discussed in [15].

Concerning the collection of exsiccata, each document is represented by a sheet of paper holding one or more specimens with a label associated. Since specimens are not completely flat and often fragile, a planar scanner would have damaged them; consequently, a contactless scanning technique was employed, thanks to a DSLR camera in controlled conditions. The device was a Canon EOS 2000D, mounting Canon EF-S 35mm f/2.8 Macro IS STM lens. The main lighting was a compact fluorescent light bulb with a power of 45W, emitting 470 lm with a color temperature of 4000 K, although some residual indirect ambient light coming from linear fluorescent lamps was present. Light settings were kept consistent during the whole digitization campaign.

The exsiccata were placed in horizontal position over a solid table. The camera was placed about 1 mt above the specimen through an IFF Super Repro stand. The light was placed just near the camera, with a light diffuser sheet. In order to reduce motion, camera mirror was lifted and locked and the shutter was remotely triggered by a smartphone via Wi-Fi, thanks to the Canon Connect app.

Camera was configured as follows: Output format set to RAW (CR2) + JPG; Picture style (for JPG generation) to Faithful; Aperture to f/4.5; Shutter speed to 1/25; Sensitivity to ISO-400; Autofocus to AF One Shot; White balance to manual, measured against a gray card (temperature 4900 K, tint +116); Flash to Off; Embedded lenses lights to Off.

The software used to post-process images was Adobe Lightroom 6.1.1. To employ such a software, first we had to convert CR2 raw files into Adobe Digital Negative (DNG v1.4) files using Adobe DNG Converter 11.1.0.112 with lossless compression settings. The configuration settings customized in Lightroom were: color noise reduction set to 7; vignetting correction (automatic from lens profile); barrel distortion correction (automatic from lens profile); chromatic aberration correction (automatic from lens profile); non-mentioned settings were left at default values. We checked the aberration automatic corrections against an A3 black and white checkerboard. The same checkerboard also permitted a precise measure of the actual resolution, that resulted to be 305.105 dots per inch (6000 $\times$ 4000 pixels for an area slightly bigger than an A3 sheet format). Concerning the digital objects in output, for each physical object we obtained: a CR2 original raw file produced by the camera; a JPG file produced by the camera; a DNG raw file coming from software post-processing; a JPG file coming from software post-processing; a JPG at lower resolution to be used as a thumbnail in the Web portal.

Another category of objects addressed by the project is the one of wall charts (see Figure 1). Most of them had been already photographed and are preserved in form of slides. In this case, a dedicated hardware was used to scan them at 4000 dots per inch. Conversely, part of the collection had never been acquired in alternative formats, and the only option was to digitize the original objects. As an additional issue, many wall charts, after their restoration, have been framed into a glass tray that cannot be removed. For this reason, once again a digital camera was used, with some ad-hoc adjustments in the setup. The lens employed for this activity was a Canon EF-S 35mm f/2.8 Macro IS STM, 1.5 to 3.0 mt from the chart (depending on

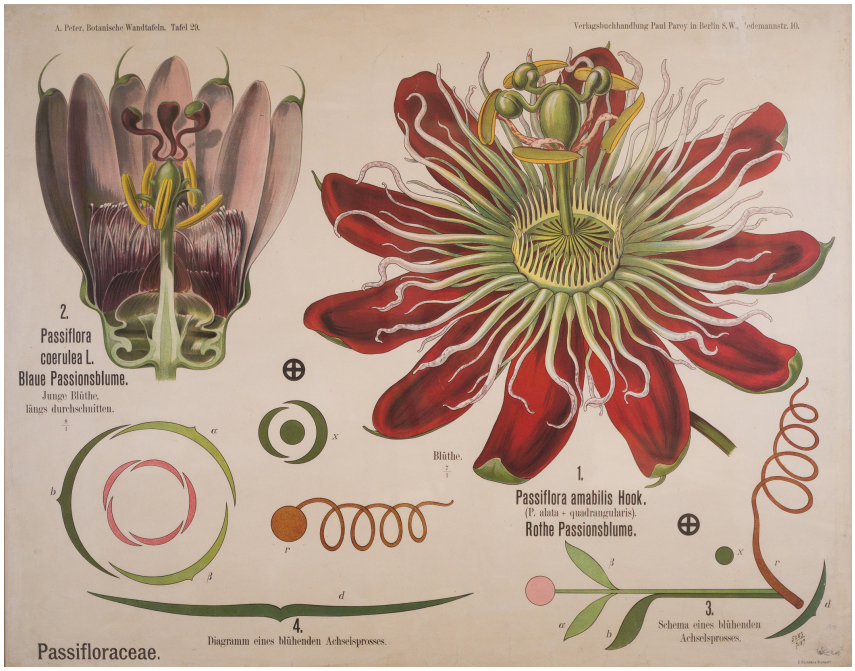


**Figure 1.** One of the wall charts of the collection.

the dimension of the panel), held in vertical position. Light was provided by two led lamps, emitting 830 lm with a color temperature of 6500 K, placed at both sides of the chart, at an angle suitable to avoid specular reflections. Also in this case, some residual indirect ambient light coming from linear fluorescent lamps was present. In order to overcome the presence of residual reflections, we mounted a polarizing filter on top of the lens when needed. Camera settings were the same listed above, but the exposition time was reduced to 1/30 due to better illumination; when the polarizing filter was mounted, the aperture was set to f/2.8; finally, the white balance point was set to 5850 K, tint +139. The output images were post-processed in the same way, so as to obtain the same set of digital objects for each wall chart. We obtained a maximum image resolution of 150 dots per inch, since all digital images are sized 6000 × 4000, regardless the actual chart size.

## 4. The Web Portal

The aim of the project was not only the preservation of the Herbarium's collections, but also their promotion and dissemination. For this reason, a Web interface has been designed, implemented and published in order to make data and metadata available online in a structured and easily accessible way. In accordance with previous experiences conducted on digital archives [16], we aimed to emphasize relationships among materials (e.g., exsiccated plants and their lithographical representations), so as to highlight correlated information and propose non-linear navigation paths. This approach can be easily applied to other archives that present heterogeneous information.

The web interface of the Herbarium has been conceived to be integrated within a wider portal embracing also the 3 botanical gardens of the University of Milan: Brera, Città Studi, and Toscolano Maderno. Due to the early phase of development of the global project, the Herbarium's section is currently available as a stand-alone Web site, at the URL `http://erbario.unimi.it`.

From a technical point of view, the Web site was developed by adopting the World Wide Web

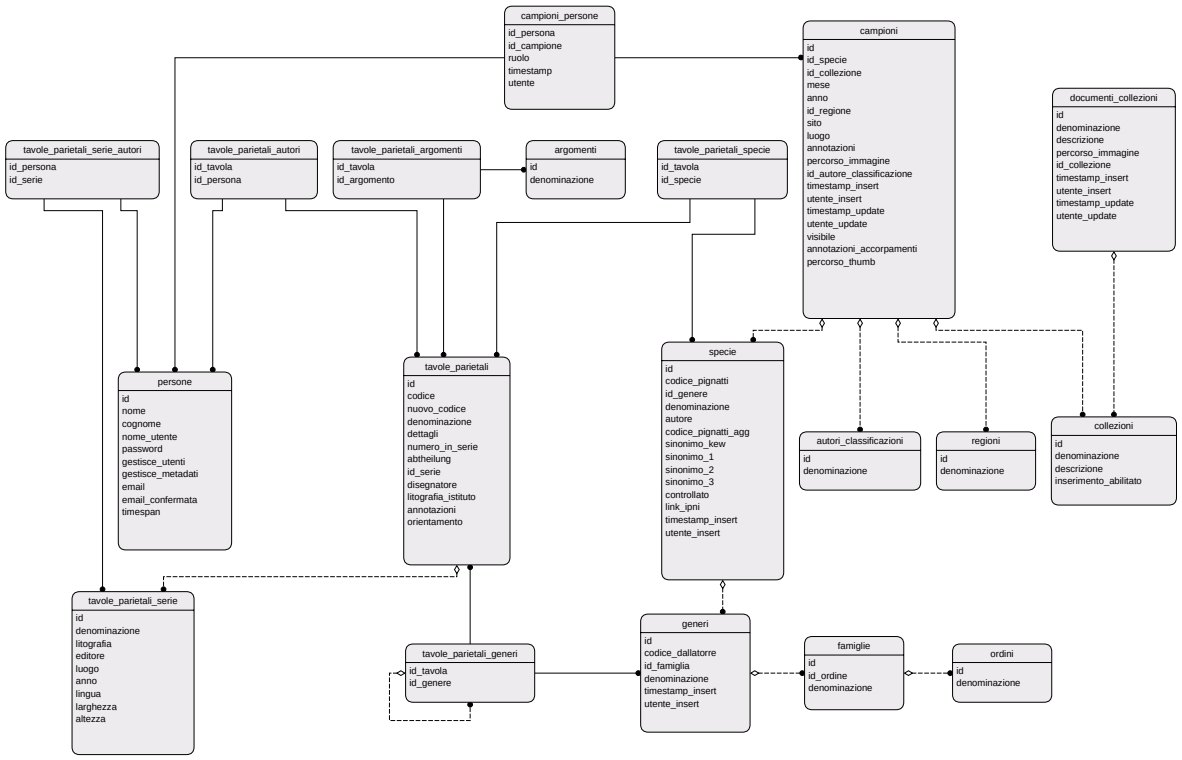


**Figure 2.** ER diagram for the Herbarium's database.

Consortium (W3C) standards, in particular HMTL5, CSS, JavaScript, and PHP. Its design is responsive, conceived to be experienced on a variety of devices and window or screen sizes. A final validation step was carried out, so as to ensure maximum compatibility with different Web browsers and operating systems. The underlying database is a relational one, implemented in PostgreSQL; its entity–relationship model is shown in Figure 2.

Figure 3 shows the homepage, which represents the entry point to access the 4 sections available to users: *exsiccata*, *collections*, *wall charts*, and *genera and species*. Such a structure has been designed to foster a quick access to information, but, as explained below, the 4 sections are far from being compartmentalized.

Hidden to not-authorized users, the portal includes a back-office section that allows to insert, modify and delete metadata and manage digital objects. Moreover, the database supports interoperability from and towards other environments. For example, catalogue information is validated and possibly integrated through an automatic link to the International Plant Names Index (IPNI, `https://www.ipni.org/`).

Now we will highlight the key features and the main advantages offered by the portal, discussing how this tool can provide an advancement in the dissemination of cultural heritage.

The first strong point of the project is the availability of a great number of high-quality digital objects, coming from the digitization campaign described in Section 3. Moreover, the Herbarium preserves not only a huge collection of exsiccata, but also a variety of other related materials, such as wall charts and xylotheques. The goal of the Web portal is to showcase and enhance such a richness by making materials easily retrievable not only by scholars, typically through metadata, but also by non-experts, thanks to intuitive navigational paths.

Concerning the latter aspect, thanks to the richness and variety of the Herbarium's assets, but also to an integrated vision of its heterogeneous contents, the goal was the creation of a

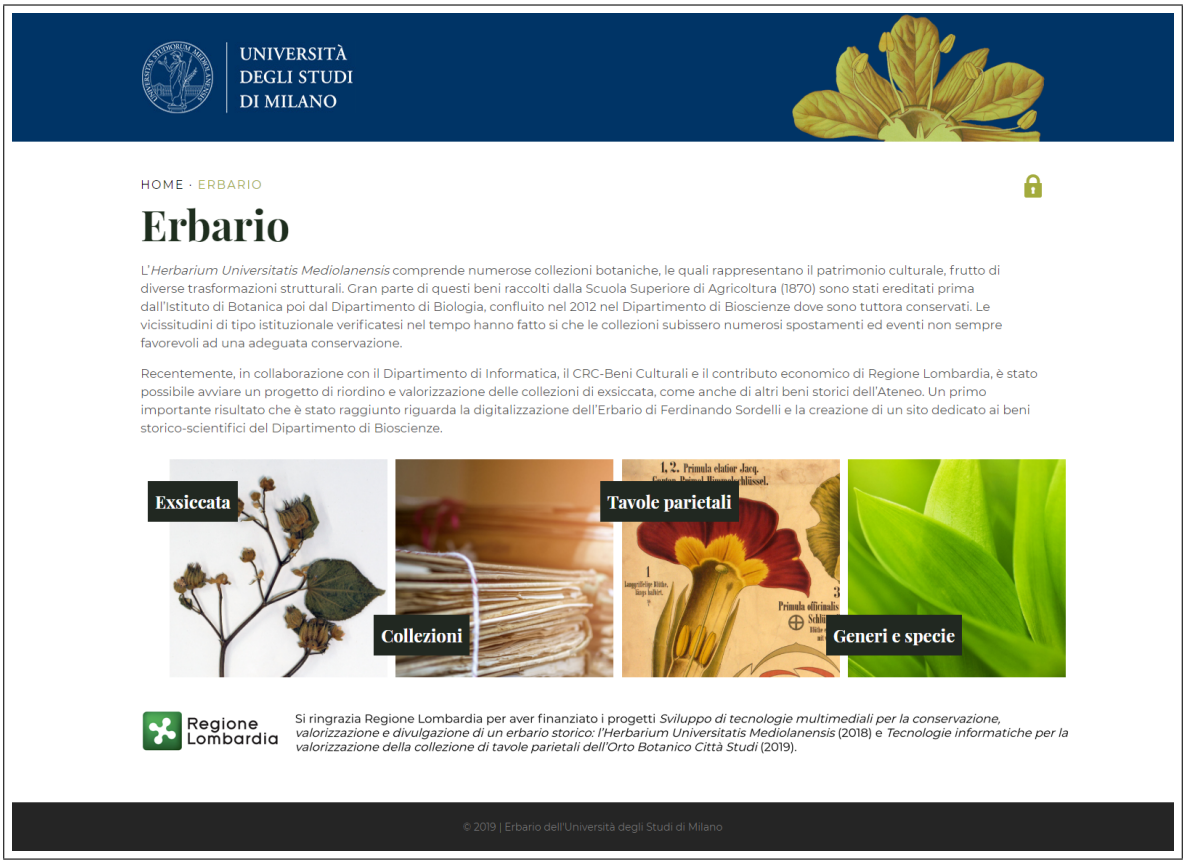


**Figure 3.** The homepage of the Web portal.

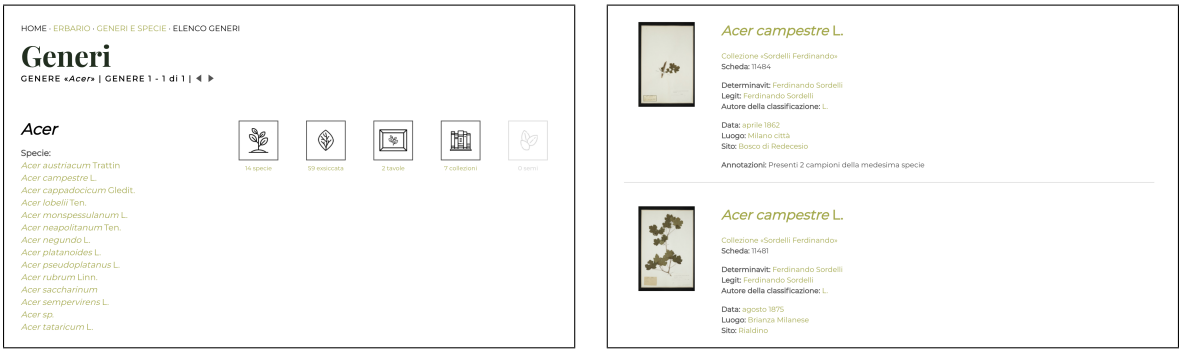


**Figure 4.** Synoptic table related to *Acer* (left) and the detail page of *Acer campestre* (right).

user-friendly interface that: i) makes relationships emerge among different instances (e.g., all the specimens of a given species), and ii) lets the user experience heterogeneous views of the same entity (e.g., the wall charts and the corresponding exsiccata of a given species, plus information about the people involved in their original classification, gathering and cataloguing). These aspects are implemented in the form of synoptic tables (see Figure 4) and detail pages rich in links towards other entities (in olive green in Figure 4).

In this way, intuitive and quick access to information is guaranteed to different classes of users. Scholars can directly access to information of interest by using search forms, whereas non-expert users can scroll through the list of available materials and explore the Herbarium's

content following the proposed links. Regarding public engagement, the activities of scientific dissemination and promotion of cultural heritage are fully in line with the so-called third mission of academia.

Finally, in order to highlight the advantages of this approach in the context of cultural heritage dissemination and involvement of a wider audience, let us describe a possible navigational path for a non-expert user. Starting from the homepage and intrigued by Herbarium's collections, the user can enter the dedicated section, open the complete list, evaluate with immediacy the richness of contents for each collection thanks to synoptic tables, and finally select the Sordelli fund, which – at the moment of writing – contains 5650 exsiccata, 848 genera and 2245 species, and 6 related documents. By clicking on the genus icon, the user jumps to a filtered view of all the genera included in the Sordelli collection, discovers that *Abies* has 5 species associated, and for them 12 exsiccata and 4 wall charts are available in 2 collections (the Sordelli and the Lombardy funds). By selecting the wall chart icon, now the user jumps to the corresponding 5-item list, that presents for each wall chart both a number of clickable metadata and the high quality scan. After opening images, the user realizes that each table contains multiple genera and species, that can be selected to move forward in a potentially never-ending exploration of contents.

## 5. Conclusion

This paper has described a multidisciplinary project dealing with the cultural heritage of the *Herbarium Universitatis Mediolanensis* (HbMI), aiming at its preservation and promotion through digital technologies. The archive hosts a number of historical collections, mainly composed by exsiccated plant specimens and wall charts.

Thanks to the richness of the original materials – concerning their number and variety – and to the transdisciplinary competences of the project staff, it has been possible not only to preserve such a cultural heritage through a digitization campaign, but also to make it publicly available to experts and easily accessible even for people untrained in Botany.

The first step of the project, that achieved about 6000 records with digital objects attached, has been completed with a budget of 25,000€ approx., covering hardware (digital camera, lenses and filters, a personal computer, storage devices, lamps, etc.), software (the database and a web site with a back-office section), ad-hoc personnel (digitization and classification operators) and external service providers (e.g., slide digitization) as well as outreach activities (i.e. exhibition panels, leaflets). In the future, we plan to extend the project to other historical funds and other categories of materials, such as xylotheque collections.

## Acknowledgements

The authors wish to acknowledge CRC Beni Culturali of the University of Milan and are grateful to Regione Lombardia for its financial support of the projects "Sviluppo di tecnologie multimediali per la conservazione, valorizzazione e divulgazione di un erbario storico: l'*Herbarium Universitatis Mediolanensis*" (2018) and "Tecnologie informatiche per la valorizzazione della collezione di tavole parietali dell'Orto Botanico Città Studi" (2019).

## References

[1] Corney D, Clark J Y, Tang H L and Wilkin P 2012 *Taxon* **61** 231–244
[2] Carranza-Rojas J, Goeau H, Bonnet P, Mata-Montero E and Joly A 2017 *BMC Evolutionary Biology* **17** 181
[3] Younis S, Weiland C, Hoehndorf R, Dressler S, Hickler T, Seeger B and Schmidt M 2018 *Botany Letters* **165** 377–383
[4] Daru B H, Park D S, Primack R B, Willis C G, Barrington D S, Whitfeld T J, Seidler T G, Sweeney P W, Foster D R, Ellison A M *et al.* 2018 *New Phytologist* **217** 939–955
[5] Schmidt M, Kreft H, Thiombiano A and Zizka G 2005 *Diversity and Distributions* **11** 509–516
[6] Seregin A P 2016 *Taxon* **65** 205–207

[7] James S A, Soltis P S, Belbin L, Chapman A D, Nelson G, Paul D L and Collins M 2018 *Applications in plant sciences* **6** e1024
[8] Torre K and Harms H 1958 *Register zu de Dalla Torre et Harms: Genera Siphonogamarum ad Systema Englerianum Conscripta* (H.R. Engelmann (J. Cramer))
[9] Thiers B M, Tulig M C and Watson K A 2016 *Brittonia* **68** 324–333
[10] Blagoderov V, Kitching I J, Livermore L, Simonsen T J and Smith V S 2012 *ZooKeys* 133
[11] Barber A, Lafferty D and Landrum L R 2013 *Taxon* **62** 581–590
[12] Tegelberg R, Mononen T and Saarenmaa H 2014 *Taxon* **63** 1307–1313
[13] Nelson G, Sweeney P, Wallace L E, Rabeler R K, Allard D, Brown H, Carter J R, Denslow M W, Ellwood E R, Germain-Aubrey C C *et al.* 2015 *Applications in plant sciences* **3** 1500065
[14] Cecchi L and Nepi C 2018 *Notiziario della Società Botanica Italiana* **2** URL `http://notiziario.societabotanicaitaliana.it/wp-content/uploads/2019/02/Erbari-5.pdf`
[15] Harris K M and Marsico T D 2017 *Applications in plant sciences* **5**
[16] Baratè A and Ludovico L A 2016 *Journal of e-Learning and Knowledge Society* **12** 109–123 ISSN 1826-6223 (print), 1971-8829 (electronic)