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Digitization of G. B. Pant University Herbarium (GBPUH) and development of Virtual Herbarium Pantnagar, Uttarakhand (INDIA)

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ABSTRACT: Virtual herbarium is a database of images of herbarium specimens and these images can be accessed via internet. It is advancement in herbarium use as physical specimens are not damaged in consultation, many users can see specimen at the same time, and the consultation of herbarium is faster and economic. Virtual herbaria can be developed from existing physical herbaria to facilitate access of herbarium. This study presents the digitization of the physical herbarium of G. B. Pant University of Agriculture and Technology, Pantnagar (GBPUH), which is also listed in Index Herbariorum. The herbarium contains more than 1500 specimens collected from different parts of Uttarakhand, and out of which 1,342 specimens, representing 34 orders, 84 families, 301 genera, and 416 species of angiosperms, were systematically digitized. High-resolution images were captured, and brief metadata which include scientific names, collection locality, and collector information, were recorded. An online database, 'Virtual Herbarium Pantnagar', was developed using the Google Sites platform, comprising 7 main pages and 97 subpages, each dedicated to a specific plant family or other information. The database hosts 454 images of herbarium specimens, with an additional 365 images accessible through embedded hyperlinks. This digital herbarium enhances accessibility of stored specimens to all interested in the flora of Uttarakhand.

Keywords: Digitization, Google sites, herbarium specimens, online access, Uttarakhand Flora

Herbarium is a storehouse of dried plant specimens collected from their natural habitat, mounted on standard herbarium sheet, arranged according to some recognized system of classification and kept in a steel or wooden cupboard and are generally associated with botanic gardens and educational institute or research organization (Paul *et al.*, 2020; Davies *et al.*, 2023). Since public herbaria are accessible, students and researchers usually visit these herbaria for plant identification and other objectives. The physical herbaria are prone to damages when not handled carefully. Such damages to herbarium specimens may result in disfigurement or even complete loss of specimen. A researcher may have to visit more than one herbarium which can be time and resource-consuming. Herbarium digitization, to a certain extent, can solve a number of issues that arise with physical herbarium. Digitized herbaria are also known as virtual herbaria which are databases consisting of images of herbarium specimens and the supporting text, available over the internet (Singh,

2019). Researchers, educators, and the general public can easily visit virtual herbaria and examine specimens from any location in the world. Herbarium digitization reduces the possibility of harm and loss of specimens and rapid exchange of information and data between institutions and researchers (Flannery, 2023; Phillips *et al.*, 2023). Virtual herbaria also make research more rapid and effective in biodiversity studies by reducing the amount of time spent on searching of specimens in the herbarium.

There are many virtual herbaria known globally, while few exist in India. Kew Herbarium Catalogue, Australian Virtual Herbarium, United States Virtual Herbarium, Virtual Herbarium of New York Botanical Garden, are some of the well-known global virtual herbaria. Large number of herbarium specimens can also be accessed through the portal of Global Biodiversity Information Facility (<https://www.gbif.org/>). In India, the largest virtual herbarium has been developed by Botanical Survey of India under the

name Indian Virtual Herbarium (IVH) (<https://ivh.bsi.gov.in/>) through which about 104,996 specimens (belonging to 12,180 species of cryptogams and phanerogams) including 27,939 type specimens can be accessed (Bharati *et al.*, 2023). In addition to IVH, some other important virtual herbaria are Janaki Ammal Herbarium, Indian Institute of Integrative Medicine, Jammu, Kerala Forest Research Institute Herbarium, Peechi, Kerala, Herbarium (JCB), The Center for Ecological Sciences, Indian Institute of Sciences, Karnataka, National Herbarium of Cultivated Plants, ICAR, Pusa, New Delhi etc.

A virtual herbarium can only be developed based on the available physical herbarium. A small physical herbarium exists in the Department of Biological Sciences, College of Basic Sciences & Humanities, G. B. Pant University of Agriculture & Technology Pantnagar which is now listed in Index Herbariorum (Thiers, 2025) with the herbarium code (acronym) as GBPUH. It includes plant specimens of different angiosperm families along with voucher specimens of scientific studies conducted on the plants by different researchers in the university. These plant specimens are majorly collected from Kumaun and Garhwal region of Uttarakhand. To make this specimen wealth accessible for researcher through the internet, digitization of this herbarium was done with limited available resources.

MATERIALS AND METHODS

To develop a virtual herbarium of the pre-existing physical herbarium, quality images of herbarium specimens are essentially required. All herbarium specimens of GBPUH were rearranged in the linear sequence of the families following Angiosperm Phylogeny Group classification (APG IV, 2016) with partial modifications given by Mabberley (2017). The genera were arranged alphabetically under the families. The current names of the species represented by the specimens were carefully checked in the standard international databases- Plants of The World Online (POWO, 2025) and Catalogue of Life (Banki *et al.*, 2025). Digital images of specimens were taken using DSLR camera Nikon D7000 (20.4 MP, with 18-105mm lens) fitted on a tripod. Photographs

were taken at 10 MP resolutions so that each image obtained is of 3-4 MB. To add scale to specimens, a 30 cm long transparent plastic scale was placed judiciously on the herbarium sheet so that it does not cover plant parts in the specimen. A copy of each obtained image is resized to 600-800 KB size in Microsoft Office Picture Manager Tool and autocorrected for best view. Unnecessary peripheral part below specimen in original images of large size was also trimmed and these images were saved separately. Resized smaller images (600-800KB) were saved in family folders. Each image was named with the updated name. All family folders were placed in a common folder and uploaded in Google drive linked to the Google Workspace account (Gmail account). The virtual herbarium template was designed using the design of online database eflorapantnagar (<https://sites.google.com/view/eflorapantnagar/home>) designed on Google Site tool (Rawat and Rao, 2020). Google site tool is a free website builder facility available with each Google Workspace account (https://en.wikipedia.org/wiki/Google_Sites) where 15 GB space is provided freely with a Gmail account. No web designing or programming language knowledge is required for developing a website here.

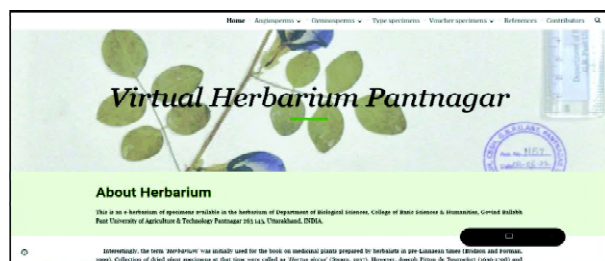
RESULTS AND DISCUSSION

Seven main pages and 90 subpages were created initially in 2022. This structure is summarized in the (Table 1). The home page (Figure 1) introduces this virtual herbarium; provide brief history of the herbarium, types of herbaria, names and herbarium holdings in larger herbaria of world, India and Uttarakhand. Families are arranged alphabetically and can be accessed from drop-down menu located at the top of the home page. For each species, only one suitable specimen image was uploaded on family page. Just below the image currently accepted name of the species is added. In addition, accession number of specimen and collector name is also displayed below specimen. Image of the specimen stored in the Google drive is linked with the scientific name displayed below image by hiding the hyperlink in it. There are four types of specimens in this herbarium (GBPUH). These are- 1) Specimen displayed at the family page on the website, 2) Specimen

Table 1: Structure of Virtual Herbarium Pantnagar (VHP)

Main Pages	Subpages	Content
Home	Home	About the herbarium
Angiosperms	Catalogue of GBPUH 86 family pages	Detailed catalogue of specimens in GBPUH Each family page contain: 1. Small image of herbarium specimen of a species 2. Current scientific name of species hyperlinked with larger image of specimen 3. Accession number of the specimen shown 4. Name of collector 5. Images of more specimens of the species, hyperlinked with numbers (1, 2, 3, 4 etc)
Gymnosperms	2 family pages	Pages contain similar information as in angiosperms
Type specimens	-	Images of 3 type specimens
Voucher specimens	3 pages	Images of voucher specimens submitted by researchers of the university
References	-	List of literature cited in the text on different pages
Contributors and	-	Details of the research students (M. Sc. & Ph. D.) who submitted their specimens
Curator		in GBPUH, and the curators
Books*	-	List of books which are available as hard copy in GBPUH

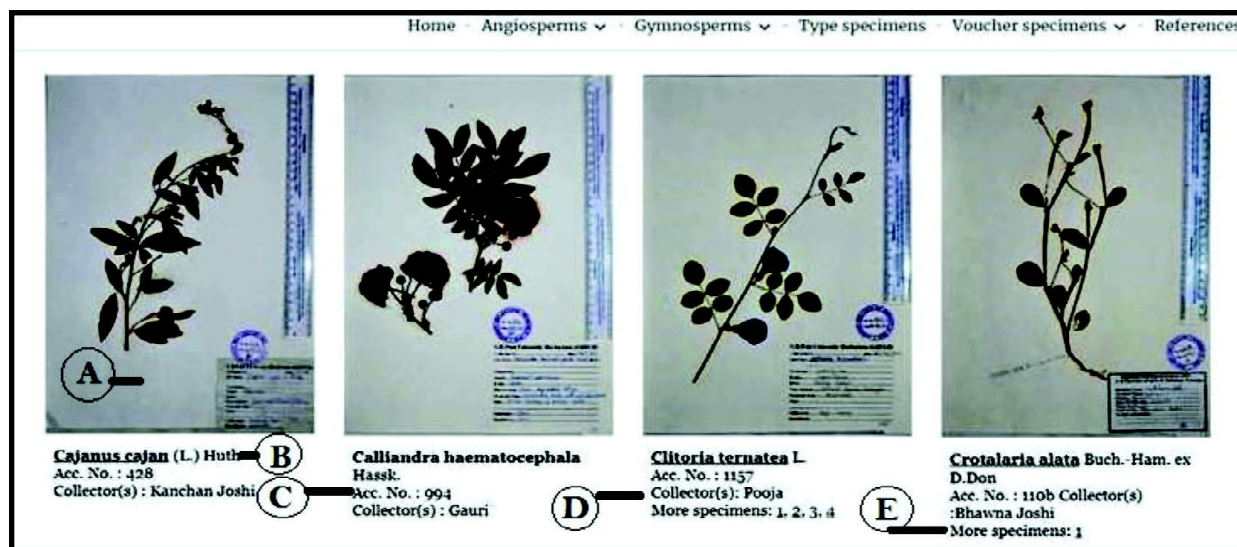
(*page added later)

**Fig.1: Home page of Virtual Herbarium Pantnagar**

mens which are hyperlinked with numbers (1, 2, 3, etc) under 'More Specimens', and can be seen by clicking on any number, 3) Specimens which are not uploaded on website, 4) Unidentified specimens

which are not uploaded on website (Figure 3). After completion of all the uploading of images and text on the pages, the Google site entitled 'Virtual Herbarium Pantnagar' (VHP) was published on the internet on 17th November, 2022. VHP is the digital face of physical herbarium GBPUH and both are not static; rather these are dynamic, being added with more specimens and information continuously.

Digitization and online access to specimens with associated data are progressing rapidly in natural history collections, including herbaria (Hedrick *et al.*, 2020). In light of this, the present study aimed to

**Fig.2: A screen shot of Virtual Herbarium Pantnagar showing specimens and details at family page; A- displayed specimen, B-currently accepted name, C-accession number, D-Collector's name, E- more specimens with link to image.**

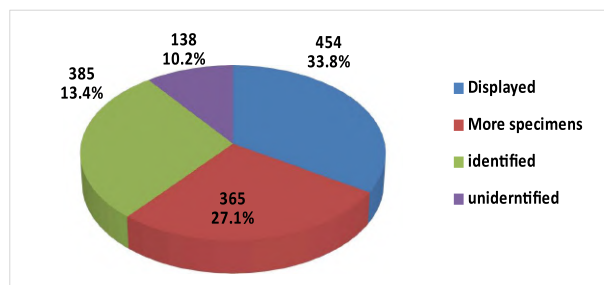


Fig.3:Status of all herbarium specimens in the physical herbarium (GBPUH) and Virtual Herbarium

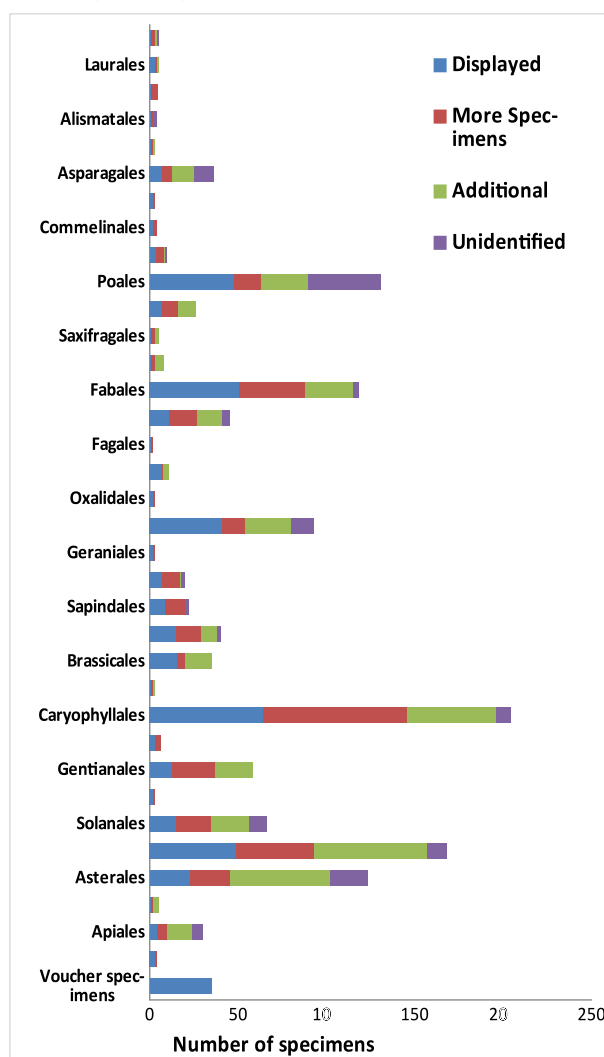


Fig.4:Specimen wise status of seed plant orders and voucher specimens in herbarium

prepare a catalogue of the physical herbarium (GBPUH), digitize it using simple, low-cost tools and techniques, and make it accessible via the internet (Sharma, 2022).

The developed online portal of the Virtual Herbarium Pantnagar (Figure 1), available at <https://sites.google.com/gbpuat-cbsh.ac.in/virtualherbariumpantnagar/home>, displays specimens as thumbnails on the family pages. The larger image of a specimen is hyperlinked to the scientific name provided below the thumbnail and can be accessed to view the specimen along with its label. A specimen of a particular species can be searched using the search box available at the top-right corner of the menu bar. GBPUH is the physical herbarium of the Department of Biological Sciences, College of Basic Sciences & Humanities, G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand (India). As of 2022, this herbarium contained about 1,500 specimens submitted by Master's and Doctoral students of the department. In addition, it includes voucher specimens from scientific studies conducted on specific plants within the university. The herbarium sheets stored in the physical herbarium (GBPUH) represent about 419 angiosperm species belonging to 35 orders, 86 families, and 304 genera, as well as a total of 4 gymnosperm specimens belonging to 1 order, 2 families, 3 genera, and 3 species, along with 35 voucher specimens. Initially, 819 specimens (approximately 60%) were made accessible out of a total of 1,342 digitized specimens. The specimen-wise status of seed plant orders in GBPUH is depicted in Figure 4, which shows *Caryophyllales* as the largest order, comprising 204 specimens belonging to 7 families, 34 genera, and 64 species, followed by *Lamiales* (159 specimens belonging to 11 families, 37 genera, and 49 species) and *Poales* (92 specimens belonging to 2 families, 36 genera, and 48 species) (Figure 4). At the family level, *Asteraceae* is the largest family, with 123 specimens belonging to 23 genera and 23 species, followed by *Fabaceae* (118 specimens belonging to 34 genera and 51 species) and *Caryophyllaceae* (110 specimens belonging to 18 genera and 43 species).

Although, India presently has more than 170 herbaria indexed in 'Index Herbariorum' (Thiers, 2025), many are still not indexed in it (Singh, 2010). However, only a small number of them provide online access to their specimens. The largest virtual

herbarium in India is developed by Botanical Survey of India, Kolkata and available at <https://ivh.bsi.gov.in/> giving access to 104,996 specimens belonging to 12,180 species of cryptogams and phanerogams which includes 27,939 type specimens (Bharati *et al.*, 2023). Some other important herbaria giving access to all or some of their herbarium specimens are The Center for Ecological Sciences, Indian Institute of Sciences, Karnataka (<http://florapeninsula-indica.ces.iisc.ac.in/welcome.php>), Janaki Ammal Herbarium, Indian Institute of Integrative Medicine, Jammu (<https://iiim.res.in/herbarium/herbarium.htm>), Kerala Forest Research Institute Herbarium, Peechi, Kerala (<http://www.kfriherbarium.in/>), Virtual Herbarium of the University of Trans-Disciplinary Health Sciences and Technology, Bangalore, Karnataka (<https://www.tdu.edu.in/herbarium>), National Herbarium of Cultivated Plants, ICAR, Pusa, New Delhi (<http://www.nbpg.ernet.in:8080/nhcp/NHCP-Index.aspx>) etc. Some other larger herbaria like Herbarium of Forest Research Institute, Dehradun (DD), Herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG) have also started digitization of their herbaria and online access of their specimens can be expected soon in the coming days.

CONCLUSION

A detailed catalogue of physical herbarium specimens available in the herbarium has been prepared in this work and the website entitled 'Virtual Herbarium of Pantnagar' (VHP) is designed as its digital face. This online access of specimens through VHP will benefit all those who are interested in flora of Uttarakhand or Pantnagar region. In India and globally, large number of smaller herbaria associated with universities or colleges exist and expected to house a large number of herbarium specimens together. However, these herbaria are hardly visible globally for not being available on the internet, and consequently rarely accessed or referred in standard publications. Smaller herbaria are equally important in contributing unique biogeographical records to county, locality, and temporal scales, and therefore, must prioritize digitization and data sharing (Marsico *et al.*, 2020). VHP also displays voucher

specimens of scientific studies conducted on selected plants and these vouchers fortify the authenticity of such studies as vouchers are important reference point for much biological work and are integral to studies where knowing the identity of a sample is essentially required (Funk *et al.*, 2005; Pleije *et al.*, 2008; Funk *et al.*, 2018). The virtual herbarium developed here using minimum possible resources and innovative approach has a potential to become a template for such smaller herbaria to unravel their wealth of herbarium specimens to all interested researchers at world arena.

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