

Virtual herbarium of Kerala Forest Research Institute, Peechi, Kerala, India

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A virtual herbarium of the specimens preserved in the Kerala Forest Research Institute, Peechi, Kerala, India has been created. Herbarium specimens were digitized using an image station and a website was developed using open-source software like Apache, MySQL and PHP. The database provides a total of 5718 records representing 203 plant families. The predominant families with maximum records represented are Arecaceae (1167 records), Poaceae (381), Orchidaceae (347), Fabaceae (270), Euphorbiaceae (239) and Rubiaceae (217). Details such as collection number, name of collector, date of collection, collection location, brief description of the habitat, phenology, besides the binomial as recorded on the herbarium specimen label are further computed and shown along with digitized specimens for each species on the species page. The 'digital herbarium' is rendered accessible at <http://kfriherbarium.org/>. The data presented are informative, user-friendly and easily accessible. The initiative is a gesture of sharing information on plant diversity of Kerala that was gathered by several researchers who have also contributed to building the herbarium.

Keywords: Flowering plants, open-source software, plant diversity, virtual herbarium.

HERBARIA are collections of dried plants, catalogued and arranged systematically for research in taxonomy, systematics and conservation. The herbarium specimens are now widely used for comparing phenology, developing species distribution models through ecological niche modelling, documenting the spread of invasive weeds and as voucher specimens for DNA barcoding¹. Herbarium specimens provide a useful means of tracking changes in the vegetation of a region over time. For example, Ronald Stuckey made 11 historical reconstructions of exotic plant spread from 1966 (ref. 2) to 1985 (ref. 3). The herbarium specimens were used to document the impact of exotic species on the floristic composition of urban or natural areas^{4,5} and also to study pollution caused by carbon dioxide⁶⁻⁸, hydrocarbons⁹, heavy metals¹⁰⁻¹², nitrogen¹³⁻¹⁵ and phosphorus¹⁶. The relevance of herbarium specimens for reconstructing phenological changes associated with climate warming is well established¹⁷⁻¹⁹. Herbarium specimens have also been used in the fields of chemical ecology^{20,21}, pollination ecology^{22,23} and insect-plant interactions²⁴. With the advent of molecular systematics, the protocols for DNA isolation from herbarium specimens have been standardized^{25,26}, and DNA extrac-

tion protocols from herbarium specimens of vascular plants as old as 200 years have been achieved.

Digital/virtual herbarium

The term 'virtual herbarium' or 'digital herbarium' has widely been applied for a web-based collection of digital images of preserved plants or their parts. Over the past five years, considerable progress has been achieved in the creation of digital assets from herbarium specimens, and in the dissemination of this information. One of the major advantages of digitization is that the specimen morphology can be visualized without damage to the original specimen. The high-resolution images of digitized specimens can be magnified; hence researchers can examine micro-morphological features of plant parts and can further access specimen information recorded on the data sheet. International herbaria like the Herbarium at the Royal Botanic Gardens Kew (<http://apps.kew.org/herbcat/navigator.do>; 468,400 specimens), C. V. Starr Virtual Herbarium at New York Botanical Garden (<http://sciweb.nybg.org/science2/vii2.asp>; 2.5 million specimen records and 1.5 million images), Geneva Herbaria Catalogue (<http://www.ville-ge.ch/musinfo/bd/cjb/chg/?lang=en>; 135,747 images), RBGE Herbarium Catalogue of Edinburgh (<http://elmer.rbge.org.uk/bgbase/vherb/bgbasevherb.php>), etc. have opened up their digital collections to a wider audience. In India, the major initiatives on digitization of

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herbaria have been accomplished by the Indian Institute of Science Herbarium {(JCB) <http://florakarnataka.ces.iisc.ernet.in/hjcb2/>}, Herbarium, Raw Drug Repository of FRLHT ((FRLH) <http://envis.frlht.org/digital-herbarium-main.php>}, Herbarium of JNTBGRI {(TBGT) <http://www.jntbgri.in/tbgtherbarium/contacts.asp>}, Janaki Ammal Herbarium in the Indian Institute of Integrative Medicine {(RRLH) <http://www.iiim.res.in/herbarium/herbarium.htm>}, the Herbarium of French Institute of Pondicherry {(HIFP) <http://ifp.plantnet-project.org/search>} and Herbarium of Regional Plant Resource Center, Odisha (http://www.rprcbbsr.com/View/digital_herbarium.aspx).

KFRI herbarium

The Kerala Forest Research Institute (KFRI) herbarium was established in 1982 as part of a research project by Sasidharan and Nambiar²⁷ with 6000 specimens. It is recognized by the International Association of Plant Taxonomists (IAPT), and is known by the acronym KFRI by Index Herbariorum (Taxon 37: 503. 1988). Presently, the herbarium holds over 11,000 specimens representing more than 2140 species from 203 families. It holds a wide collection of medicinal plants from South India and a Pan Indian collection of rattans, palms and bamboos including those from the Andaman and Nicobar Islands. In addition to this, accession process is underway especially for the completed regional floras such as Flora of Parambikulam Tiger Reserve²⁸, Flora of Aralam²⁹, Flora of Shendurney Wildlife Sanctuary³⁰, Flora of Chinnar³¹, Flora of Periyar Tiger Reserve³², Flora of New Amarambalam Reserve³³, Flora of shola forests³⁴ and lichens of Kerala³⁵. This will strengthen the herbarium to become one of the major centres representing a repository of the dried specimen collection of both lichens and flowering plants of South India. To facilitate access to the KFRI herbarium collection, a database has been prepared that includes information presented on the herbarium specimen label, such as species name, author citation, subspecies if any, family, collection number, location, date of collection, habitat and name of collector. Nomenclature status of the specimens was updated using 'The Plant List' (<http://www.theplantlist.org/>) and the DVD version of Flowering Plants of Kerala³⁶. Herbarium specimens were digitized using Canon PowerShot G9 camera fixed on an imaging station and high-resolution images (12.1 megapixels) thus obtained were stored in TIF format. Images have been edited and a standard scale is provided.

Data and web design

The website was developed using standard open-source softwares such as Apache, a web server (<http://www.apache.org/>); MySQL, a database system (<http://www.mysql.com/>), and PHP, a scripting language (<http://www.php.net/>).

The website provides search interface with provision to search for different parameters of herbarium. Plant taxonomic data are stored in the database that allows rapid indexed search. High-quality digital images are stored as separate files for greater efficiency in magnifying and are displayed using advanced graphics. The database includes a total of 5718 records representing 203 families. The predominant plant families with maximum records represented are Arecaceae (1167 records), Poaceae (381), Orchidaceae (347), Fabaceae (270), Euphorbiaceae (239) and Rubiaceae (217).

Search from the home page

The website provides basic and advanced search capabilities. Default/basic search is carried out in all fields of the herbarium database, whereas advanced search is allowed in specific fields like genus, species, local names, etc. For accessing specimens, text is entered in the text box provided on the home page and search is allowed for the text string in the fields of family, genus/species (scientific name), locality, local name, etc. (Figure 1). To search specimens of a particular family, typing the initial letter of the family in the text box is sufficient as search criteria (Figure 2). In the results section, three columns will be displayed; the entire list of specimens with basic details in the first column, collection details with thumbnail images in the second column and larger images of each thumbnail for full-screen option in the third column. The first column will enable monitoring rich/poor representatives of the collection family-wise. The second column displays full details for a single specimen record. Here the details of accession number, date of collection, locality, botanical name, habit, altitude, habitat, local name, other morphological details, name of the collector, Determinavit can be referred. The genus/species field can be used to search scientific name of the plants. For example, the search term 'wightii', helps filter all specimens with specific epithet 'wightii' such as *Anaphyllum wightii*, *Arenga wightii*, *Atalantia wightii*, etc. For search in criteria habit or habitat, queries can be made through the search window such as river, mangrove, evergreen forests, solitary, clustered, herb, shrub, tree, shola, etc., Queries can also be built on multiple keys by clicking on string 'all' and typing 'climber deciduous forest yellow flower' in the text box as an example. Then six hits will appear displaying the climbers found in deciduous forest with yellow flower. For searching specimens of plants in different altitudes, four sub-categories are provided by selecting exact, above, below or between options as given in the left of the search window. The interface is also built on Unicode Malayalam for search using vernacular names of plants and location.

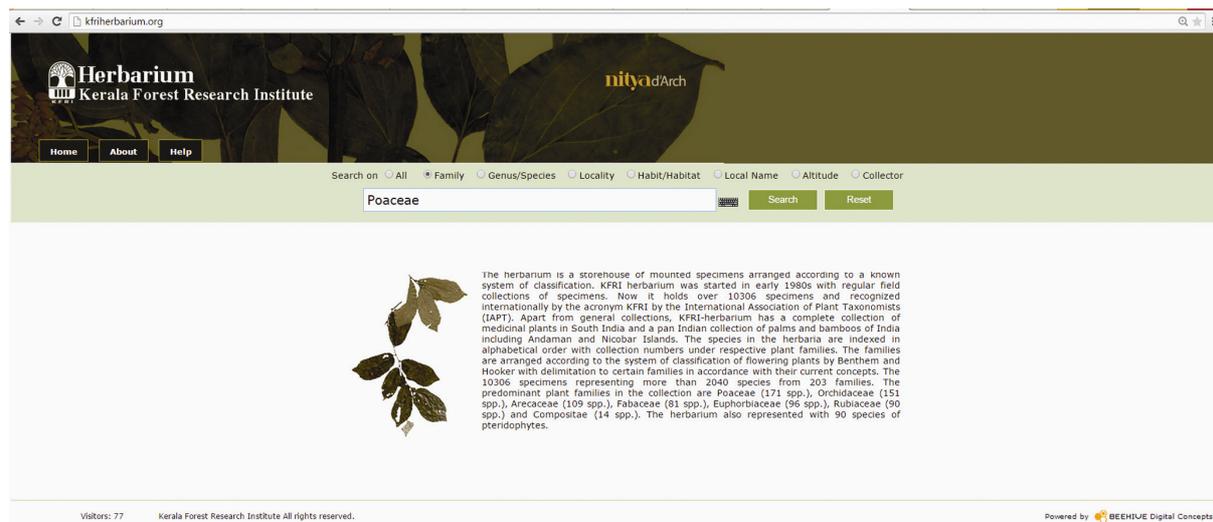


Figure 1. Home page of the KFR digital herbarium.

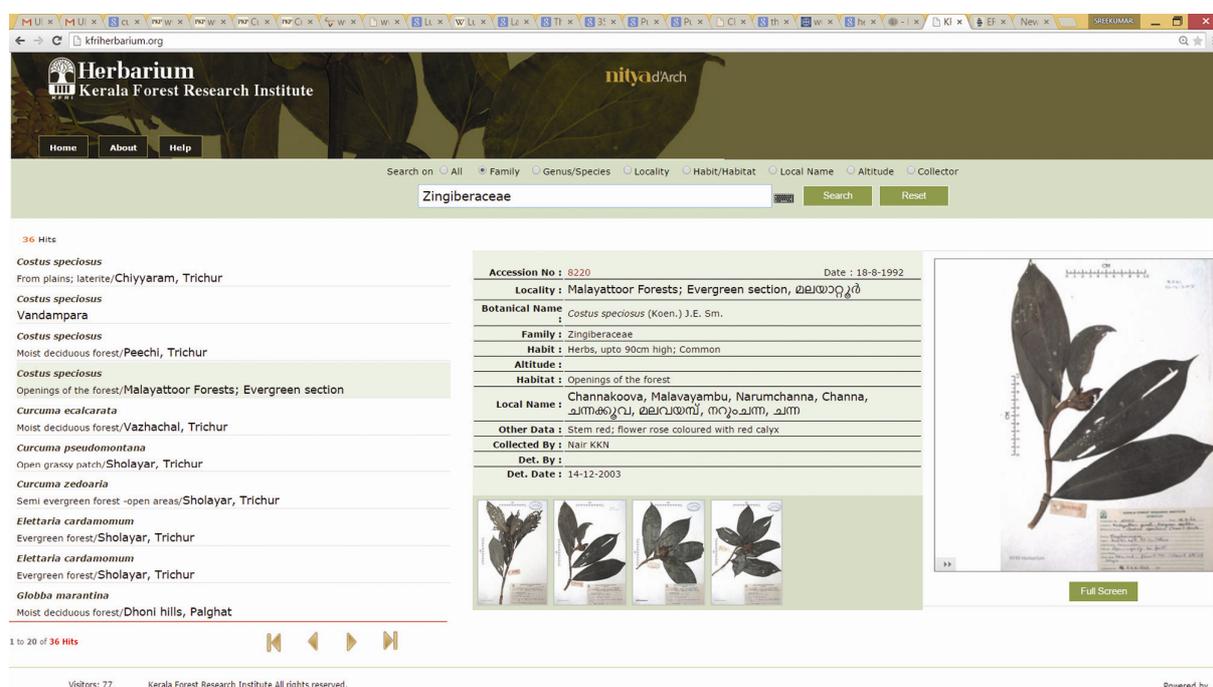


Figure 2. Family-wise search criteria showing species page details.

The ‘full-screen’ option in the third column, opens a new window displaying a screen-size image of the specimen. For certain accessions, several images are available for each hit representing different morphological parts. The larger image of each thumbnail will provide zooming, and moving pan options will facilitate analysis of the micro-morphological features of specimens (Figure 3 and 4).

Conclusion

The KFR herbarium database provides a comprehensive, high-quality information system on plant resources of

Kerala. The availability of on-line digital images will form an indispensable part of primary data provision for floristic research, and this will strongly influence the work of professional botanists. Moreover, this on-line database will have tremendous impact on research and education in plant systematics, ecology, plant community analysis, phenological studies, environmental sciences, agriculture and forestry. Also, regular updating of this database will provide access to data on plant diversity of a region(s) or on the collection that the herbarium has in its care. KFR digital herbarium representing forest flora will be highly useful to the Forest Departments, State

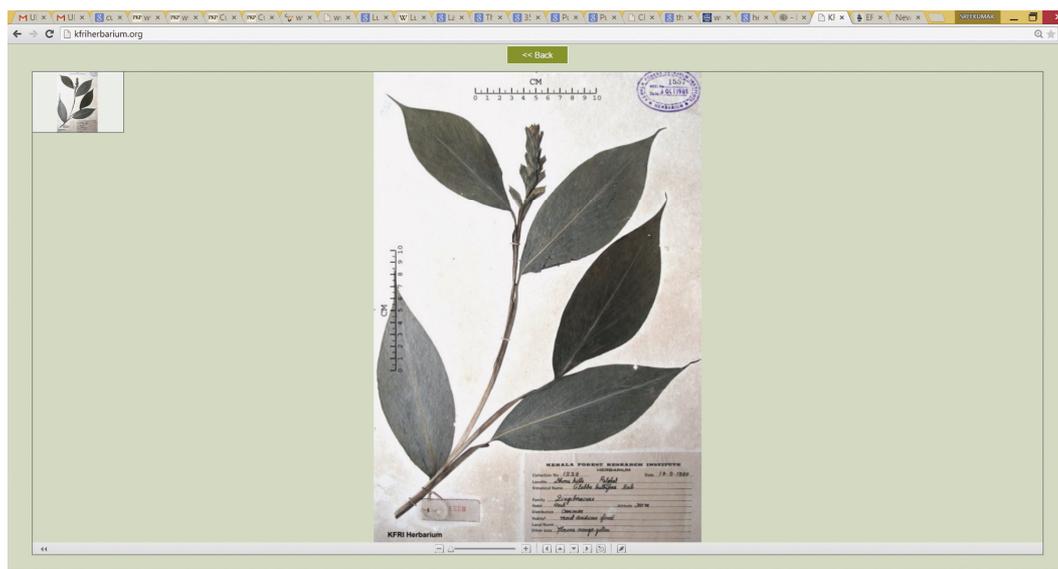


Figure 3. A specimen webpage.

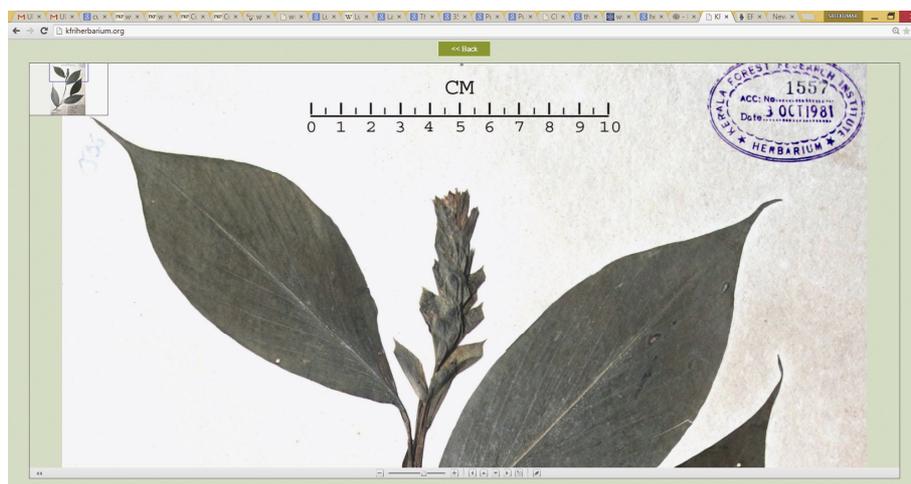


Figure 4. Zooming option to enable study of micro-morphological features.

Biodiversity Boards, universities, research institutions, students and teachers. KFRI herbarium data can be accessed at <http://kfriherbarium.org/>

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