

# A digital herbarium for the flora of Karnataka

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*A herbarium-based database (virtual herbarium) is a referral system for plants that maximizes the usefulness of the collections. The information content of such a database is essentially built on the voucher specimens that the herbarium has in its care. The present article reports on the construction of a 'virtual herbarium' for the state-wide collection of flowering plants in the Herbarium JCB housed at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, that is expected to be launched soon. The taxonomic data on each species include all information presented on the herbarium specimen label, namely species name, author citation, sub-species if any, variety if any, family, subfamily, collection number, locations, date of collection, habitat and the collector's name. The data further comprise 'flora' in which the species are described. Additional information includes the nomenclature update according to 'The Plant List', a detailed description, phenology, species distribution, threat status and comments on any special features of the taxon. The live images of the species provided in the database form an information synergy on the species. This initiative is the first of its kind for herbaria in peninsular India.*

**Keywords:** Field images, flora of Karnataka, flowering plants, Herbarium JCB, virtual herbarium.

THE flora of Karnataka is one of the richest in the country and belongs to diverse vegetation types and formations ranging from coastal land plants to montane flora of the Western Ghats, from four-storied tropical evergreen monsoon forests to semi-arid thorn forests and scrub. Of the 38,224 sq. km of forest spread over 33 districts, a large portion is embedded in the sprawling Western Ghats, regarded as one of the global hotspots of biodiversity<sup>1</sup>. The Western Ghats is also home to an overwhelming majority of plant species of the state with immeasurable diversity.

Information on this plant wealth collected over many decades is vouchered as herbarium specimens in the bio-resource repository, Herbarium JCB (JCB, the international acronym) at the Centre for Ecological Sciences (CES), Indian Institute of Science (IISc), Bangalore. Currently, Herbarium JCB is unquestionably the only holding in this state that has specimens collected from all over Karnataka, correctly identified and the determinations authenticated by specialists, and with duplicates deposited with herbaria of the Royal Botanic Gardens at Kew, England and the Smithsonian Institution, Washington DC, USA. Herbarium JCB contains 14,000 collections ranging from lichens to flowering plants.

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Cecil J. Saldanha (who was associated with CES) and his associates made significant contributions to this herbarium in the late 1980s and early 1990s. Further, the information derived from his state-wide collection was compiled into publications<sup>2-4</sup>. Therefore, it emerges that the collection in Herbarium JCB has both the voucher specimens and their descriptions published in floras in place.

Enumeration of the state's flora was attempted at different points in time. *Flora of the Presidency of Madras* by Gamble<sup>5</sup>, one such earlier work that included parts of present-day Karnataka, was carried out before independence. Post-independence, floristic work was carried out by the Botanical Survey of India<sup>6</sup>, but not with the intent and intensity to accomplish an exhaustive inventory exclusively for the state. Nevertheless, several valuable district-level floras<sup>7-18</sup> were brought out within the state from time to time. *Flora of Karnataka* was the first ever state-wide floristic initiative carried out between 1978 and 1996 under the stewardship of Saldanha.

Herbaria are repositories to safeguard plant samples of a given area or region and serve as reference and study material to help improve our knowledge of biodiversity. Herbaria constitute an irreplaceable wealth for research and education. Properly sampled and preserved herbarium specimens are valuable aids in teaching and research. Herbarium specimens are now used for studies in disciplines which were probably never ever imagined at the time early collections were made. Importantly, they provide the archival material for comparison of species earlier and now in eco-physiological, climate and global



**Figure 1.** Home page of the digital herbarium database.

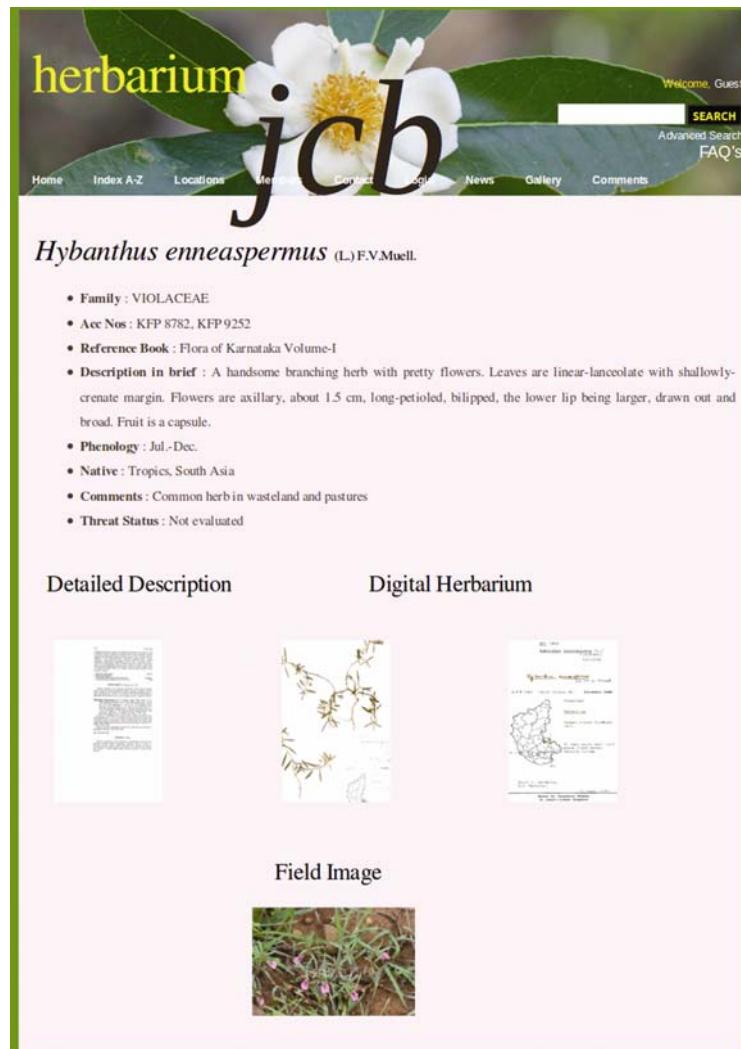
change research. For example, herbarium specimens have been used to study changes in leaf nitrogen<sup>19</sup> and stomatal density<sup>20</sup> in forest trees in response to reactive nitrogen deposition and increase in global atmospheric carbon dioxide respectively. Herbarium specimens as such are essential for a lasting record of the flora of a location or a region. A herbarium further helps in making knowledge available for a given species. This knowledge ultimately will be used for the preservation of the species and spaces (habitats).

Modernization of herbaria in tune with changing needs would enhance their potential usefulness as a baseline for scientific utility. Today, information on botanical collections is made more accessible than ever before through digitization, database development and the internet. The construction of a comprehensive database for Herbarium JCB remained a goal of the highest priority for CES, since this is the only means by which the large quantities of data concerning the native and naturalized plants of Karnataka can be made readily available for diverse purposes for which they are required. This could equally benefit the scientific community and the public at large. Our continuing interest in the development of an information system for the flowering plant flora of Karnataka has prompted us to make serious efforts in this direction and

from our ongoing work, the database has reached a stage of near completion.

## Data content

Plant taxonomic data to be presented on the 'Herbarium JCB' website (Figure 1) encompassing about 4,000 flowering plant species were first entered into Microsoft Excel spreadsheets by herbarium staff and volunteers. Each entry has all the information presented on the herbarium specimen label, including species name, author citation, sub-species if any, variety if any, family, subfamily, collection number, locations, date of collection, habitat and the collector's name. The data further comprise 'Flora' in which the species are described. Additional information includes the nomenclature update according to 'The Plant List' (<http://www.theplantlist.org/>), a detailed description in a scanned copy of the Flora pages, phenology, distribution, threat status and comments on any special features of the taxon. The digitized herbarium specimens at a minimum resolution of 300 dpi and images of live specimens provided in the database form an information synergy on the species. Once entered, the data were



**Figure 2.** A specimen webpage.

subjected to scrutiny for accuracy and formatting consistency, and subsequently imported into MySQL database tables. Editing is nearly complete for most records (entries) and these have been already imported. A map is provided showing the approximate location from where each specimen was collected (Figure 2).

### Website design

The website was developed using standard open-source software on the Linux operating system, including 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/>). Plant taxonomic data are stored in the database, which allows rapid indexed searches to be carried out and the content to be generated dynamically. Binary (non-text) content such as high-quality digital image files and documents requiring considerable storage are stored on the file system instead of inside the database, for greater efficiency.

### Website user interface

An image gallery is provided that allows species to be identified by browsing images. Each image is hyper-linked to the corresponding species webpage. Alphabetically sorted species and family lists allow users to browse by species name and family respectively. The website provides basic and advanced search capabilities. Text entered in basic search is searched in all fields of the herbarium database, while advanced search allows text to be searched in one or more fields (for example, genus, threat status or common name). A comment widget allows users to report corrections or provide any feedback.

### Herbarium-based databases

Herbarium-based databases (virtual herbaria) worthy of mention are Herbarium Catalogue of the Royal Botanic Gardens (RGB) at Kew (<http://apps.kew.org/herbcat/navigator.do>); Tropicos, the interactive database of Missouri

Botanical Garden (<http://www.tropicos.org/>); C. V. Starr Virtual Herbarium from New York Botanical Garden's International Plant Science Centre (<http://sciweb.nybg.org/science2/VirtualHerbarium.asp>); BGCI – Botanic Gardens Conservation International with several centres (<http://www.bgci.org/>); Herbarium Berolinense of Botanical Garden and Botanical Museum (BGBM) at Berlin – Dahlem (<http://www2.bgbm.org/Herbarium/default.cfm>), and Plant Database, Northern Ontario, Canada (<http://www.northernontarioflora.ca/>).

## Databases in India

Although India has an excellent collection of specimens vouchered and maintained in several well-known herbaria, interactive, online virtual herbaria are few. Recently, some virtual herbaria are being launched. LWG – virtual herbarium of the National Botanical Research Institute, Lucknow (<http://www.nbri.res.in/herbarium/>) is one such database that carries digitized specimens with information that is present on the species name labels. Images of live specimens of corresponding species and their detailed descriptions, however, are not provided. The other digital herbarium that needs a mention is that of the Regional Plant Resource Centre (RPRC digital herbarium), Odisha (<http://www.rprcbsr.com/herbarium/>), the Janaki Ammal Herbarium (formerly RRL, Jammu; <http://www.ijim.res.in/herbarium/herbarium.htm>), and the National Institute of Oceanography (NIO) – Digital Herbarium ([www.nio.org](http://www.nio.org)). Other than these, there are some attempts to digitize herbarium specimens and make them web-based at other places, including the Botanical Survey of India. These are either partially complete or still in infancy<sup>21,22</sup>.

## Conclusions

A herbarium-based database is an information system that provides access to data on plant diversity of one or more regions, or on the collection that the herbarium has in its care. The information content of the database is essentially built on the voucher specimens. The presentation of this information implies that the voucher specimens shown are available with that herbarium for examination and for further research, and that the data strictly pertain to the species vouchered in the specimens. Herbarium specimens hold such hidden information that is not obtainable in a photograph or in a lengthy description. For this reason, herbaria and organizations hosting databases must exercise management activities to safeguard these specimens. A conventional herbarium database, thus, maximizes the usefulness of the collection by providing authentic and lasting information. In this context, the cur-

rent initiative is the first of its kind for herbaria in peninsular India.

1. Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, A. B. and Kent, J., Biodiversity hotspots for conservation priorities. *Nature*, 2000, **403**, 853–858.
2. Saldanha, C. J. and Nicolson, D. H., *Flora of Hassan District, Karnataka, India*, Amarind Publishing Co Pvt Ltd, New Delhi and C. J. Saldanha, 1976.
3. Saldanha, C. J., *Flora of Karnataka*, Oxford and IBH Publishing Co, New Delhi, 1984, vol. 1.
4. Saldanha, C. J., *Flora of Karnataka*, Oxford and IBH Publishing Co, New Delhi, 1996, vol. 2.
5. Gamble, J. S., *Flora of the Presidency of Madras*, West, Newman and Adlard, London, 1915–34, vols 1–3.
6. Sharma, B. D., Singh, N. P., Raghavan, R. S. and Deshpande, U. R., *Flora of Karnataka: Analysis*, Botanical Survey of India, Kolkata, 1984.
7. Ramaswamy, S. V. and Razi, B. A., *Flora of Bangalore District*, Prasaranga, University of Mysore, Mysore, 1973.
8. Ramesh, S. R., Studies on the flora of Kolar District. Ph.D thesis, University of Mysore, Mysore, 1990.
9. Rao, R. R. and Razi, B. A., *A Synoptic Flora of Mysore District: With an Appendix of Unani, Ayurvedic, and Trade Names of Drugs*, Today & Tomorrow's Printers and Publishers, 1981.
10. Murthy, K. R. K. and Yoganarasimhan, S. N., *Flora of Coorg (Kodagu), Karnataka, India with data on Medicinal Plants and Chemical Constituents*, Vimsat Publishers, Bangalore, 1990.
11. Gopalakrishna Bhat, K., *Flora of Udupi*, Indian Naturalist, Udupi, 2003.
12. Seetharam, Y. N., Kotresha, K. and Uplaonkar, S. B., *Flora of Gulbarga District*, Gulbarga University, Gulbarga, 2000.
13. Manjunath, B. K., Krishna, V. and Pullaiah, T., *Flora of Davanagere District*, Regency Publications, New Delhi, 2004.
14. Ramaswamy, S. N., Radhakrishna Rao, M. and Arekal, G. D., *Flora of Shimoga District, Karnataka*, Prasaranga, University of Mysore, Mysore, 2001.
15. Singh, N. P., *Flora of Eastern Karnataka*, Mittal Publications, New Delhi, 1988, vols 1–2.
16. Gowda, B. K., *Vanaspatti Kosha – Plant Wealth of Sringeri*, Kalpatharu Research Academy, Bangalore, 2004.
17. Yoganarasimhan, S. N., Subramanyam and Razi, B. A., *Flora of Chikmagalur District*, International Book Distributors, Dehra Dun, 1982.
18. Bhat, K. G. and Nagendran, C. R., *Sedges and Grasses: Dakshina Kannada and Udupi Districts*, Bishen Singh Mahendra Pal Singh, Dehra Dun, 2001.
19. Hietz, P., Turner, B. L., Wanek, W., Richter, A., Nock, C. A. and Wright, S. J., Long-term change in the nitrogen cycle of tropical forests. *Science*, 2011, **334**, 664–666.
20. Woodward, F. I., Stomatal numbers are sensitive to increases in CO<sub>2</sub> from pre-industrial levels. *Nature*, 1987, **327**, 617–618.
21. Chaudhri, N. and Kumar, S., Digital archiving and management at NIC. *Informatics*, 2010, **18**, 12–13.
22. Tetali, P., Tetali, S. and Lale, M., Computer-based herbarium sheets and their uses in plant identification. In Proceedings of National Seminar on Plant Biodiversity, Systematics, Conservation and Ethnobotany, Department of Botany, North Bengal University, 9–11 November 2000.

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