

Indian Herbaria: Legacy, floristic documentation and issues of maintenance

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Abstract

Indian herbaria have a long history of providing data for taxonomic and floristic studies of Indian plants; now they also have a number of other special functions: they act as guiding sources for prioritized field work in unexplored or underexplored areas and for focussed collections of species that are inadequately represented in herbaria. Fresh collections of rare species resulting from such field work may represent rediscovery of species from already known localities or may represent new habitats. New collections may help to bring in clarity on morphology of less known taxa owing to poor or scarce material. In the last 10 years, about 40 species, which were previously only known from the type collections, were located again in the field by the Botanical Survey of India or by other taxonomy research centres or departments in the country. A good proportion of the Indian plants in European herbaria represent type specimens or other authentic material, but many names also have isotypes in or can be typified solely on old collections in Indian herbaria, thus underlining the importance of these old collections in India. Although data from the period 2007–2013 showed that the majority of new species in the Indian flora were described from fresh material resulting from field work, the gathering of some of this material was prompted by the need for further collections of incomplete or poor specimens from the past, specimens that had been left unidentified in Indian herbaria. Here, we survey the wealth of historical and modern specimens kept in Indian herbaria and the multiple implications of conserving this wealth of material, including financial consequences. Recent progressive explorations in unexplored or under-explored areas have added numerous specimens to the holdings of Indian herbaria, which further adds to the financial and practical challenges of herbarium maintenance. New methods pave the way for more effective documentation of the flora and use of the specimens, but also add to the tasks of herbarium curation: High-quality photographs of plants in the field and their habitats; more detailed information about the precise location of specimens, using coordinates obtained with GPS; increased accessibility of specimens by scanning and digitization. Currently, multinational collaborative projects promote joint exploration and facilitate full exposure of specimens, as well as of old literature and correspondence (published and unpublished) relating to the Indian flora. These projects are carried out in collaboration with renowned experts and reputable organizations and will boost our pace of publishing a National Indian Flora with desired excellence.

Key Words: digitization, floristics, herbaria holdings, multilateral collaboration, specimens, taxonomic literature

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The earliest literature referring to Indian plants is in the Sanskrit classic, *Charaka Samhita*, probably written 1000–800 BC). This work had been in use for preparing herbal formulations in agreement with Ayurveda ('science of life'), the traditional Indian mind-body health system. Garcia de Orta (1563), a Portuguese physician, published a treatise on medicinal and economic plants of India based on plants grown in his garden at Goa. Hendrik Adriaan van Rheede tot Drakenstein (Rheede 1678–1693) gave a detailed account of Malabar plants (*Hortus Malabaricus*) in 12 comprehensively illustrated folio volumes.

Indian botany according to the principles of Linnaeus began with Royal Danish physicians and explorers. Johann Gerhard König was born in what is now the Baltic state of Latvia, but came early to Denmark. He studied in 1757–1759 with Carl Linnaeus in Uppsala, Sweden, and returned to live in Denmark from 1759–1767 to study pharmacology and medicine and work as an assistant with botanical exploration of Denmark. In 1767, he was sent to work as a doctor at the Danish trading post at Tranquibar (known in Tamil: *Tharangambadi*), which he reached in 1768. From 1773 to his death in 1785, he worked as a naturalist for the Nawab of Arcot, a state in southern India, and formed an informal botanical association, the 'United Brethren', mostly Moravian and the Lutheran missionaries, but his associates also included British medical officers of the Madras Presidency. König sent duplicates of his collections to Copenhagen and a number of other European herbaria. He published relatively little himself, but sent specimens and descriptions to European botanists, who published them. Examples of this are the descriptions of the new genera *Metroxylon* Rottb. (Arecaceae), *Thottea* Rottb. (Aristolochiaceae) and *Wormia* Rottb. (Dilleniaceae) by the Danish botanist C.F. Rottböll (1783) in the early publications of the Royal Danish Academy of Sciences and Letters, the institution which now organize this symposium. König became a friend of William Roxburgh, a fellow medical doctor, who attended him on his deathbed, where König donated his manuscripts to Sir Joseph Banks in London.

The continued expansion of the British Empire

between the 17th and 19th centuries was driven mainly by search for commodities, such as spices and crop plants, and the establishment of new markets for British goods. As a part of this objective, by the late 18th century, the East India Company had established botanic gardens at Samarlakot (now, nonexistent) and Calcutta (now Kolkata, more precisely on the right bank of the Hooghly River at Howrah) in West Bengal, specifically to know and experiment with native plants suitable for cultivation. The Establishment of the Garden at Calcutta was initiated by Col. Robert Kyd (Superintendent of the garden 1787–1793). William Roxburgh was appointed in 1794 as the next Superintendent of the Calcutta Botanic Garden. He was the author of the *Plants of the Coast of Coromandel*, dealing with plants from southern India (Roxburgh 1795–1820), the *Hortus Bengalensis*, a catalogue of the garden at Calcutta (Roxburgh 1814) and the *Flora Indica*, the first attempt at an Indian flora, edited posthumously by the missionary and botanist William Carey and Nathaniel Wallich at Serampore (Roxburgh 1820–1824, 1832), and he organized a large collection of illustrations of Indian plants, *Icones Roxburghianae*, 35 volumes, with duplicate sets at the Calcutta Botanic Garden and the Royal Botanic Gardens, Kew, UK, now published by the *Botanical Survey of India* (Roxburgh 1964–1978). His descriptions are remarkably complete, as he grew the plants in his garden and examined them in all stages of their growth.

From 1817–1845 Nathaniel Wallich was superintendent of the botanic garden at Calcutta. At first he acted in a temporary position after Roxburgh, who had retired to Scotland in 1813, was replaced by the Scottish physician Francis Buchanan-Hamilton in 1814–1815, but obtained permanent position as superintendent in 1817. He produced notable works in the flora of India and Nepal. Wallich was born in Copenhagen, Denmark, and had been sent as a surgeon to work at the Danish trading post of Serampore north of Calcutta. Following an expedition to Nepal in 1820, he produced *Tentamen Florae Nepalensis Illustratae* (Wallich 1824–1826), printed at the Missionary Press at Serampore, where Roxburgh's *Flora Indica* had also been printed. From 1826–1827 Wallich studied the na-

ture of Ava and Lower Burma. After a number of years as Superintendent of the Calcutta botanical garden he produced the beautifully illustrated work *Plantae Asiaticae Rariores* (Wallich 1829-1832), with illustrations mainly by Indian botanical artists employed by the Calcutta Botanic Garden: 146 drawings were by Gorachand, 109 were by Vishnupersaud and one by Rungiah. Another of Wallich's most important publications, *A numerical list of dried specimens of plants in the East India Company's museum, collected under the superintendence of Dr. Wallich (1828-49)*, contains in all 9148 species and is known as *The Wallich Catalogue* (Wallich 1828-1849). It is a work of basic importance for the understanding of Indian plants, and was compiled in London by Wallich and a group of collaborators from the specimens in the herbarium of the East India Company which had been sent to England (a set of these plants have remained at CAL).

William Griffith, English, served as superintendent for a short period (1843-1844) during the absence of Wallich; he revived and built the herbarium which he called 'Public Herbarium' (prior to this, the herbarium had been kept in Roxburgh's and later Wallich's official residence). It was during the period (1855-1861) of Thomas Thomson, another Scottish surgeon, as superintendent of the garden, then known as the 'Company *Bagan*', was officially renamed as the Royal Botanic Garden, Calcutta. Thomson associated himself with J.D. Hooker in the publication of *Flora Indica*, of which only vol. 1 appeared (Hooker & Thomson 1855).

Thomas Anderson (Scottish medical doctor, superintendent 1861-1869) was instrumental in the introduction of *Cinchona* from Kew in 1861. After Anderson, Charles Baron Clarke (English) took briefly charge of the garden and contributed to 52 family accounts in the *Flora of British India* (Hooker 1872-1897), a work which was completed, following Hooker and Thomson's unsuccessful *Flora Indica*. Separately, Clarke also produced monographic accounts of Comelinaceae, Gentianaceae, Begoniaceae, Leeaceae and Cyperaceae.

George King (Scottish medical doctor, superintendent 1871-1897) was the founding Director of the

Botanical Survey of India; during his period, the landscaping of the Calcutta Garden was laid out. In 1882, he was instrumental in the construction of a new building to receive the rapidly growing herbarium, which, by the time he left the Calcutta Botanic Garden in 1897, had risen to contain a million specimens. In 1891, the title superintendent was replaced by the title director, and David Prain (Scottish medical doctor) was promoted to become director of the Royal Botanical Gardens, Calcutta, in 1898, and also in the same time director of the *Botanical Survey of India*, a posts in which he remained until 1903, later to become director of the Royal Botanic Gardens, Kew, in 1905. He produced the work *Bengal Plants* in two volumes (Prain 1903).

Wilhelm Sulpiz Kurz was a German botanist arriving in India from Dutch service in the Dutch East Indies (now Indonesia); he was appointed curator of the garden's herbarium by Anderson in 1864 and worked in that function to his death in 1878. He explored Burma and Pegu and spent three months in the Andaman Islands. The *Forest Flora of British Burma* (Kurz 1877) is his major work and his most representative Burmese collections are at CAL.

By the end of the 19th and early in the 20th centuries, botanical studies continued in Bombay and Madras presidencies and also in the north-western provinces through the gardens at Poona, Madras and Saharanpur. Some of the most renowned naturalists, forest officers and army officers had left behind a rich legacy of specimens to the herbaria as well as inventories for the *Botanical Survey of India*. Thomas Fulton Bourdillon, a Conservator of Forests in the princely state of Travancore, authored a book on *The Forest Trees of Travancore* (Bourdillon 1908).

James Sykes Gamble founded the Forest School Herbarium, now part of the Forest Research Institute in Dera Dun, and produced *A Manual of Indian Timbers* (Gamble 1881) and *Flora of the Presidency of Madras* (Gamble 1915-1936). Colonel Richard Henry Beddome, an army officer, produced *The Trees of the Madras Presidency* (Beddome 1863), *The Ferns of Southern India* (Beddome 1863-1864), *The Flora Sylvatica for Southern India* (Beddome 1869-1874), *The Ferns of British India* (Beddome

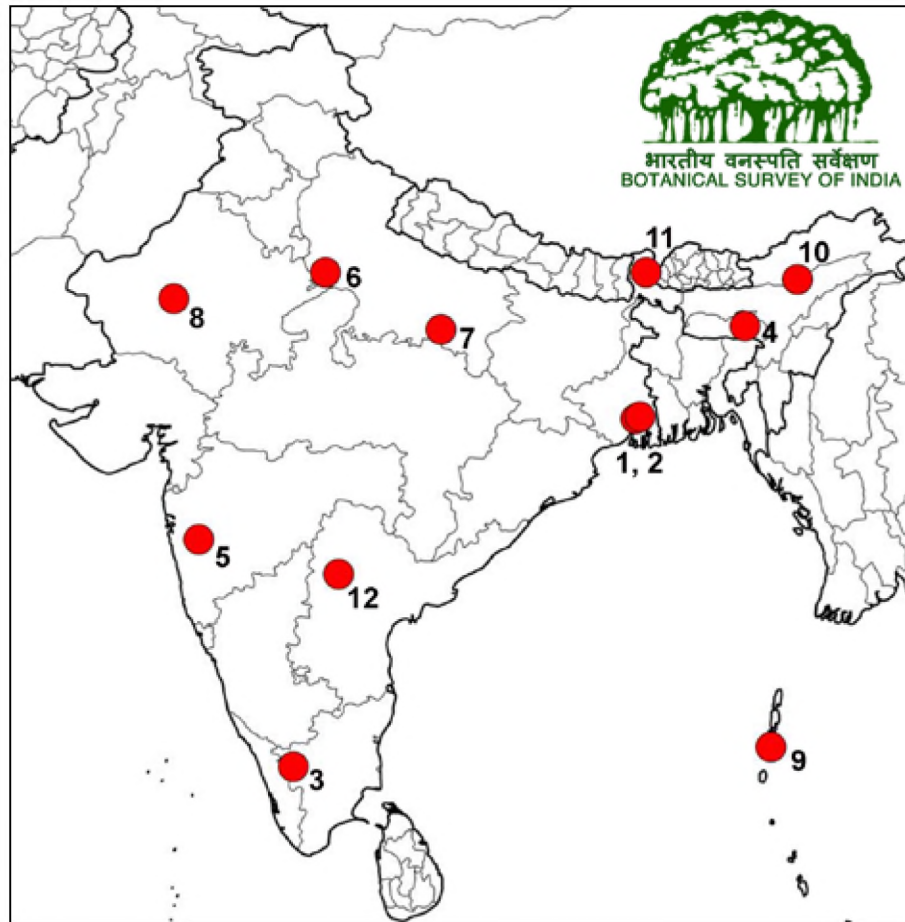


Fig. 1. The locations of the present centres of the Botanical Survey of India. 1. The Central National Herbarium in the Indian Botanic Garden (the Acharya Jagadish Chandra Bose Indian Botanic Garden) in Howrah south west of Kolkata, where the Botanical Survey of India was founded in 1890, and where the Central Botanical Laboratory is now located. 2. The present headquarter of the Botanical Survey of India in Salt Lake City, a north-eastern suburb of Kolkata. Not shown is the Industrial Section, Indian Museum, Kolkata, located in central Kolkata and housing a herbarium of useful plants and samples of their uses. 3. Southern Regional Centre in Coimbatore, Tamil Nadu (established in 1955). 4. Eastern Regional Centre in Shillong, Meghalaya (established in 1956). 5. Western Regional

Centre in Pune, Maharashtra (established in 1955). 6. Northern Regional Centre in Dehra Dun, Uttarakhand (established in 1955). 7. Central Regional Centre in Allahabad, Uttar Pradesh (established in 1962). 8. The Arid Zone Regional Centre in Jodhpur, Rajasthan (established in 1972). 9. The Andaman and Nicobar Regional Centre in Port Blair, the Andaman Islands (established 1972). 10. The Arunachal Pradesh Regional Centre in Itanagar, Arunachal Pradesh (established in 1977). 11. The Sikkim Himalayan Regional Centre in Gangtok, Sikkim (established in 1979). 12. The Deccan Regional Centre in Hyderabad, Telangana (established in 2006). The logo of the Botanical Survey of India is inspired by the more than 250 years old banyan tree (*Ficus benghalensis* L.) in the Indian botanical garden in Howrah; the tree is older than the botanic garden and now more than 450 m in diameter, with ca. 3000 prop roots supporting the canopy.

1883) and the *Icones Plantarum Indies Orientalis* (Beddome 1874), not to be confused with the well-known work by Wight (1840–1853) with the same title. Dietrich Brandis, another forest officer, documented botanical wealth of sacred groves in various parts of India, and produced an important botanical work, *Indian Trees*, dealing with 4400 species of woody plants (Brandis 1911).

Herbaria in Present Days' India

As mentioned in the historical review, the importance of the classical collections made by the European collectors during the 18th and 19th centuries was recognised with the establishment of the *Botanical Survey of India* in 1890, which was created to document historical, floristic, taxonomic, nomenclatural and environ-

Table 1. Herbaria of the *Botanical Survey of India*

Name of Herbarium & location	Code	Total Holdings	Types
Central National Herbarium, Howrah	CAL	2,050,000	15,000
Eastern Regional Centre, Shillong	ASSAM	271,000	509
Southern Regional Centre, Coimbatore	MH	275,000	2750
Western Regional Centre, Pune	BSI	170,000	57 ¹
Northern Regional Centre, Dehra Dun	BSD	121,500	140
Industrial Section, Indian Museum, Kolkata	BSIS	70,000	120
Central Regional Centre, Allahabad	BSA	69,000	28
Andaman Nicobar Regional Centre, Port Blair	PBL	22,000	100
Arid Zone Regional Centre, Jodhpur	BSJO	24,800	18
Sikkim Himalayan Regional Centre, Gangtok	BSHC	40,000	22
Arunachal Pradesh Regional Centre, Itanagar	ARUN	13,500	22
Deccan Regional Centre, Hyderabad	BSID	30,000	30

mental aspects of Indian botany. The plant collecting was an activity sustained after India's independence in 1947, particularly after the revival of the *Botanical Survey of India* in 1954 with the continued objectives of (1) undertaking intensive floristic surveys and collecting accurate and detailed information on the distribution, ecology, and economic importance of Indian plants, (2) collecting, identifying and distributing materials of use to educational and research institutions, and (3) acting as the custodian of the authentic collections in herbaria and living collections, as well as documenting plant resources in the form of publications of local, district, state and national floras. The Indian government supports the *Botanical Survey of India* as an exclusively taxonomic and floristic research institution, which organizes more than 100 field explorations on average per year under various action plan programs and in different parts of the country. These programs have a purpose to explore unexplored areas for the discovery and documentation of species and distributions new to science and also to study the range of variations and extent of distribution of all known species with the purpose to build a

revised manual of the Indian flora covering all territories within the present Indian political boundaries. This enhanced collecting activity keeps enriching the various herbaria attached to the Survey and other institutions.

Herbaria of the Botanical Survey of India

The *Botanical Survey of India* maintains herbaria in all its regional centres. Its Central National Herbarium is located at Howrah on the right bank of the Hoogli River near Kolkata, and it has the largest specimen holdings in India and is a National Reference Centre. Apart from this, the Survey's 11 Regional Centres maintain herbaria located in different bio-geographical regions (Table 1 & Fig. 1).

Considered together, the Indian herbaria have the most important botanical collections in South Asia. Some of them are known by their exclusive collections of a few explorers, apart from their general collections. Others, such as CAL, MH, ASSAM, BSIS, and BSI, have impressive historical collections representing a many classical collectors (Table 2).

Table 2. Important collections in selected *Botanical Survey of India* Herbaria

Herbarium Code	Important Collectors
ASSAM	Bor, N.L., Fischer, C.E.C., Hooker, J.D. & Thomson, T., Kanjilal, U.N., Mann, G., Perry, L.M., Ward, F.K.
BSI	Bhide, R.K., Cooke, T., Ritchie, J.C., Talbot, W.A., Thaker, I., Woodrow, G.M.
BSIS	Barber, S.A., Burkill, I.H., <i>Brühl</i> , P., Srinivasan, K.S., Watt, G.
CAL	Aitchison, J. E.T. , Anderson, T. , Baker, C.F., Barber, C.A. , Beddome, R.H., Biswas, K.P., Blandford, C.F., Bor, N.L., Borthakur, S.K., Bourdillon, T.F. , Brandis, D., Buchanan-Hamilton, F., Burkill, I.H., Calder, C.C. , Campbell, J., Cave, G.H. , Clarke, C.B., Cleghorn, H.F.C., Collett, H., Cooke, T., Craib, W.G., Curtis, C., Dalzell, N.A., Deb, D.B., Debbarman, P.M., Deka, G.K., Dixit, R.D., Drummond, T., Duthie, J.F., Edgeworth, M.P., Ellis, J.L., Elmer, A.D.E., Falconer, H. , Fischer, C.E.C., Forbes, J. , Forrest, G., Gage, A.T. , Gallatly, G., Gamble, J.S., Gammie, G.A., Griffith, W., Haines, H.H., Hance, H.F., Heinig, R.L., Helfer, J.W., Henry, A., Heyne, H. , Hohenacker, R.F. , Hole, R.S., Hooker, J.D., Hooper, D., Hope, C.W.W., Horsfield, T., Hume, A.O., Jenkins, F., Jerdon, T.C., Joseph, J., Kanjilal, U.N. , Kerr, W., King, G., Kingdon-Ward, F., Kittoe, M., Kotschy, C.G.T., Kurz, W.S., Lace, J.H. , Law, J.S., Lawson, M.A., Lister, J.L., Lobb, T., Mackinnon, P.W., Maingay, A.C., Masters, J.W., Maximowicz, C.J.I., Mc Clelland, J., Meebold, A.K., Merrill, E.D., Modder, E.A.C., von Mueller, F.J.H., Pantling, R., Parish, W.H., Parkes, J., Prain, D., Prazer, J., Pringle, C.G., Ridley, H.N. , Rogers, C.G., Rosenberg, W.A.V., Rottler, J.P., Roxburgh, W., Royle, J.F., Schimper, A.F.W., Schlechter, F.R.R. , Schmid, B., Scortechini, B., Scully, J., Simons, K.J., Smith, W.W., Stainton, J.D.A., Stapf, O., Stocks, J.E., Stoliczka, F., Strachey, R., Talbot, W.A. , Teysmann, J.E., Thompson, G., Thomson, T., Thwaites, G.H.K., Vicary, N., Wallich, J. N., Watt, G., White, J.C., Wight, R., Winterbottom, J.E., Wood, J.J., Youngusband, F., Zollinger, H.

Table 3. Herbaria affiliated to other institutions

Name of Herbarium, Location	Code	Total Holdings	Material and/or collectors
Blatter Herbarium, Bombay	BLAT	200,000	Angiosperms, Algae, Mosses and Fungi; seed samples and wood samples from Maharashtra are the other referable collections.
Madras Presidency College Herbarium, Chennai	PCM	100,000	Flowering plants; Flora of the Presidency of Madras (Barber, C.A., Gamble, J.S., Fisher, C.E.C.) and Flora of Nilgiris and Pulney Hills (P.F. Fyson) have their vouchers/ cited specimens deposited here.

The Rapinat Herbarium, Tiruchirappally	RHT	225,000	Flowering plants from Central and Northern Tamil Nadu, Tamil Nadu Coast, the Palni Hills and Sirumalais. Flora of Tamil Nadu and Carnatic (Matthew, K.M.) vouchers and cited specimens deposited here.
The Herbarium, Indian Institute of Science, Bangalore	JCB	17,000	Flowering plants; specimens of Dr. C.J. Saldanha and his colleagues/students from Karnataka; also collections of others from the Western Ghats including the Nilgiris Biosphere Reserve.
The Herbarium, Lucknow University, Lucknow	LWU	35,000	Indian bryophytes, lichens, and angiosperms; collections of many recent explorers are in this herbarium.
The Herbarium, French Institute of Pondicherry, Pondi- cherry	HIFP	24,000	Flowering plants specially of Western Ghats; important collections include those of Balasubramanyam, K., Blasco, F., Guinet, P., Kostermans, A.J.G.H., Meher-Homji, V.M., Suresh, S.R., Thanikaimoni, G.
Forest Research Institute, Dera Dun	DD	340,000	Flowering plants; collections of Aitchison, J.E.T., Bahadur, K.N., Beddome, R.H., Bor, N.L., Bourdillon, T.F., Brandis, D., Collett, H., Cooke, T., Dalzel, N.J., Donald, J., Drummond, J.R., Duthie, J.F., Falconer, H., Fischer, C.E.C., Flemming, R.L., Gage, T.A., Gamble, J.S., Gammie, G.A., Govan, G., Haines, H.H., Hole, R.S., Jameson, W., Kanjilal, U.N., King, G., Lace, J.H., Lowrie, A.E., Mangain, K., Mann, G., Mooney, H.F., Osmaston, B.B., Parker, R.N., Parkinson, C.E., Prain, D., Royle, J.F., Stewart, R.R., Stocks, J.E., Strachey, R., Talbot, W.A., Winterbottom, J.E.
Botany Department, University of Calicut, Calicut	CALI	40,000	Flowering plants; The herbarium holds specimens from (1) Silent Valley National Park, (2) Wayanad District, (3) Agasthyamala of Southern Western Ghats of Kerala and (4) Pteridophytes of South India and Bryophytes of Kerala.
TJawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvanan- thapuram	TBGT	40,000	20,500 specimens of flowering plants and 10,000 fungal specimens. The collections include nearly 2000 specimens collected by Beddome, R.H., Bourdillon, T.F., Narayanaswamy, Sankara Iyer, Venkobarao and many recent explorers.

Herbaria maintained by other institutions

Even with use of the *Index Herbariorum* (Thiers continuously updated), it is difficult to provide detailed information on all the herbaria outside the *Botanical Survey of India*. However, there is a publication exclusively devoted to this subject, which may be consulted for further details (Singh 2010). There are about 2.5 million specimens of flowering plants in herbaria outside the *Botanical Survey of India*. The authors listed a few of them above (Table 3).

Herbarium Specimens: Importance and limitations

The utility of herbarium specimens has some limitations. Specimens in dried state will only give clues of how the plants look in their natural habitat: Particularly larger plants that can only be preserved as fragments, and dissections of dried material may fail to give all the information necessary for verification and identification, for example in cases where flowers have complicated coronal processes and unification of staminal and stylar portions into columns, as in the Asclepiadaceae. There are other limitations with respect to water plants, succulents, members of Orchidaceae and bamboo species that do not preserve well as herbarium specimens. Many tropical trees shed leaves prior to producing their flowers, thus making it difficult to obtain complete material unless one returns again and again to the same plant and collect during several seasons. The pressing and drying of fleshy flowers may be difficult, particularly if the flower structure is complicated. Often, the flowers lose their colour in the drying process and quite often the flowers get separated and lost after mounting, leaving the naked stems behind. Monographers are often compelled to complement their work in the herbarium with field studies in order to complete their descriptions and analyses. In spite of these limitations, herbaria remained cardinal in taxonomic research, primarily with regard to reliable identification of specimens and in revisionary and monographic works. The importance of herbaria and other collec-

tions of dried and other preserved plant material for focussed floristic exploration and for improved documentation is further discussed and documented below.

The need for fresh collections

A large number of unidentified specimens are often placed at the end of genera and families in Indian herbaria. Some of these specimens are too poor to identify correctly. But fresh collections of such materials may help significantly in arriving at complete understanding of the taxa concerned.

While describing *Polyalthia crassa* R. Parker (Annonaceae) in 1929, the author had quoted his own collection made during 1926 from erstwhile Burma (Myanmar). He also quoted specimens collected by Parkinson (*Parkinson* 213, 584, 880, 1010) from Andaman Islands. Mitra (1999) and Karthikeyan *et al.* (2009) included *P. crassa* based on Parker's report (1929). Rao (1999) and Pandey and Diwakar (2008), in their checklist of the flora of Andaman and Nicobar Islands, included information based on Mitra's authority. But none of the authors managed to make any fresh collections or to improve the original description. Only recent, fresh collections from North Andaman Islands made it possible to draft a complete description and to improve the distribution notes (Venkat Ramana *et al.* 2012).

The unresolved status assigned to *Mitrephora andamanica* Thoth. & D. Das in most plant databases was essentially due to incomplete material and characterization when it was first published (Thothathri & Das 1968), and also due to absence of any other collection than the type from the Middle Andaman Islands. It was recently collected again from North Andaman Islands. Its complete description, with information on population status was reported (Venkat Ramana *et al.* 2015a). Unfortunately, quite a few endemic species reported from the Andaman and Nicobar Islands appear with unresolved status in important plant databases as they are represented by very few collections or poor descriptions, and therefore were treated under different synonyms in different works.

Similarly, fresh collections often help in the reviewing of the identity of earlier collections. The fresh collections of *Suregada* material from the North Andaman Islands helped in establishing the taxonomic identity and diagnosis of *Suregada bifaria* (Roxb. ex Willd.) Baill. (= *Gelonium bifarium* Roxb. ex Willd.). Its earlier place in synonymy under *Suregada multiflora* (A. Juss.) Baill. (= *Gelonium multiflorum* A. Juss.), as found in Indian floras and the *World Checklist of Euphorbiaceae* (Govaerts *et al.* 2000), could be corrected (Venkat Ramana *et al.* 2015b).

Species represented by single collections often prompt explorers to rediscover them again. A good number of species were rediscovered in explorations undertaken with such purposes. Some of them were even introduced in gardens of the *Botanical Survey of India*. Some such species, which have been collected again after having for long been only known from one collection, are reported from various regional centres (Table 4).

Undetected novelties

Indian herbaria have good number of specimens left unexposed for future critical studies. There are many reasons why some specimens representing new spe-

cies remain undetected in herbaria. Lack of expertise in specific groups is one reason. In many other cases, the specimens are incomplete (lack of flowers or fruits) or the species are represented by fragments with no field data or, in a few cases, with the locality illegibly written.

As mentioned, novelties go unnoticed when there is lack of expertise in specific groups, and the number of experts associated with Indian herbaria is not adequate to secure sufficiently qualified identification. In some instances, some of specimens were recognised as representing new species, and annotated as such on the sheet, but never described or published. Between 1955 and 2000, as many as 500 new species published from India were the results of studies on such collections. Interestingly, most of these were collected again from the localities given on the labels of the older collections, very rarely from different localities with comparable habitats.

Some specimens of *Indigofera* L. (Fabaceae) were collected by C.B. Clarke from Khasia Hills (Meghalaya) and named by him as *I. sesquipedalis*, but also called 'Khasia heterantha' because of its resemblance with *Indigofera heterantha* Wall. ex Brandis of Himalaya. However, several other sheets were erroneously identified by him as *I. dosua* Ham. (C.B. Clarke 7296), *I. het-*

Table 4. List of rare species rediscovered and introduced in botanic gardens

Arunachal Pradesh Regional Centre	Name of taxon	First/Subsequent collection
	<i>Impatiens laevigata</i> Wall. var. <i>grandifolia</i> Hook. f. (Balsaminaceae)	1873/ 2012
	<i>Justicia anfractuosa</i> C.B. Clarke (Acanthaceae)	1885/ 2009
Sikkim Himalayan Regional Centre	<i>Cymbidium whiteae</i> King & Pantl. (Orchidaceae)	1890/ 2010
	<i>Oberonia jenkinsiana</i> Griff. ex Lindl. (Orchidaceae)	1859/ 1898, 2013
	<i>Platanthera biermanniana</i> (King & Pantl.) Kraenzl. (Orchidaceae)	1896/ 2013

Eastern Regional Centre	<i>Eria lacei</i> Summerh. (Orchidaceae)	1938/ 2007
	<i>Epigenium treutleri</i> (Hook. f) Ormerod (Orchidaceae)	1890/?
	<i>Appendicula cornuta</i> Blume (Orchidaceae)	1890/ 2007
	<i>Geodorum appendiculatum</i> Griff. (Orchidaceae)	1845/ 2012
	<i>Pyrenaria khasiana</i> R.N. Paul. (Theaceae)	1871/ 1983
Central National Herbarium	<i>Zeuxine reflexa</i> King & Pantl. (Orchidaceae)	1885/ 2013
	<i>Zeuxine rolfiana</i> King & Pantl. (Orchidaceae)	1891/ 2012
	<i>Taeniophyllum filiforme</i> J.J. Sm. (Orchidaceae)	1867/ 2002
Central Botanical Laboratory	<i>Salix obscura</i> Andersson (Salicaceae)	1849/ 2006
Northern Regional Centre	<i>Corydalis lathyroides</i> Prain (Fumariaceae)	1884/ 1958, 2013
	<i>Trisetum micans</i> (Hook. f.) Bor (Poaceae)	1883/ 1892, 1941, 2002
	<i>Arenaria kumaonensis</i> Maxim. (Caryophyllaceae)	1884/ 2002, 2003
	<i>Parnassia kumaonica</i> Nehr. (Parnassiaceae)	1884/ 1974, 2002, 2003
Western Regional Centre	<i>Canscora stricta</i> Sedgw. (Gentianaceae)	1917/ 2007
	<i>Tillaea schimperi</i> Fisch. & C.A. Mey. subsp. <i>schimperi</i> (Crassulaceae)	?/ 2007
Southern Regional Centre	<i>Vanda thwaitesi</i> Hook. f. (Orchidaceae)	1861/ 1998, 2011
	<i>Brachystelma elenaduense</i> Sathyan. (Apocynaceae)	1969/ 2012, 2013
Andaman & Nicobar Regional Centre	<i>Marsypopetalum crassum</i> (R. Parker) B. Xue & R.M.K. Saunders (Annonaceae)	1916/ 2012
	<i>Ginalloa andamanica</i> Kurz (Annonaceae)	1872/ 2007
	<i>Cassine viburnifolia</i> (Juss.) Ding Hou (Celastraceae)	1896/ 2006

erantha Wall. ex Brandis (C.B. Clarke 18598), *I. leptostachya* DC. (C.B. Clarke 40103) and *I. pulchella* Roxb. (C.B. Clarke 18614). Prain, after scrutiny of all the

specimens at CAL, had annotated them as *I. sesquipedalis* C.B. Clarke. Indeed, on critical study of all the above sheets and many other specimens from differ-

ent herbaria, they were found to represent a distinct species which is allied to *I. heterantha*, as was suspected earlier by Clarke. Because this species had not been validly published by Clarke or by others and was listed as *I. sesquipedalis* C.B. Clarke MSS in Index Kewensis, it was validly published with illustrations by Sanjappa (1984).

Typification and standardization of names

It is difficult to give an overview of older names typified by British and other European collections until type databases of all the herbaria with Indian types are completed. Wood (1994) had lectotypified many older Acanthaceae specimens collected from India by Campbell and Wight available at Edinburgh (E). Eleven names of *Strobilanthes* Blume (Acanthaceae) described in the 19th century by Anderson and Kurz from China, India and Myanmar were typified based on specimens from the CAL herbarium (Albertson & Wood 2012).

What is important is to envisage meaningful collaboration on specific groups with the World's established taxonomic institutions so that monographers can sort, detect, and add authenticity in determinations of these specimens or otherwise establish them as new. CAL has the best set of collections from Myanmar collected when it was under British rule (1824-1948), and these collections have not been much studied by specialists or those who prepared the various editions of the check-lists of that country (latest edition Kress *et al.* 2003). Similarly the collections from Sri Lanka, Malaysia and Indonesia in CAL need critical study as many of them are type-specimens or their duplicates. Some of them could be new species or records.

CAL has also volumes of correspondences and a number of manuscripts that reach back to the establishment of the botanic garden at Calcutta in 1787. Their study has relevance to construct botanical history of India with greater authenticity.

Herbarium Maintenance

Herbaria require regular attendance particularly in humid tropical situations for their continued survival. This is very important because great pains have been involved in establishing, building and maintaining them, and many specimens represent extremely valuable scientific documentation. Despite herbaria being air-conditioned, specimens are exposed to high humidity during the rainy seasons. Particularly in humid tropical climate there are problems with the continued conservation of important specimens, and without sufficient financial support and manpower, there is no certainty of their continued well-being.

Indeed, specimens in herbaria maintain a necessary link with the floras and other taxonomic works published in the past, and without well preserved herbarium material we cannot be sure that we can maintain scientifically reliable identification of plants. Unfortunately, there is sometimes lack of understanding of this among administrators at various levels and governing agencies of institutions, which are responsible for housing such herbarium collections. Taxonomy in general may be given low priority, and resource allocation towards field collections and continued management of existing collections may be low. Many universities and non-governmental organizations' herbaria have no facilities to maintain large collections. Herbaria, which are outside the Government system of the *Botanical Survey of India*, require support in terms of human resources and capital infrastructure to maintain herbarium collections. The *Botanical Survey of India* has recently drawn up a plan for such assistance.

Fortunately, the herbaria of the *Botanical Survey of India* do have curatorial staff for taking care of specimens on a regular basis. The Central National herbarium of the *Botanical Survey of India* headquarters at Howrah (CAL) has a maintenance expenditure (annual fumigation, annual maintenance and service charges for central air conditioning and electricity charges) amounting to 5 Rupees (\approx 0.06 Euros) per specimen per year. This does not include the salaries of personnel involved in maintenance. The annual

earnings from the technical services provided by CAL are significantly less than the expenditure needed for the maintenance of the herbarium.

Digitization

Many Indian herbaria are now resorting to digitization since this offers easy access and retrieval of specimens for study also outside the institution, where the collections are held. The *Botanical Survey of India* has about three million specimens housed in various herbaria located at its Headquarter at Howrah and in its Regional Centres, Gardens and Museums. A pilot project on digitization of herbarium specimens at Central National Herbarium (CAL) at Howrah was sanctioned by the Ministry and was executed at the Central National Herbarium in 2009-2010 to digitize 20,000 herbarium specimens. A Data Centre was created housing the hardware and software for the establishment of an Indian Digital Herbarium, with high resolution digital images and detailed label data associated with each specimen through a web based application software operating in a local area network environment, and an Indian Virtual Herbarium, with a centralized inventory to provide open single point access to low resolution images and associated label data of the specimens available in BSI's herbaria located at various locations in India through the Internet.

Two Data Production Lines (DPLs), having servers, computers and scanners, were created for digitization, which included scanning and data capturing. Around 10,000 herbarium specimens were digitized by employing the manpower for one data production line on project basis for the duration of one year. The hardware, application software, methodology and work flow and total process of digitization were tested in an initial pilot project.

Now, all the regional centres have also built facilities for scanning and digitisation of specimens. In 2015, nearly 30,000 specimens had been digitized: 1612 sheets (all ferns) from the Sikkim Himalayan Centre in Gangtok (BSHC), 600 type sheets from the Eastern Centre at Shillong (ASSAM), 8000 Types

from the Central National Herbarium at Howrah (CAL), 2134 sheets (includes 872 type specimens of Angiosperms and 87 type specimens of ferns) from the Northern Centre at Dehra Dun (BSD), 4336 sheets from Western Centre at Pune (BSI), 800 sheets Decan Regional Centre, Hyderabad (BSID), 2000 type sheets from the Southern Centre at Coimbatore (MH) and 9922 sheets from the Andaman and Nicobar Centre at Port Blair in the Andaman Islands (PBL). At least 100,000 more specimens will in all probability have been digitized by various centres of the Botanical Survey of India by the time this article appears in print.

Conclusion

To expedite the production of a comprehensive national Indian flora, multinational projects, involving institutions such as the herbarium of the Royal Botanic Gardens, Kew, the Natural History Museum of London (formerly British Museum - Natural History), the Royal Botanic Garden of Edinburgh and other European herbaria are to be promoted. Joint explorations in all phytogeographic regions and the study of specimens of particularly difficult or poorly known taxonomic groups are to be encouraged and organized in order to understand tropical plant diversity in its totality. Writing a flora at the national level, producing monographs of specific groups with worldwide syntheses are possible only through such collaborations. If properly financed and otherwise supported, such international collaborations are bound to succeed, because in combination the European and Indian herbaria have built up the collections, the expertise and the necessary historical and geographical data. The Indian herbaria represent both rich legacies from the past and are essential tools for the future study of the Indian flora.

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