



HERBARIUM: HISTORICAL ACCOUNT, SIGNIFICANCE, PREPARATION TECHNIQUES AND MANAGEMENT ISSUES

Surender Singh Yadav

Department of Botany, Maharshi Dayanand University, Rohtak, Pin-124001 (Haryana) India.

Abstract

Herbaria are the storehouses where dried plant specimens, collected from far and wide, are preserved according to some internationally recognized system along with abundant first hand field data about plants. The origin of herbaria dates back to 15th century. Today ca. 3,000 herbaria are registered in Index Herbariorum and contain over 350 million specimens. Herbaria cover a wide range of taxonomic lineages, from plants to fungi, algae and myxomycetes. The present article provides brief historical account of herbarium, sources of materials in the herbaria and major herbaria of world and India. Functions of the herbaria has been discusses in details because herbaria are known as veritable gold mines of taxonomic, floristic and biogeographic information. They are remarkable and irreplaceable sources of information about plants and the world they inhabit. Herbarium specimens are the basis for identification and foundation for nomenclature. They provide the comparative material that is essential for studies in taxonomy, systematics, ecology, anatomy, morphology, conservation biology, biodiversity, ethnobotany and paleobiology. In addition to the uses of the herbaria in basic plant science, they play crucial role in the knowledge and preservation of biodiversity and in the improvement of species for commercial use. In this article detailed methodology for herbarium preparations. Purpose of plant collection; types of field work; specimen collection procedure; recording of field notes; pressing, drying, preservation, mounting; preparation of herbarium labels, identification of plants and process of accessioning and filing has been discussed in details. Worldwide, herbaria are facing serious financial crunch and apathy of modern biologists, hence some problem of has also been discussed. Moreover, the recent progress in analytical techniques and information technology increased the diversity of users and uses of herbaria significantly. It is suggested that modernization and updations of herbaria in tune with changing needs should be done in order to enhance their usefulness as a baseline for scientific utility. Emphasis should be given for digitizing the specimens, developing their user friendly database and making them online on website. It is also suggested that goals and practices of herbarium should be further reviewed, particularly in the light of the recent developments in the plant science in general and taxonomy in particular.

Key words: Herbarium, plant collection, field notes, taxonomy, systematic botany.

Introduction

Herbarium is a store house of plant specimens collected from far and wide places, mounted on appropriate sheets arranged according to some known and accepted system of classification and kept in cupboards. Herbarium is a good source of information about plants in the form of actual specimens, pictures and recorded notes. It is a component of most state universities, natural history museums, botanical gardens and botanical research institutions. Across the globe, presently there are 3,400 herbaria store botanical collections which are an invaluable record of the world's biodiversity (Krishtalka *et al.*, 2016; Thiers, 2019).

Herbarium, a special kind of museum, can also be regarded as a data bank with vast quantities of raw data. Each specimen has information content and therefore value which will, of course, vary depending on completeness of specimen and data and the source of the material. Each specimen has information about the vegetation of an area, a population and the taxon to which it belongs (Rollins, 1965). Excellent background and introduction to the herbarium are also provided by von Reis Altschul, (1977) and Simpson, (2006).

Now-a-days the herbarium specimens are also used for studies in the disciplines which were probably never even dreamed of at the time early collections were made and herbaria organized. These studies include such fields

**Author for correspondence* : E-mail: ssyadavindia@gmail.com

as phytochemistry (Eloff, 1999), phytogeography (Barney, 2006; Rosen *et al.*, 2006), weed science (Carter *et al.*, 2007) climate change (Primack *et al.* 2004; Bolmgren and Lonnberg 2005; Lavoie and Lachance 2006; Miller-Rushing *et al.*, 2006; Gallagher *et al.*, 2009) molecular systematics (Ribeiro and Lovato, 2007). Robbirt *et al.*, (2011) provided the first direct validation of the use of herbarium collections to examine the relationships between phenology and climate when field-based observational data are not available.

Botanical research in general and floristic and taxonomic in particular is greatly enhanced when substantiated by herbarium specimens available for study by contemporaries and scientists in the decades and centuries to come. Preparation of herbarium specimens is a routine part of research in plant science but very few researchers know the correct methodology of plant collection and herbarium preparation. The purpose of this article is to provide information to the plant science community on basic procedures for preparing and handling plant specimens.

Historical Account

The origin of herbaria traces back to the 15-16th century. The word herbarium referred to a book about medicinal plants. Herbaria were initially used as a tool to identify and illustrate medical plants. Since the Renaissance, Botanical Gardens and Universities were founded throughout Europe. They promulgated the importance of making herbaria. The beginning of the herbarium as a collection of dried specimens affixed to paper for a lasting record is attributed to Luca Ghini (1490-1556). According to Arber, (1938) Ghini seems to have been the sole initiator of the art of herbarium-making and this art was disseminated over Europe by his students. Gherards Cibo, a pupil of Ghini, began collecting and preserving specimens as early as 1532 and his herbarium is extant today. John Falconer, an Englishman, is mentioned as possessing an herbarium in the writings of Lusitanus in 1553 and William Turner in 1569 and it is believed that he also learned of herbarium making either directly or indirectly from Ghini (Arber, 1938). The status, operational aspects and future of herbaria have been reviewed by Turrill, (1964); Beaman, (1965) (Fosberg and Sachet, 1965) and Shetler, (1969).

The early years' focus changed in the 17th century when new continents were explored and an overwhelming biodiversity was discovered. Botany gradually established its independence from medicine. Different methods were used to create bound and loose sheet herbaria. The specimens were either sewn, attached using strips of

paper, or stuck plain to the paper support. Sometimes the method of attachment was a combination of solutions. The adhesives used to attach the specimens were animal glue (first mentioned by Tournefort), isinglass (described by Linnaeus), gum Arabic, starch adhesives or mixtures (*e.g.* Felix Platter used a mixture of animal glue and starch adhesive). In the earlier times the specimens were mounted on sheets and bound in the form of book. Although the herbarium technique was a well-known botanical practice at the time of Linnaeus, he departed from the convention of the day (mounting specimens and binding them into volumes) by mounting his specimens on single sheets and storing them horizontally much as is the practice today (Dewolf, 1968).

Today the plants are mounted on single sheet and arranged according to classification. The present concept of herbarium collection alongside detailed field data is also due to the experience of botanists over four centuries. The present procedure of pressing and drying specimens for storage has been amazingly successful and has stood the test of time. Plants so preserved provide a concrete basis for past, present and future reference. The present concept of herbarium collections alongside detailed field data is also due to the experience of botanists over four centuries. In the early days the size of sheets also varied with the size of plants. The present size of herbarium sheets (29 × 41 cm ± 1 cm) is also the result of the combined effort and experience of many scientists.

Index Herbariorum

Index Herbariorum is a catalogue of the world's officially recognized herbarium collections and a useful source with addresses and contact information for herbaria. It was established in 1935 by the International Association for Plant Taxonomy (IAPT) who published its first six editions. According to the data in Index Herbariorum as of 1 December 2017, there are 3001 active herbaria in the world, containing 387,007,790 specimens. These herbaria are found in 176 countries. Table 1 includes some of the major Herbaria of world and the number of specimen present in it.

Sources of Materials in the Herbaria

Though the most common sources of materials in the herbarium are collections deposited by students, research scholars and scientists but herbarium are enriched by many other ways. The influx of material into a herbarium is usually from the following sources:

Staff and Student Collections

These vary according to staff research, interests, speciality and herbarium goals. Collections may be for

Table 1: Some of the largest Herbaria in the World (Source: The World's Herbaria 2017).

Rank	Organization	Code	Country	Specimens	Year Founded
1	Muséum National d'Histoire Naturelle	P	France	8,000,000	1635
2	The New York Botanical Garden	NY	U.S.A.	7,800,000	1891
3	Royal Botanic Gardens	K	U.K.	7,000,000	1852
4	Naturalis	<i>L, WAG, U¹</i>	Netherlands	6,900,000	1819, 1829, 1896
5	Missouri Botanical Garden	MO	U.S.A.	6,600,000	1859
6	Conservatoire et Jardin botaniques de la Ville de Genève	G	Switzerland	6,000,000	1824
7	Komarov Botanical Institute of RAS	IE	Russia	6,000,000	1823
8	Naturhistorisches Museum Wien	W	Austria	5,500,000	1807
9	The Natural History Museum	BM	U.K.	5,200,000	1753
10	Harvard University	<i>HUH²</i>	U.S.A.	5,005,000	1842
11	Natural History Museum	FI	Italy	5,000,000	1842
12	Smithsonian Institution	US	U.S.A.	5,000,000	1848
13	Swedish Museum of Natural History	S	Sweden	4,570,000	1739
14	Université Claude Bernard	LY	France	4,400,000	1924
15	Botanic Garden Meise	BR	Belgium	4,000,000	1870
16	Botanischer Garten und Botanisches Museum Berlin-Dahlem	B	Germany	3,800,000	1815
17	Université de Montpellier	MPU	France	3,500,000	1809
18	Friedrich-Schiller-Universität Jena	JE	Germany	3,500,000	1896
19	University of Helsinki	H	Finland	3,350,501	1751
20	Botanische Staatssammlung München	M	Germany	3,200,000	1813
21	Museum of Evolution	UPS	Sweden	3,100,000	1785
22	Royal Botanic Garden Edinburgh	E	U.K.	3,000,000	1839
23	University of Copenhagen	C	Denmark	2,797,000	1759

¹ Naturalis now houses L, WAG, and U although they are curated as separate collections
² "HUH" is an informal code for the Harvard University Herbaria, which includes A, AMES, ECON, FH, GH,

floristic, monographic, biosystematic, or taximetric studies. Staff and students at institutions which have no herbarium or only teaching or reference collections, may choose to document their studies by sending specimens to other institutions. These specimens may be sent either as gifts or loans and published works should always include the name of the herbarium where vouchers are deposited.

Exchange

Duplicates or special collections are exchanged among various institutions, usually on a one-for-one basis. This is one of the major means of adding to a collection and an efficient means of getting needed materials at minimal costs to all concerned.

Gifts

These are variously interpreted in different herbaria. Some treat receipt of all specimens other than exchange or loans as gifts while others include only those for which no staff services are required. These may range from an entire herbarium to a few specimens sent to a staff specialist.

Loans

Loans are generally either temporary (short term;

e.g., a study of specific taxa for preparation of a monograph) or indefinite (permanent; *e.g.*, the loan of an entire herbarium from one institution to another). The latter is a particularly desirable procedure for historic and other collections which may be for the most part inaccessible to most botanists or where proper housing facilities are lacking. These can often be loaned to another institution and still have the original name maintained.

Purchases

The purchase of an herbarium is an uncommon event today. Usually private or institutional herbaria are donated or are deposited on permanent loan at an institution. Most purchases today involve collections from specific areas (particularly the tropics) with prices ranging from ten cents to over one dollar per sheet. In some cases an institution may help to sponsor a collecting trip in exchange for a set of specimens.

Identification Service

In most herbaria specialists are willing to determine specimens for other workers and interested amateurs. Some herbaria have staff members whose specific job is service identifications. In general the specimens sent for

Table 2: Some Important National Herbaria in India.

S. No.	Name	Acronym	Established in year	No. Herbarium sheet (approx.)
1.	Central National Herbarium, Howrah	CAL	1795	2000,000
2.	Forest research institute & College Herbarium, Dehra Dun U.P. (now I. C.F.R.E.)	DD	1890	3,30,000
3.	Botanical Survey of India, Southern circle Coimbatore , Tamil Nadu	MH	1955	2,59,073
4.	Blattr Herbarium, Bombay Maharashtra	BLAT	1906	2,00,000
5.	Botanical survey of India Andaman & Nicobar circle , Port Blair A & N Island	PBL	1972	26,000
6.	Botanical survey of India Arid Zone circle Jodhpur Rajasthan	BSJO	1972	21,289
7.	Botanical Survey of India Sikkim Himalayan Circle, Gangtok, Sikkim	BSHC	1979	26,000
8.	Botanical Survey of Indian Eastern circle Shilong, Meghalaya	ASSAM	1956	2,60,000
9.	Botanical Survey of India, Western circle, Pune Maharashtra	BSI	1880	1,45,464
10.	Botanical Survey of India Northern circle DehraDun , U.P.	BSD	1956	1,02,169
11.	Botanical Survey of India Central Circle Calcutta W. B.	BSIS	1897	52,675
12.	Botanical Survey of India Central Circle Allahabad U.P.	BSA	1962	63,000
13.	National Botanical Garden, Lucknow U.P. (Now NB.R.I.)	LWG	1948	2,50,000
14.	Central Salt and Marine Chemicals research institute Bhavnagar Gujarat	BHAV	1961	3,000
15.	Marine Algae Herbarium Central Drug research institute Lucknow U.P.	CDRI	1951	40,000
16.	Herbarium Division of mycology, and plant Pathology I.A.R.A. New Delhi	HCIO	1905	41,000
17.	National Herbarium of Cultivated Plant N.B.P.G.R., I.A.R.I. New Delhi		1968	6,000
18.	Mycology and Plant Pathology Herbarium, Maharashtra Association for the Cultivation Science Research Institute Pune, Maharashtra	AMH	1962	27,000
19.	Institute of Genetics and Tree Breeding, Coimbatore, Tamil Nadu	FRC		36,382
20.	Botanical Survey of India, Arunachal Pradesh Circle, Itanagar	ARUN	1977	10,000

identification are kept by receiving institutions unless other arrangements are made in advance.

Functions of Herbarium

A modern Herbarium serves many valuable functions or utility. Herbaria have unique advantages over other botanical repositories such as germplasm banks or botanical gardens in producing good quality data for native flora conservation, among other uses (Funk, 2018). Funk, (2002, 2012) has documented the 100 uses for the herbarium (well at least 72) and categorised them into different basic functions & research related, research, education & training, money making ventures. Some of the important functions of the herbarium are summarized as under:-

(i) Herbarium is the founding pillars in classical taxonomic research. It is storehouses of collection including the valuable type specimens. The herbaria greatly aid in all kinds of taxonomic researches. It serves as a repository of voucher specimens on which varieties botanical researches are carried out. It also serves as a vital source of information for monographs and floristic works.

(ii) The herbarium specimens provide the foundation

for nomenclature, the basis for identification, the common reference for communication and the vouchers for floras and bio-systematic studies (Haridasan *et al.*, 2018). They serve as a fundamental resource for identification of all plants of the world.

(iii) Herbarium serves as an aid in teaching botany. Dried specimen is available all the time as compared to the fresh plant which may or may not be available. It helps in identifying the newly collected specimen. Rollins, (1965) has also pointed out some of the roles of the herbarium in research and teaching.

(iv) Herbarium collections also provide a wealth of information on our natural heritage, which extends back to hundreds of years (Haridasan *et al.*, 2018). They provide verifiable and citable evidence of the occurrence of particular plants at particular points in space and time and are vital resources for assessing extinction risk in the particularly in tropics, where plant diversity and threats to plants are greatest (Nic Lughadha *et al.*, 2019).

(v) Herbarium specimens are invaluable resources for understanding ecological and evolutionary species' responses to global environmental change (Meineke *et al.*, 2018; Lang *et al.*, 2019). Atmospheric carbon dioxide levels have been recorded in herbarium specimens

Table 3: Some Important University and College Herbaria in India.

S. No.	Name of University	Acronym	Established in year	No. of specimens (approx.)
1.	Central taxonomic Studies St. Joseph's College 'Bangalore	JCB	1964	50,000
2.	Department of Botany, Punjab University, Chandigarh	PAN	1947	28,620
3.	Department of Botany, Rajasthan University, Jaipur	RUBL	1963	21,061
4.	Department of Botany, Calcutta University, Calcutta	CUH	1921	25,000
5.	Rapita Herbarium St. Joseph College Tiruchirapalli, Kerala	RHT	1967	86,077
6.	Department of Botany, Presidency College Madras	PCM	1901	1,00,000
7.	Department of Botany Delhi University New Delhi	DUH	1947	19,000
8.	Department of Botany Punjabi University Patiala	PUN	1967	40,000
9.	Department of Botany, Kashmir University, Srinagar	KASH	1972	55,300
10.	Department of Botany University of Garhwal Srinagar , U.P.	GU	1978	8,000
11.	Department of Botany North Eastern Hill University , Shillong	KASH	1975	14,000
12.	Botany department, St. Xavier's College Bombay	BLAT	1906	2,00,000
13.	Botany Department of University of Lucknow	LWU	1925	35,000
14.	Botany Department Banaras	BAN	1918	25,000

collected in the late 1700s and compared with recently collected plants to document changes in the concentration of greenhouse gases since the industrial revolution (Bonai *et al.*, 2011).

(vi) Herbaria throw light on the ecology and population status of the species, as detailed information is well documented and stored in the field labels and notes attached to the specimen (Haridasan *et al.*, 2018).

(vii) Herbaria provide the reliable and verifiable record of the changes to our flora during the expansion of human population. Vouchers specimens can also be used for research and management of plant invasions (Gairola *et al.*, 2013).

(viii) Herbaria offer the scope for comparative analysis of morphology; inter- and intra-species relationships, along with phenological and morphological inputs (Haridasan *et al.*, 2018).

(ix) All fields of biological science, from the level of molecular biology to ecosystem science, are dependent on collections, not just for application of names, but also as the referencing point of study in all aspects of biodiversity (Haridasan *et al.*, 2018).

(x) Herbaria serve as the storehouse of world's biodiversity. Most estimates on global biodiversity today are based on herbarium collections only. They also help in assessment of conservation status of a taxon. Herbarium is a versatile encyclopaedia for plant biology, which can help reverse the trend of threats by appropriate conservation measures (Haridasan *et al.*, 2018).

(xi) Herbarium aids in biodiversity monitoring by carrying out security of herbarium collection to obtain quantitative baseline data on the distribution and

abundance of keystone species is essential for all monitoring programmes.

(xii) Vast collection of a particular species in a herbarium aids in assessing the diversity or variations exhibited by a species in its distributional ranges helping in population biology studies.

(xiii) Herbarium collections are an enormous resource for DNA studies underutilised genomic treasure troves (Särkinen *et al.*, 2012). They serve as a source for search of new genetic material for improvement of cultivated stock.

(xiv) The tags of herbarium carry all the information about habitat, habit, local name, flower colour and other characters of the plant, use of plant, frequency and abundance of species etc. It also includes the morphological description, range of distribution, variation and uses.

(xv) Herbarium provides valuable data for botanical, ethnobotanical, agronomic, pharmacognostic and phytogeographical studies etc.

(xvi) Specimen may be used as a source of material for Anatomy, Palynology and Cytotaxonomy, Ecology, Chemistry, Molecular biology, Pharmacognosy and Environment impact assessment.

(xvii) Herbarium data also provide insights into the history and geographical extent of use of plant (Souza *et al.*, 2017). Locality data from herbarium specimens is also useful in studying the spread of invasive weeds (Fertig *et al.*, 2016).

(xviii) Seeds of the herbarium specimens can be used to resurrect species extinct in the wild using modern technology.

(xix) It aids in assessment and cataloguing of all species of economic potential, as commercial species, medicinal herbs, food plants etc.

(xx) Herbarium specimens can also be a source for new records of pathogens and parasites (Fertig, 2016).

(xxi) It helps in development of computer data base on plants and maintains active links to international network of systematic resources and electronic base.

(xxii) Herbaria are the invaluable conservatory of plant material and data. They are storehouses of irreplaceable knowledge (Gairola *et al.*, 2013).

Herbarium Preparation Techniques

Herbarium preparation involves many steps. It involves plant collection, drying, poisoning, mounting, stitching, labelling and deposition etc. The various aspects and methodology related to plant collection are discussed as under:

Purpose plant collection

Process for gathering plant from the regions of their occurrence with particular objective is called collection. Plants are collected from nature with various pertinent purposes. They may be collected for the purpose of: (a) to edifice new herbaria or enriching old herbaria, (b) collecting the plant material from a particular region to prepare or writing a flora, (c) collecting for museum establishment or practical work in the class rooms, (d) collecting live plants for introduction in fernery, garden or some other sort of experiments viz. hybridization, (e) collecting the targeted genus or species for the research works, (f) collecting huge amount of particular taxa or part of it for crude drug, (g) for ethnobotanical studies to display the uses and interrelationship of plants with local inhabitants, (h) collecting the specimens for sale to raise economy and serve the educational organization for developing the knowledge of human resources.

Types of Field work

The type of field work depends on purpose of the plant collection. It may be for preparing flora, monograph of a region or to collect the particular taxa or group of plant for foresaid variable purposes. The type of field work may be categorized as below:

(i) Plant collection trip: The collection trip is comprised of very short period or usually for one day to some nearby areas. It is for some sort of experimental studies or to gather particular taxa as teaching material or to incorporate in musea or living repository of the plants.

(ii) Plant exploration: The plant exploration trip is made for detailed floristic account or building up of herbaria

and for study of economic plants of certain region. In exploration the area is intensively surveyed and the collections are made regularly in different season. The minimum unit for explorative collection is district.

(iii) Plant expedition: The plant expedition trips are made for difficult and remote regions, which are usually for few months. An expedition trip to Antarctic region can serve as best example.

Preparation for field work

It involves advance preparation and understanding about the plan for long period field work to avoid any inconvenience in the field. Planning and arrangement for field work depends on nature of the work, purpose, duration and area of work.

(i) Study: Prior to commence the field work one should be perfectly aware with earlier publications on the regions and the plants or groups of interest. That will surely help out to plan the kind of pursuance for the field work. Information about the regional boundaries, connectivity and the proposed regions for intensive survey shall be gathered studying and consulting appropriate sources.

(ii) Advance arrangement of journey and stay: An advance initiative shall be taken to get reserve and confirmed mode of transportation either by rail or road. Pre-requisition shall be pursued to relevant authorities for getting permission to study their territories and make confirm the facilities of accommodation. Usually the Chief Conservation of Forests and District Forests Officers are requested for granted approval to survey the regions under their administration, but now the State Biodiversity Board is also to be taken in confidence before planning for a field work.

Materials or equipments required for plant collection

It also varies with the kind of weather in the region, duration of trip, area of work, mode of conveyance, places of stay, purpose of collections and other articles required for gathering (cutting, digging, pruning) plants, their processing, preservation and pressing for herbarium works. Amongst these, certain articles are as: kudal, scattier, knife, khurpi, plant press, polythene bags, rain coat, field book, pitty boucher, field shoes, service stamps, letter heads, camera, bags, utensils, clothes, first aid box, pencil, rubber, pen, scale, field lenses, blotting sheets, old newspapers, ropes, seal and rubber stamp, identity card, candles, torch, match box, medicines, shoulder bags, bags for plants etc.

Camp arrangement

As soon as arrive to camp for the work, contact must be established with the local authority and ask them to

provide local people who can assist and guide throughout the period of field work. The local officer and people must be talked about purpose of your visit and the area proposed for survey. Each area is to be surveyed on particular day thus the plan must be designed in advance. Usually, it should be noted that the duration of field work shall be in between 7.00 AM to 3.00 PM

General hints and caution

(i) Camping site: Usually the camping in deep forests and bank of the rivers should be avoided. In deep forests, in the case of emergency, rescue becomes more difficult and along the riverside unexpected flood can harm more and non-compensational damage may occur.

(ii) Wild animal and leeches: In dry deciduous forests of central India and even in the tropical forest many wild lives are more deadly. The camping shall be avoided from the proximity of these wild and dangerous animals. The leeches are very common in rain forests of tropics mainly Eastern Himalayas and Western Ghats. Proper covering of the body shall be ensured and precautionary extract of tobacco or a small packet of salt must be included in the collection kit to keep away the leeches.

(iii) Health and other miscellaneous: The big difficulty appears when any member of the party falls ill during the field work. Little care about food and water must be taken, while some common medicines for treatment of cold, fever, dysentery and other disorders must be pertained.

Collection work

Precaution must be taken while making collection of the plant for firmed purposes. The kind of plant to be collected and appropriate quality as well as quantity must be given high consideration prior to gather the plant samples.

(i) What to collect: The collection of plant depends on the basis of different purposes. If the plant is collected for preparation of the flora in any region or establishing a new herbarium, the collection should be exhaustive and samples of each plant of the regions should be collected.

(ii) Size: Usually the size of herbarium sheet on which the specimens are mounted is approximately 28 × 42 cm in India; 42 × 29 cm in USA; 42 × 26 cm at Kew and certain other European herbaria; 44 × 29 cm in Natural History Museum, London. Thus this length of the herbarium sheet limits size of the plant samples.

(iii) Number: To ensure the long lasting and availability of plant samples in herbarium usually six specimens of each plant are collected. These specimens would serve as duplicate isotypes while the original type

specimens may be landed on loan by any reputed herbaria or damaged in any mishappening. Unmounted duplicates are useful for certain detail studies, such as in the paleontology, anatomy etc.

(iv) Field number: Field number serves as an instant designative sign which is a definite serial number in the field and later on is overwritten as the accession number. Somewhere, these field numbers are considered as the accession number. These numbers are tagged with the plant samples and pasted on top in right corner of the herbarium sheet.

(v) Field book: The field number is printed on the field book. The field book includes information about the name of plants, its vernacular name, uses, date of collection, locality, habitat, altitude, name of collectors and a little description about the plants.

(vi) Pressing and drying of specimens: Plant pressing and drying of specimen is an inevitable procedure for preparing herbarium sheet. The plant samples are pressed in a rectangular steel wired framed plant press at high pressure. Usually the fresh samples are placed in old news papers for first or second day of collection, thereafter it is shifted to the blotting sheets which perfectly soaks the moisture and water content of the plants. Certain long plants are pressed in a definite pattern of V, N, Z, M or W.

(vii) Collection of special groups or kind of plants: The collection of plant samples also varies with the purpose of study and investigating the plant resources of any region. If the study is aimed to enlist the species composition of particular plant group, one must ensure that the collection is to be made for the purpose of the concern plant group. These will avoid unnecessary damage to plants, consumption of time and labour.

Preservation of specimens

In tropical regions, the high temperatures and humidity promote rapid growth of herbarium pests (Bridson and Forman, 1998). Herbarium specimens will last indefinitely if properly prepared, cared for and protected from water, humidity and a variety of pests, such as insects, moths, fungi and other microbes. The collected plant samples either are poisoned in the field or after accomplishing the field work and reaching to the organisation. Usually the dried samples are poisoned with various combinations of the chemicals which in turn kill the damaging organisms. To make the plant samples repulsive for these organisms various preservations technique are involved as below:-

(i) Mercuric chloride and Ethyl alcohol: The plant samples are usually dipped in combination of mercuric

chloride and ethyl alcohol with the percentage of 1:10. A thin layer of mercuric chloride is coated around the samples then the samples are left for evaporation of the alcohol. The thin covering of mercuric chloride further inhibits attack of microbes.

(ii) Lauryl pentachlorophenate: The Lauryl pentachlorophenate is another poisoning material used as a substitute of mercuric chloride in many of the herbaria. It has shown its efficacy better than to the mercuric chloride and is safer in handling.

(iii) Formalin: The plant samples are bundled in a polythene bags and 10% of the formalin is sprayed over the bundles so that it just get soaked thoroughly by the specimens. The plastic bags are then air tight and brought to the concern herbaria for their proper processing.

(iv) Fumigation: It is another alternative for killing the pests attacking mounted for unmounted specimens. It involves one of the volatile liquids like methyl bromide, carbon tetra chloride, carbon disulphide and para-di-chloro benzene. These volatile compounds placed in a small petridishes are left in the corner of herbarium almirah and the almirah is closed for a week. This practice leads to kill all the micro-organism including pest and avoid any damage to the herbarium samples.

(v) Heating: This is another procedure where moisture of the samples is reduced increasing temperature of the herbarium. As a result, there is less opportunity for the invasion of any micro-organisms.

Mounting

The dried and poisoned plant samples are mounted on the herbarium sheets with definite length (28×42 cm) in such a way so that characteristics of all the plant parts should be apparent and one can easily observe it while going through morphological investigations. The mounting also includes pasting of a herbarium label where detail about the plant is to be furnished.

(i) Gluing: It is a process where plant sample is pasted to herbarium sheet with the glue. The glue is homogeneously spread on a glass sheet and the plant samples are placed on the glass in such a way so that the glue is adhered to the opposite side of the plant samples. In this way the next side of the sample having maximum taxonomic attributes will remain more apparent in front of the observer. The glued samples are then placed on the herbarium sheet in such a way so that all part of the samples may display. A slight pressure is created by a wet absorbent so that sample can easily adhere to sheet and excess amount of glue may be absorbed.

(ii) Strapping: It is an alternate procedure to make

stuck the plant samples with herbarium sheet without using any glue. The samples are simply stitched with ordinary thread using stitching needle. It must be ensured that orientation of the sample should be perfectly displayed.

Preparation and pasting of herbarium labels

Herbarium label is about 8×12 cm and contains all information about the plant samples. Usually label contains: name of family, name of genus and species, locality of collection, habit, date of collection, description about plant, field number, accession number, vernacular name, uses, collectors name and name of the identifying person. This label is pasted on the right corner of the herbarium sheet bottom about 1 cm away from edges of the mounting sheet.

Identification of plants

It is a process through which an unknown plant specimen is determined either by any published literature with illustrations on it or comparing the samples with identical or more allied taxa. For the purpose of identification, the scientific method is to first study the characters of the plant, check them with the flora of the region (locality of collection), work through the family, genus and species keys and compare with the full description and illustration. Hence, the herbarium specimens are first recognised by its character, to be similar to some known plant and accordingly given a name and thereafter, carefully compared with earlier identified plants of that species or variety as the case may be.

Accessioning

When the specimens are ready (mounted, labeled and identified), they are stamped with distinctive mark of the herbarium or institution. The stamp carries the name of institution, a serial number called accession number and some time the date of accession. The accession register serves as reference to easily trace out the plant samples while required for any kind of investigation in future.

Incorporation (Filing) of specimens

It is a process where all the mounted, labelled and identified herbarium sheets are sorted out in family, genus and species wise. In filing of specimens, all the herbarium sheets of a single species are placed in a light weight single folder which is called "species folder". All the species belonging to single genus are placed in a thicker single folder which is called "genus folder". Similarly the entire genus belonging to single family is placed in a thick single folder which is called "family folder". These folders protect the specimen from any damage.

Arrangement of the specimens in the Herbarium

The specimens are usually arranged in the herbarium according to some recognised system of classification. In many Indian herbaria including Central National Herbarium, the order and numbering of families and genera is according to Bentham and Hooker's *Genera Plantarum*. In case of ferns, arrangement is generally according to Copeland's *Genera Filicum*. The pigeon-hole, where bundles of a new family start, is marked by a fixed label or by hinged flap-board separator cardboard. The name of the family is printed or written on this in bold letters.

There are many herbarium sheets on single species. Depending on the kind of herbarium specimens and the services it provide, special arrangements are also made type specimens, cultivated, sheets for students, undetermined specimens, bulky herbarium, unmounted duplicate.

Precautions for Using Herbarium (Sharma, 2009)

- Handle the plant specimens with extreme care.
- Dry specimens are brittle and easily damaged so keep the specimen sheet flat.
- Store the specimens always in herbarium cases.
- Keep the materials in folders when not in use.
- Never keep heavy books or other heavy objects on the specimens.
- Support the specimens with a ventilator when carrying them here & there
- Do not write anything on sheets of herbarium, unless permitted to do so.
- Do not reshelv specimens in the herbarium cases.
- If you have taken specimens on loan from another institution, return them before the loan period is over.

Challenges for herbarium management

Herbaria are a valuable source of information for scientists and specialists in different domains. At the same time they are very complex artefacts that are not easy to maintain, as they consist of various materials. It is also quite pertinent to mention that herbaria are facing multiple challenges from multiple quarters. Traditional herbarium taxonomy has declined in prestige and funding (Fertig, 2016).

It is clear that herbaria contribute to the development of all biological disciplines but today herbaria are completely ignored by so called modern biologists who have least knowledge of the significance of a herbarium.

They consider herbaria merely a storehouse of collections of dead plants. They further consider that herbaria can neither contribute to the national development nor can generate funds.

Worldwide, herbaria are facing serious financial crunch. In the past twenty years one herbarium in seven has closed due to budget cuts or shifts in academic priorities (Deng, 2015). Due to lack of funding, herbaria are in danger (Dalton, 2003). Current annual costs of maintenance of the collections and the curator's salary, volunteer support, materials, storage cabinets and equipment replacement has increased manifold. There have never been adequate funds for herbarium maintenance though herbarium is an essential tool for all botanical. The lack of dedicated and stable funding places the maintenance of the collections at risk and subject to annual fluctuations in herbarium finances (Gropp, 2003).

In developing country like India, the increasing financial squeeze and thoughtless prioritization of research programmes has greatly affected the overall health of the herbaria (Rao, 2018). In India, big herbaria like the Central National Herbarium (CAL), Herbarium of the Forest Research Institute, Dehra Dun (DD) and the Herbarium of the National Botanical Research Institute, Lucknow (LWG) are critically endangered due to lack of sufficient trained man power, facility and even due recognition by the so called experimentalists (Rao, 2018).

Conclusions

Herbarium is the collection of plant specimens arranged in the sequence of an accepted calcification. Plant specimens are dried, pressed and mounted on sheets. Though herbarium preparation is labour intensive, time consuming and costly affair but at the same time it is highly significant field of study and research. While conventional taxonomic research remains important, herbaria are also increasingly relevant in the fields of ecology, biogeography and conservation biology. Specimens are also valuable for building public appreciation of plants and of botany in general. Botanical collections and herbarium preparation form the foundation of all botanical studies. Voucher specimens and herbarium collections are essential components of any well-designed research and academic studies. The main objective of herbaria is to document, identify and describe 'plant' diversity, however herbaria contain a huge potential for cutting edge research in other disciplines as well.

The nature of the herbarium as an institution and collection remained unchanged until about few decades ago. Today, information on botanical collections is made more accessible than ever before through digitization,

database development and the internet. But, now-a-days, in the current era of biotechnology and molecular biology the classical subjects like the taxonomy and herbarium have witnessed a great debacle. Developments in genetics, biochemistry, cytology, ecology, molecular biology and other fields leading to less descriptive and more experimental work have been largely responsible for the changes that have occurred.

Dr. R.R. Rao, former joint director of Botanical Survey of India and Emeritus Scientist is a strong proponent of taxonomy and herbarium related studies. He has emphasised the urgency to restore the prestige of herbaria and associated taxonomic activity. He has also warned that if study of taxonomy and herbaria is neglected than the entire biological community would soon end up in a state of confusion with regard to their own taxa of investigation and may have to knock the doors of scientists outside the country for seeking basic information on identity, nomenclature and even distribution of those taxa which occur at their door steps. Though herbaria are facing multiple challenges from multiple quarters, but at the same time there is need to accept the challenge of the future with an open mind and a resolve to deal with these problems.

Suggestions and Recommendations

- It seems desirable that herbarium goals and practices be reviewed, particularly in the light of the recent developments in the plant science in general and taxonomy in particular.

- It is needed that scientists should work more closely with herbarium botanists, to support herbarium collections and to document their research by depositing properly prepared voucher specimens in publicly accessible herbaria (Rao, 2018).

- Though the use of herbarium specimens is well established as vouchers to support ethnobotanical surveys but the complementarities of herbarium and published data on medicinal use is yet to be formally assessed. Hence, there is an urgent need to start integrative studies.

- It is recommended that modernization and updations of herbaria in tune with changing needs should be done in order to enhance their usefulness as a baseline for scientific utility.

- Similarly, phenological analyses of herbarium data offer unique insights into past responses, hence long-term phenological observation is necessary to fully understand present responses and model those in the future (Hart *et al.*, 2014).

- It is also suggested that new analytical methods

and research fields such as molecular systematics and DNA barcoding should also be complimented with conventional functioning atleast in the big herbaria.

- It is universally accepted that digital and virtual herbaria increases the usefulness of the collections, so large scale digitization of specimens is also required to provide access to the data that they contain (Rao *et al.*, 2012; Ellwood *et al.*, 2015; Carranza-Rojas *et al.*, 2017).

- Herbaria should use efficient means of specimen handling (loans, location of types and special materials) and information retrieval and could well provide research space and equipment for use of visiting botanists.

- Moreover, herbaria should also employ business-like methods and computers be used for much of the laborious retrieval work needed and demanded by scientists and laymen.

- Rather than hiding the specimens behind cabinet doors, there is a need to make them more accessible, especially digitally (Fertig, 2016). Emphasis should be given for digitizing the specimens, developing their user friendly database and making them online on website.

- There is a great need to increase funding for meeting current and future herbarium functions. Adequate funding is required for linking the database to a geographic information system, revising the list of introduced species documented.

- Herbaria should be considered as National facilities and their maintenance should be a National responsibility (Rao, 2018).

- The editors of various scientific journals should also ensure that all authors cite the accession number/ numbers of their voucher specimens and the herbaria where deposited. This will enhance the value of scientific findings and strengthens the justification of the importance of the Herbaria (Rao, 2018).

- There is also an urgent need to educate the policy makers, the experimental biologists and other key persons who matter much for development herbaria in the country about the essentiality' of a herbarium (Rao, 2018).

Acknowledgement

Financial assistance from Haryana State Council for Science and Technology (HSCST) and FIST-DST, New Delhi is thankfully acknowledged. I am also indebted to all taxonomists and botanists of the India and abroad whose work has been used for writing this article.

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