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DIGITAL HERBARIUM OF RANGE GRASSES AND LEGUMES

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SUMMARY

The digitization of herbaria and its online access greatly facilitates its access around the world. A virtual herbarium named "Virtual herbarium of IGFRI" of the specimens preserved at ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Jhansi (UP), India has been developed. This initiative was a gesture of sharing information on plant diversity collected by the institute to make these data available to a broad community of users (scientists, educators, botanical community, general public etc.) via openly accessible, free data portals. The portal was optimized for computers, tablets and mobile platforms. The ICAR- IGFRI housed over 2500 historical collection specimens dating more than 70 years, belonging to 741 species, 344 genera and 62 families. The predominant families with maximum species represented are Poaceae (396), Fabaceae (82), Cyperaceae (40), Asteraceae (26) and Brassicaceae (13). Digitized images are available through https://vbigfri.icar.gov.in/ web address.

Key words : Collections, database, digitization, IGFRI, specimen, virtual herbarium

The herbarium (plural "herbaria") is a preserved collection of pressed and dried plant specimens, with associated field information and other relevant data recorded on the label of the herbarium sheets. Herbarium specimens are the source of data on climate change, loss of biodiversity, evolution, discovery, and description of new species, agricultural development, and the impact of natural disasters (Thiers *et al*., 2016). It is now widely used for comparing phenology, developing species distribution models through ecological niche modelling, documenting the spread of invasive weeds, and as voucher specimens for DNA barcoding (Lavoie, 2013). Herbarium specimens provide a useful means of tracking changes in the vegetation of a region over time. But there are certain constraints relying on conventional herbaria *viz*. recurring cost for preparation and maintenance of herbarium specimens; sufficiently large, dedicated, and well-equipped infrastructure, and limited accessibility to users (Zunjarrao *et al*., 2015), besides, prone to physical damage to the specimen during handling or hazardous situation. To overcome this, there is an alternate and modern method of herbarium preparation that is "Virtual herbarium". It can be defined simply as "the virtual images of plant specimens in digital format". Digitization of herbarium specimens involves capturing both digital images of the specimen itself and databasing the data affiliated with each specimen. And the digital images should be linked with the virtual herbarium. The virtual herbarium is a database consisting of images of herbarium specimens and the supporting text, available over the internet. One of the major advantages of digitization is that the specimen morphology can be visualized without damage to the original specimen. The high-resolution images of digitized specimens can be magnified; hence researchers can examine micro-morphological features of plant parts, and can further access specimen information have recorded on the data sheet (Sreekumar *et al*., 2017), and it saves time and cost of transportation.

To fulfil the needs of the nation and to conduct organized scientific research exclusively on grasslands and fodder production and their utilization, the Government of India established an institute of national importance, Indian Grassland and Fodder Research Institute (ICAR-IGFRI), at the heartland/biodiversity hotspot of grasses (Jhansi) in 1962. On 1st April 1966, it became a part of the Indian Council of Agricultural Research (ICAR). Research works on herbarium started as a repository of plants in the late 1950s under the Grassland Survey Scheme of PL-480 (1954-1962) of ICAR. However, collections were further strengthened by adding other specimens collected from time to time over the years. The herbarium specimens

were collected from different parts of the country from time to time. The collection houses a number of rare, restricted, and endangered plant taxa from different parts of India. As the collections were quite old *viz.* more than 70 years, the heritage of the institute needed to be preserved for the benefit of the researchers as well as students of the plant sciences. In the year, 2018, it was realized that while physical specimens were a must in a herbarium, to increase its utility as well as to preserve the information pertaining to the specimens for a long time, its digitization was necessary. The herbaria, together with their increasing digitization and the possibility of sequencing DNA from the preserved plant material, make them invaluable resources for understanding ecological and evolutionary species' responses to global environmental change (Lang *et al.*, 2019). Data collected from herbarium specimens by botanical gardens and research institutes can be used to measure the effects of climate change on phenological events and information on flowering times collected from these locations could be gathered into one data set, and analysis could assess the responses of native species to local climate change and help predict the effects of future climate change on biological communities (Miller-Rushing *et al.*, 2004, Miller-Rushing *et al.*, 2006).

Again, due to continuous handling, fragile herbarium sheets tend to wear off, which can be prevented by making a digital copy of them. Therefore, a project was initiated to digitize all the herbarium collections with the goal to facilitate free full online access to all imaged specimens from IGFRI, Jhansi herbarium.

MATERIALS AND METHODS

A complete plant specimen possessing all parts including the root system, flowers, and fruits was collected from different regions of the country. After collection, the specimens were dried, poisoned, and mounted on herbarium sheets as per the prescribed methodology (Jain & Rao, 1977) and housed at Grassland and Silvipasture Management, Division of ICAR-IGFRI, Jhansi. The specimens were identified in consultation with regional and national floras, revisions, monographs and relevant taxonomic papers wherever required. The specimens were arranged by species, then by genera, and then by families; all in alphabetical order. Herbarium specimens were scanned

Fig. 1. Home page of the virtual herbarium database.

using the scanner Epson DS-50000 and images were captured at 300 dpi and stored as a .jpeg file. These images of herbarium specimens were linked to the portal (Fig. 1.).

RESULTS AND DISCUSSION

Data and web design : The website named "Virtual herbarium of IGFRI" was developed by WordPress version 5.2.2., which was a free and open-source content management system based on PHP language and MySQL database. The website was optimized for computers, tablets, and mobile platforms. It was used more often as it had several interactive features such as ease to use, responsive design, multiple theme options, plugins for customization, self-hosted platform, community support, eco-friendly, easy social media integration' outstanding scalability, etc. PHP was a server-side scripting language designed for web development, further, it had advantages like, cross-platform, ease of use, speed, open-source and powerful library support, stability, etc. and MySQL was an open-source relational database management system. The database includes a total of *c.* 741 species representing 62 families. The website provides two search keys on the home page *viz*. 'Family' and 'Genus' by which users can search the list of families, genera, and species which are arranged in alphabetic order. Users can browse the species page by either key, the 'Family' key would lead to all the genera under that family and genera would lead to all species under each genus.

Institutional repository: ICAR-IGFRI, Jhansi started collecting plants and housing them in the herbarium. The early collections of P. C. Nanda, K. C. Kanodia, B. D. Patel, S C Agarwal, and C. R. Rao were noteworthy for this. There were more than 2500 sheets of plant specimens housed in the herbarium. The collections were mainly composed of grasses, legumes, and forbs (weeds). Collections were made from 17 different states of India and new collections were added from time to time (Fig: 2). Taxonomic literature and study of herbaria revealed a total of 741 species under 344 genera belonging to 62 families (Table 1). Out of 741 species, 276 species of dicots were distributed under 185 genera belonging to 50 families, while 465 monocot species spread over 159 genera under 12 families (Fig. 3). The dominant 5 families with maximum records are Poaceae (396 species), Fabaceae (82 species), Cyperaceae (40 species), Asteraceae (26 species) and Brassicaeae (13 species) (Fig. 4).

TABLE 1
List of families with number of genera and species

S. No.	Family	Genera	Species
1	Acanthaceae	9	14
2	Adoxaceae	1	1
3	Amaryllidaceae	1	2
4	Amaranthaceae	8	9
5	Apiaceae	3	4
6	Apocynaceae	2	2
7	Asparagaceae	5	6
8	Berberidaceae	1	1
9	Boraginaceae	3	3
10	Brassicaceae	13	13
11	Capparaceae	1	1
12	Caprifoliaceae	1	1
13	Caryophyllaceae	5	5
14	Cleomaceae	1	2
15	Clusiaceae	1	1
16	Combretaceae	1	1
17	Commelinaceae	3	8
18	Compositeae	24	26
19	Convolvulaceae	5	7
20	Crassulaceae	1	2
21	Cucurbitaceae	1	1
22	Cyperaceae	7	40
23	Eriocaulaceae	1	4
24	Euphorbiaceae	5	12
25	Fabaceae	29	82
26	Gentianaceae	3	4
27	Grossulariaceae	1	1
28	Hydrocharitaceae	1	1
29	Hypericaceae	1	1
30	Iridaceae	1	1
31	Lamiaceae	10	12
32	Liliaceae	3	4
33	Linaceae	1	1
34	Linderniaceae	1	2
35	Lythraceae	1	2
36	Malvaceae	5	7
37	Martyniaceae	1	1
38	Moraceae	1	1
39	Nyctaginaceae	1	3
40	Onagraceae	1	1
41	Orchidaceae	1	1
42	Orobanchaceae	1	3
43	Oxalidaceae	2	2
44	Papaveraceae	2	2
45	Phrymaceae	1	1
46	Plantaginaceae	3	3
47	Poaceae	134	396
48	Polygalaceae	1	1
49	Polygonaceae	3	4
50	Primulaceae	3	3
51	Ranunculaceae	6	7
52	Rhamnaceae	1	3
53	Rosaceae	7	7
54	Rubiaceae	2	3
55	Santalaceae	1	1
56	Sapindaceae	3	3
57	Solanaceae	1	1
58	Typhaceae	1	1
59	Verbenaceae	2	2
60	Violaceae	2	2
61	Xanthorrhoeaceae	1	1
62	Zygophyllaceae	2	4

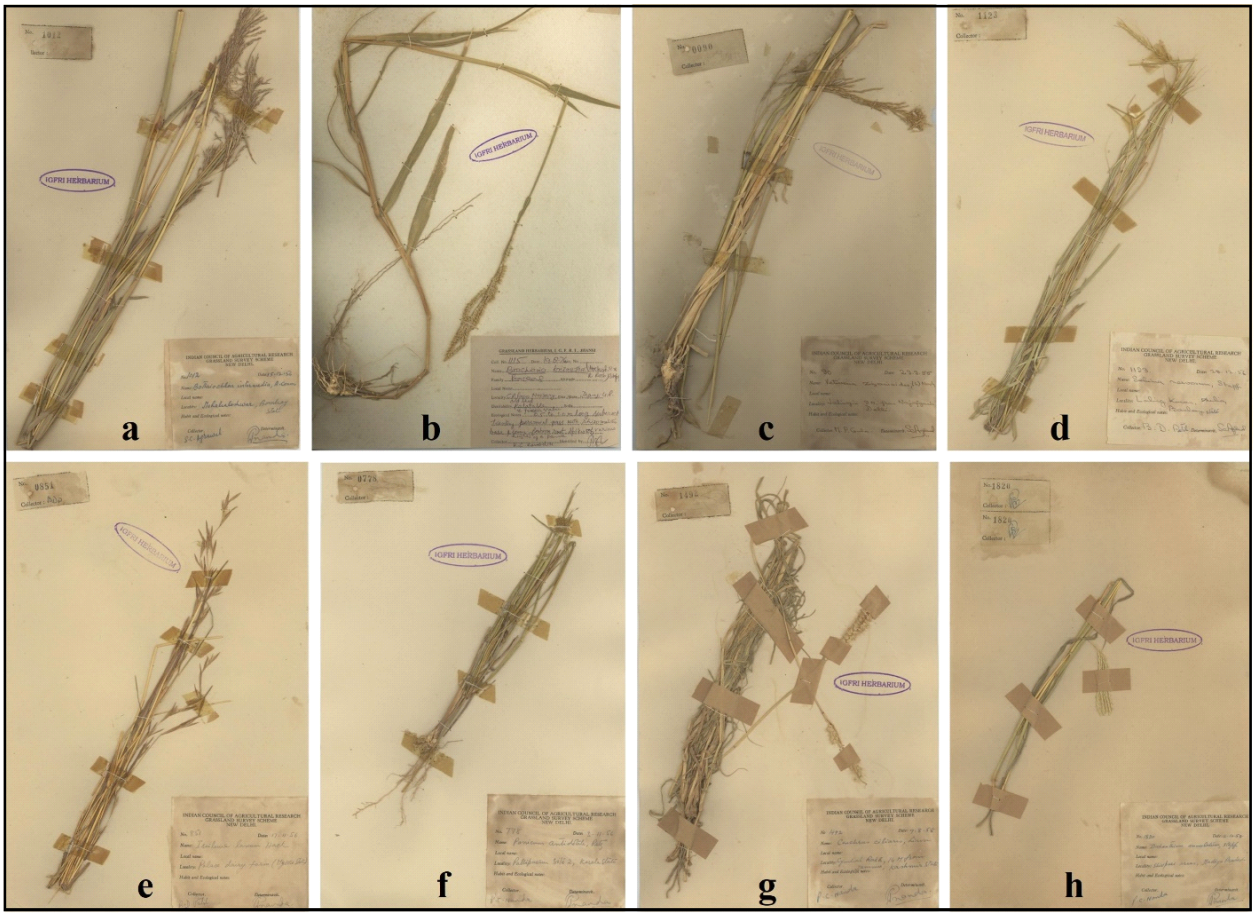

Fig. 2. Representative herbarium specimens of some of the range grasses of India: a) *Bothriochloa bladhii* (Retz.) S. T. Blake (= *B. intermedia* (R. Br.) A. Camus), b) *Urochloa brizantha* (A. Rich.) R. D. Webster (= *Brachiaria brizantha* (A. Rich.) Stapf), c) *Chrysopogon zizanioides* (L.) Roberty (=*Vetiveria zizanioides* (L.) Nash), d) Sehima nervosum (Rottler) Stapf, e) Iseilema laxum Hack., f) *Panicum antidotale* Retz., g) *Cenchrus ciliaris* L., h) *Dichanthium annulatum* (Forssk.) Stapf.

TABLE 2
List of famous virtual herbarium with e links

S. No.	Name of herbaria	E link
1.	Botanical Survey of India	https://ivh.bsi.gov.in
2.	CSIR- National Botanical Research Institute, Lucknow	https://www.nbri.res.in/herbarium/
3.	Herbarium of French Institute of Pondicherry (HIFP)	https://www.ifpindia.org/resources/herbarium/
4.	Herbarium of Regional Plant Resource Centre, Odisha	https://www.rprcbbsr.in/View/DefaultHome.aspx
5.	Herbarium of Kerala Forest Research Institute	http://kfriherbarium.org/
6.	Herbarium of JNTBGRI (TBGT), Kerala	http://www.jntbgri.in/tbgtherbarium/contacts.asp
7.	Indian Institute of Science Herbarium (JCB), Karnataka	http://flora-peninsula-indica.ces.iisc.ac.in/welcome.php
8.	ICAR- National Herbarium of Cultivated Plants, NBPGR- New Delhi	http://www.nbpgr.ernet.in:8080/nhcp/NHCP-Index.aspx
9.	Herbarium, Raw Drug Repository of FRLHT (FRLHT), Bengaluru, Karnataka	https://tdu.edu.in/resources/herbarium/
10.	Janaki Ammal Herbarium in the Indian Institute of Integrative Medicine (RRLH), Jammu Tawi	https://iiim.res.in/herbarium/herbarium.htm

Grass collections : Among 62 families, the most fodder value species were collected from the families of Poaceae and Fabaceae. The family Poaceae is mostly herbs, comprising about 11506 species belonging to 768 genera (Soreng *et al*., 2017). The grass family Poaceae is the largest angiosperm family in India having 1760 taxa belonging to 1452 species and 278 genera (Mao & Dash, 2020), which contributes to about 12.6% of the world species. 26.4% species of Indian grasses are well representing in the herbarium of ICAR-IGFRI. Many of these grasses are well known for their rich fodder value. Among 63 families, the most economic important grass family Poaceae has maximum collections (134 genera and

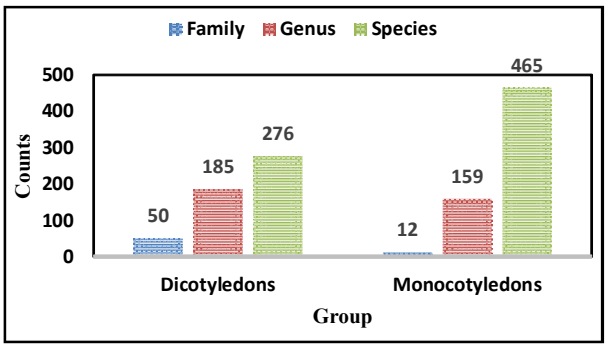

Fig. 3. Herbarium representation of families, genera and species of ICAR-IGFRI.

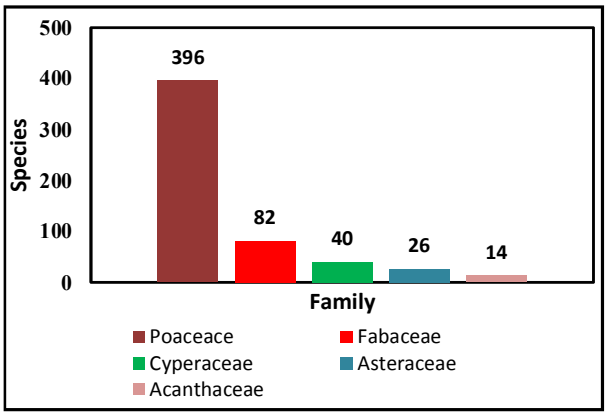

Fig. 4. Representation of top five families of ICAR-IGFRI.

396 species) from various parts of the country. The dominant genera with species are *Eragrostis* (19 species) followed by *Panicum* (15 species), *Digitaria* (14 species), *Arundinella* and *Cymbopogon* (13 species each), *Festuca*, *Ischaemum*, *Poa*, *Sporobolus* (12 species each) and *Themeda* (10 species) (Fig. 5).

Legume collections : Legumes are one of the most economically important and versatile and third largest angiosperm plant family in terms of species numbers after Asteraceae and Orchidaceae. About 23,000 species (22,939 to be precise) of legumes belonging to about 800 genera, including chickpeas, lentils, soya beans, peanuts, and many valuable timbers, including the much-prized rosewoods (Andrella *et al*., 2021). The family Fabaceae (Leguminosae) is the second largest angiosperm family in India having 1292 taxa belonging to 176 genera (Mao & Dash, 2020), which contributes to about 56.17% of the world legume species. The herbarium ICAR-IGFRI is representing 6.42% species of Indian legumes. Legumes are economically important food crops providing highly nutritious sources of protein and micronutrients that can greatly benefit health and livelihoods. They are also uniquely important as fodder and green manure in both

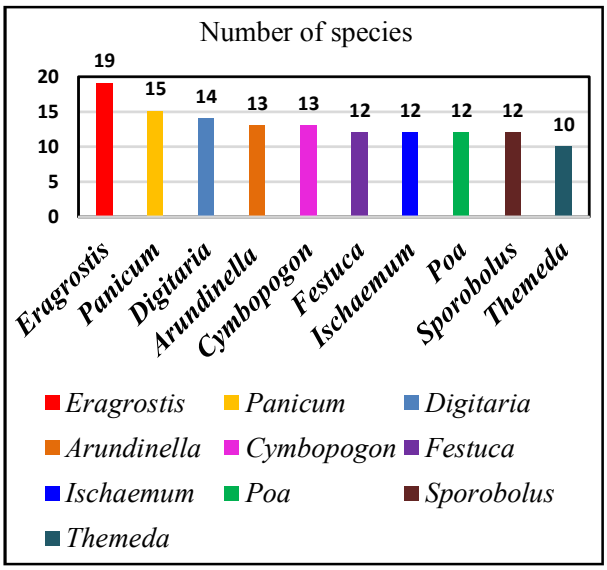

Fig. 5. Dominant genera of Poaceae with species.

temperate and tropical regions, and are used for their wood, tannins, oils and resins, in the manufacture of varnishes, paints, dyes and medicines, and in the horticultural trade (Andrella *et al*., 2021). The present analysis includes 210 specimens belonging to 83 taxa of the leguminous family under 28 genera and 82 species. It includes 52 herbs followed by 25 shrubs, 5 trees, and a climber. The genus *Indigofera* has maximum species (17 species) followed by *Crotalaria* (16 species) and *Desmodium* (7 species).

Worth mentioning virtual herbariums in India

In India, there is an excellent collection of herbarium specimens maintained in several well-known herbaria. As per the BSI ENVIS portal, Index Herbarium and latest updated information from BSI, there are more than 90 major herbaria are available in India. The specimen details are available in the link http://bsienvis.nic.in/files/List%20of%20Indian%20Herbaria.pdf. There have been initiatives to digitize herbarium specimens and make them available online, such as those done by the Botanical Survey of India. Botanical survey of India (BSI) is the apex organization to serve as custodian of authentic plant collections in herbaria and to document the same for the preparation of local/state/national flora. Out of 90 herbaria, the BSI, Central National Herbarium (CAL), Howrah has more than 2.5 million specimens, which is holding the largest collections in India, followed by the herbarium of Forest Research Institute (DD), Dehra Dun (3,50,000). A list of famous virtual herbaria has been presented in Table 2.

CONCLUSION

Herbarium specimens are basic requirements for documentation of plant diversity in any region. Digitization is a strong tool to conserve and utilize historic documents and images globally. Preservation of these specimens is as important as the collection itself. Herbarium records contain data on phenophases, species abundances, community composition, and other ecological factors in addition to the date and location of collection, offering a unique chance to examine the effects of climate change using long-term spatiotemporal data. The historic collections preserved at ICAR-IGFRI were digitized. Digitized images are available through https://vbigfri.icar.gov.in/ web address. The IGFRI herbarium database provides a comprehensive, high-quality information system on plant resources available to the institute. The information on this website will be useful in finding the correct identity of the species. This website will be highly useful to the forest departments, universities, research institutions, students and teachers. Furthermore, digital herbarium data can be accessed from any part of the world once it is uploaded to the website.

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