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IPSD: e-repository of Permian seeds from Indian Lower Gondwana

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ABSTRACT. The interest and importance of studying the reproductive strategies of Palaeozoic plants are growing. Fossil seeds play an essential role in this line of study, as they are widely described from different sedimentary formations throughout the Permian period. The Indian Permian Seed Database (IPSD) software will be an information system for ensuring the storage, safety, accessibility and recovery of the details of Indian Permian seed records in a selective manner. The current database includes 28 genera and 44 species of compressed seeds described from Lower Gondwana (Permian), with all the details for researchers. The software provides options for addition, deletion, modification and search facility. The search also includes different options (single or combination). It is a quick and organised way to look for seeds, especially on a data grid for information about seeds that have already been published in the same or different sediments. IPSD is a tool for the computer-based identification of seeds and distinguishing different genera or species within the same category. It is user-friendly and provides updated knowledge of seeds from the Lower Gondwana basins of India. It provides morphotaxonomical characters, distribution and photo documentation of seeds. The software increases accuracy through computer-assisted identification of seeds. Hence, reducing and curtailing unnecessary information while describing a new species with inadequate earlier knowledge of Permian seeds.

KEYWORDS: Database, Gondwana, Permian, photo documentation, seed, IPSD

DATABASE URL: http://14.139.63.228:9092/SeedDatabase/Login.aspx

INTRODUCTION

The *Glossopteris* leaf dominated the Gondwanaland flora during the Permian period. Along with the *Glossopteris* leaves, a good number of seeds were also described by different authors. The flora was dispersed, pronounced by the presence of naked gymnospermous seeds. The seeds described mainly by previous authors were found in the sediments in dispersed conditions. There are two types of seeds recognized: radiospermic and platyspermic, based on the type of plane in which they are preserved (Pant et al., 1985). The radiospermic seeds are preserved in more than two planes, while the platyspermic seeds are preserved in only one plane. The Lower Gondwana seeds are mostly platyspermic. Their importance was recognised after phytostratigraphic and evolutionary studies. They play an essential palaeobotanical role for geological, evolutionary and biostratigraphical studies. Recognising the importance of platyspermic seeds gained momentum after Maithy

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(1965) proposed a schematic identification and classification, which were later revised by Millan (1974, 1994). The occurrence of seeds in the Gondwana basins is comparably sporadic and mainly known from Damodar and South Rewa Gondwana basins (Gautam et al., 2013; Pillai et al., 2018). The evidence of detached seeds is from early Permian sediments in India, i.e. Talchir, Karharbari and Barakar formations (Maithy, 1965; Pant et al., 1985; Tewari et al., 2012). There are few records of seeds from the late Permian (Tewari, 2007; Srivastava and Agnihotri, 2010; Pillai et al., 2018; Patel et al., 2021). The presence of seeds in the Permian indicates the flourishing behaviour of glossopterids and their alliance with other flora (*Glossopteris* Flora). Most of the seeds are impressions that are devoid of structural details. There are rare reports of petrified seeds. Gould and Delevoryas (1977) found attached dorsiventral fructifications but these were not described in India.

Acquiring information about all Permian seeds from different journals is tedious and time-consuming. Identifying and creating a new seed genus or species require detailed literature analysis regarding all previous data. There is a significant setback with palaeontological studies concerning their characters and identification, which change over the years as they are treated by different authors differently (Riedel and Budai, 1980). To overcome this setback, the development of software plays an essential role in providing detailed knowledge of a particular taxon and the option of updating with new findings.

The present IPSD software compiles records of all seeds described in the Permian period (299–252 Ma) of Indian Gondwana. The software has the details of 28 genera and 44 species of compressed seeds described from Lower Gondwana, with all the details that will help the researchers get the information at their fingertips. The database information system is significant as it gives holistic palaeontological information, and sharing this information makes the whole world a small village. The present software is developed to provide information related to the Permian seeds of India in a systematic, detailed, comprehensive and precise manner. This software also has the option to update the relevant data.

GENERAL DESCRIPTION OF SEEDS

The ovule becomes a seed after fertilization (Chadefaud, 1944), but the ambiguity lies in whether the fossil seeds are fertilized or not. It is considered that in Lower Gondwana seeds, the embryos were absent as they shed soon after fertilization. Later, the seeds under preservational conditions were fossilized rapidly without developing into embryos. Earlier palaeobotanists considered embryoless ovules, or ovule-like or seed-like bodies, as seeds (Tiwari, 2004). Arnold (1948) and Florin (1950) considered the term seed for such reproductive bodies. However, Eames (1955) justified the term ancient seed for those unfertilized ovules or seeds with early stages of embryos. Later, the structures from Lower Gondwana were described as seeds. They were either

Table 1. List of fossil databases and their web-links

List of Database	Web Link
The Paleobiology Database	https://www.gbif.org/dataset/c33ce2f2-c3cc-43a5-a380-fe4526d63650
Fossil work	http://www.fossilworks.org/
iDigBio	https://www.idigbio.org/portal/search
macrostrat	https://macrostrat.org/
Neotoma Paleoecology Database	https://www.neotomadb.org/
Paleontology Database by Burke Museum	https://www.burkemuseum.org/collections-and-research/geology-and-paleontology/collections-database/
Database of fossil mammals	https://nowdatabase.org/
Paleontology Database by American Museum of Natural History	https://www.amnh.org/research/paleontology/collections/database
Fossil files: The Paleobiology Database	https://ieltsquangbinh.com/fossil-files-the-paleobiology-database/
PBot, The Integrative Paleobotany Portal	https://gsa.confex.com/gsa/2021AM/webprogram/Handout/Paper365361/Currano_PBot_GSA%202021%20poster.pdf
Paleobotany database	https://www.earthcube.org/paleobotany-database
Database in India	
IGMIS	http://14.139.63.228:9092/megaspore/Multisearch2.aspx

compressions or impressions that were found attached or detached.

In modern research, fossil data are used extensively for understanding the modern ecosystem, morphotaxonomical features of fossils (e.g. root, stem, leaf, fruit, seed, spore, pollen, etc.) and climate changes. Kremp (1979), for the first time, used computer-based research in palaeontology. Riedel and Budai (1980) considered that different names for the same species must be resolved in palaeontology as they may cause wrong scientific interpretations. Hence, Riedel (1989) developed a software based on Turbo Prolog to assist the user in identifying the fossils. Later, more software packages were developed, which are presented in Table 1. In India, there is only one palaeontological database software on megaspore named Indian Gondwana Megaspore Information System (IGMIS) (Govind et al., 2014), specifically for the Permian period. Hence, there is a need to develop different types of organised web-based data to enhance its efficacy and make a wealth of information accessible to the entire world. The IPSD database is a new milestone that will be an essential tool for budding researchers, who can access information at their fingertips. The database is developed as a web-based application for broader distribution (database URL: http://14.139.63.228:9092/SeedDatabase/Login.aspx). It can be accessed with a user password, which can be retained from the software administrator (e-mail: ssureshk_pillai@bsip.res.in).

DATA PORTAL OF IPSD

Information for the development of the IPSD database comes from primary and secondary resources like research papers, journals, abstracts, textbooks, monographs and catalogues, which are logically integrated following the database management system of Rawat (2010).

The present web-based software is coded in Microsoft Visual Studio 2019 with the VB scripting language, which is used as the front end and Microsoft SQL Server 2019 as the back end. The software application requires a PC with a Core i3 processor or higher and 1 GB RAM or higher on Windows 10 or higher. The seed information collected from different sources (journals, books and museums) was entered into the Microsoft SQL Server 2019 database

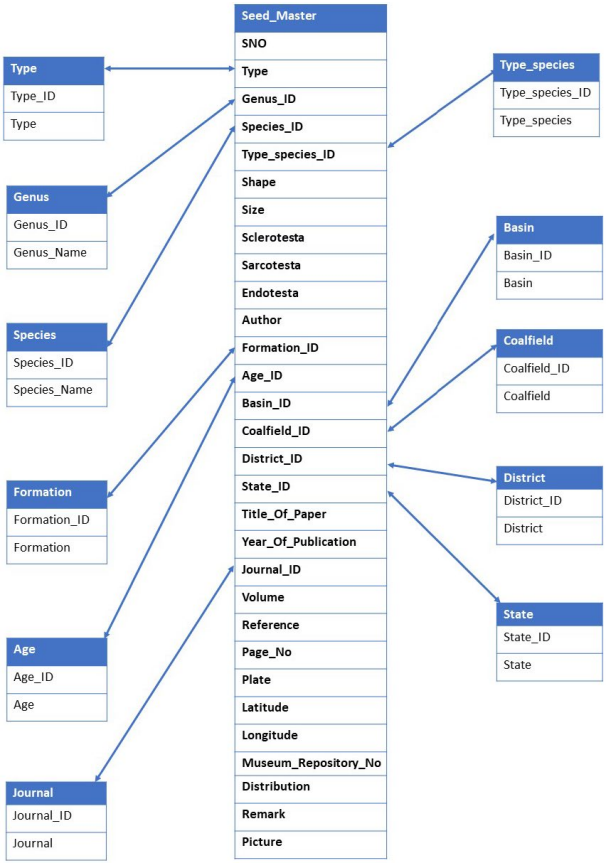

Figure 1. Data structure of IPSD

management system (Fig. 1). The tables of the software are linked through primary keys (Stevens, 1989) with one-to-one and one-to-many relationships (Connell, 1998). The IPSD database has two basic types: the transaction table and the master table (Table 2). The transaction

Table 2. Transaction table and master table

Table name	Description
Type	Information about the specific structure of seeds
Genus	Information about the genus
Species	Information about the species
Type species	Information about the first species of specific genera
Author	Information about the authors
Formation	Information about the formations from where the samples were collected
Age	Information about different ages of samples
Coalfield	Information about the coalfield from where the samples were collected
Basin	Information about the basin from where the samples were collected
District	Information about the district from where the samples were collected
State	Information about the states from where the samples were collected
Journal	Information about the particular journal from where the data have been procured
Seed Master	Complete record of seed data with images in binary form

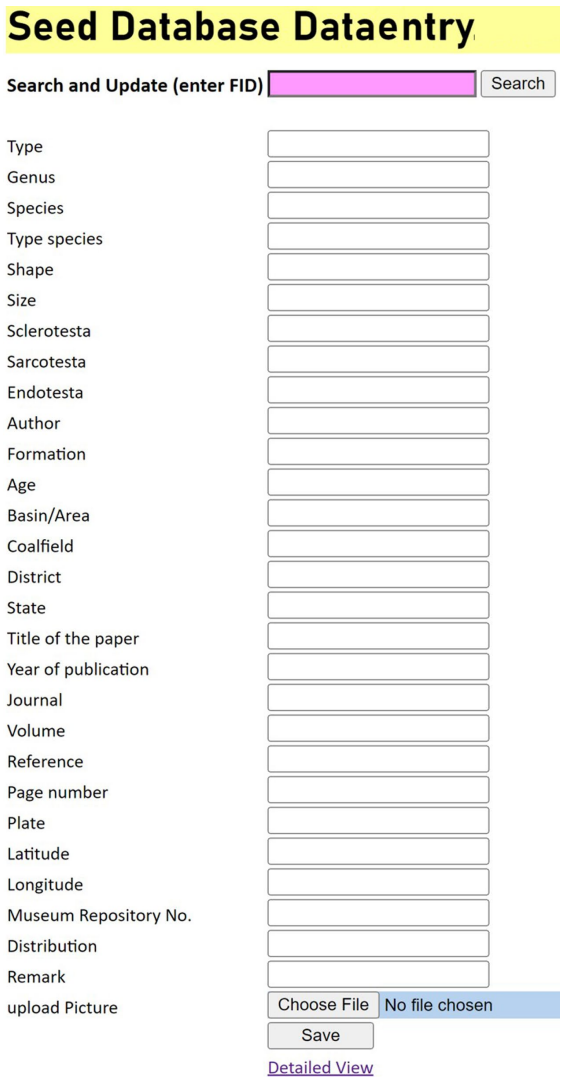

Figure 2. Data management form

table consists of information related to the original author table, which has information on the genus of the seed and the subsequent author, who has updated the information on seeds. The master table gives information about the morpho-taxonomical description of seeds and photo-documentation of all seeds described from the Permian period of India.

The front end of the current software is split into two main sections: the data management form (data entry) (Fig. 2), which is managed by the administrator only and the data manipulation form (advance search) (Fig. 3), which is for the end user. A set of data manipulation forms has been created to perform various tasks directly on the raw data. The administrator's responsibility involves accessing the data, as well as adding, removing, or altering the seed entries in the database. This makes it possible for the user to access and manage the data stored in the database (Fig. 4). The software's current information aids in describing and updating the raw data. Due to the relational database design, changes must be made once to the master seed table while altering database table information. When the data are requested, these changes are automatically reproduced the next time. Using the data entry form, the details of the seed records can be entered one by one. Hence, the complete record of seed information can be recorded digitally. The entire process takes less time, including answering the queries, viewing the freshly formatted data and importing it into the database.

The data manipulation form facilitates requests for seeds-related files to advance data retrieval activities. The data recovered and exhibited with these forms cannot be altered. Records can be looked up under the advanced search section using a combination of various fields. Using both search methods, images and seed details are displayed on the data grid.

The sample web page for advance search in IPSD is given in Fig. 3. This software aims

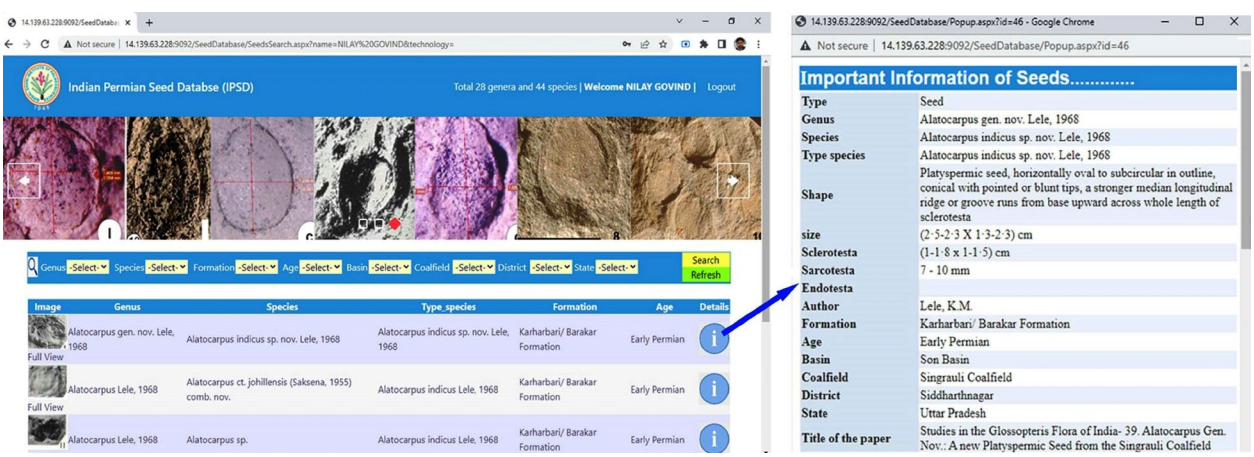

Figure 3. Web interface of IPSD advance search

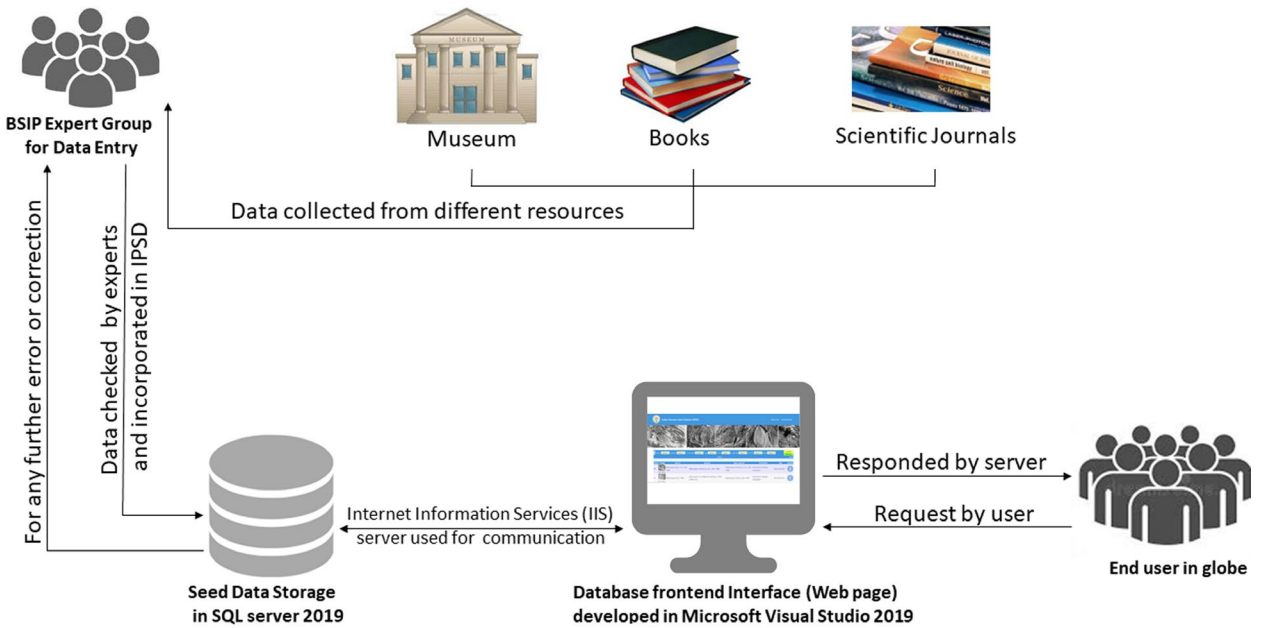

Figure 4. Overview of the technical architecture for data collections and user interface

to quickly retrieve complete information about seeds as a whole or in specific dataset combinations. The database is a crucial communication channel for academics and palaeoscience researchers, as it is accessible at any time and location. However, the data in such a system is entirely dependent on human capacity (Govind et al., 2014). The recent updates to the database of Indian Permian seeds have been confirmed by professionals and are typically error-free.

Different authors described the Indian seeds of the Permian period based on their external morphology. The ages of these seeds range from 299 to 252 Ma. In the present software, twenty-eight (28) genera and forty-four (44) species of compressed seeds have been described from the Lower Gondwana formations in India. The software provides complete details of the seeds (genus, species, formation, coalfield, reference, authors, etc.) with photographs. The species distribution graph with respective genera is presented in Fig. 5. From the above study, we find the distribution of seeds from different formations of Indian

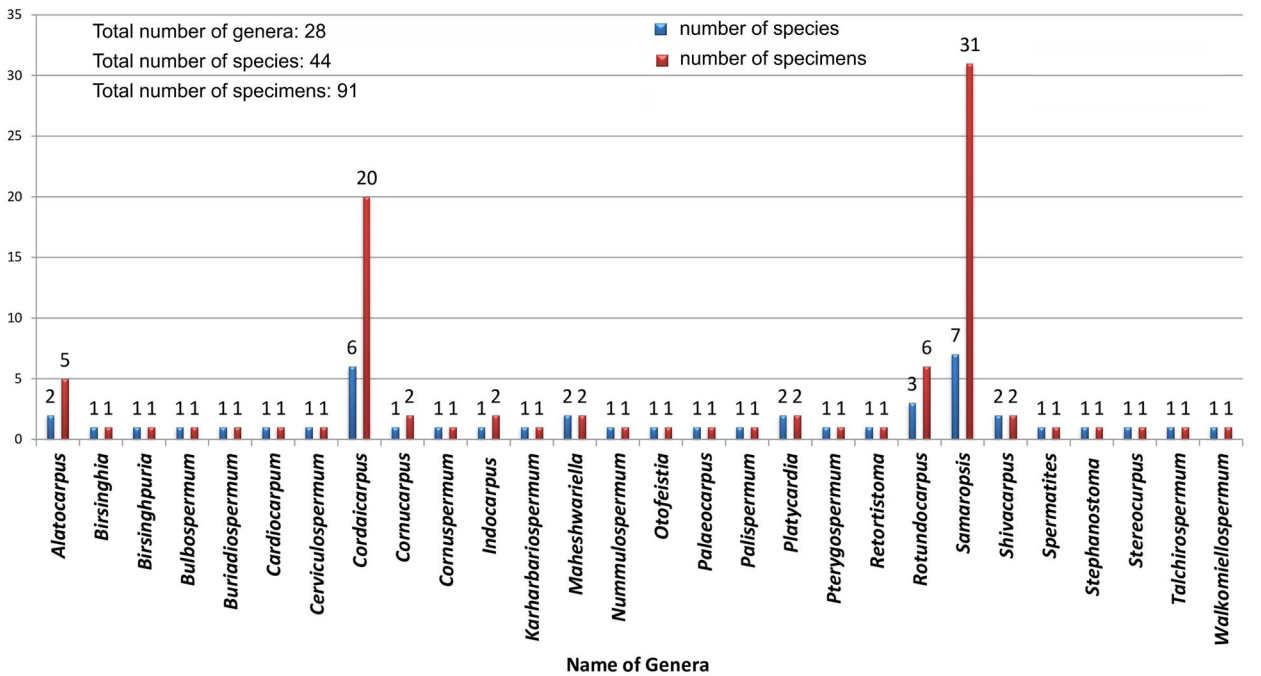

Figure 5. Species distribution graph with respective genera

Lower Gondwana, and this can be compared with the seeds described from other Gondwana continents.

SEED DISTRIBUTION DURING PERMIAN PERIOD

The seeds of the Lower Gondwana show distinct structures that help to identify their genus and species. They show significant variation in size, ranging from less than 1 mm to 50 mm in length. Their width varies from 0.5 mm to 40 mm. The seeds are generally orthotropous, but the seeds of *Palaeocarpous* and *Buriadia* are anatropous. *Otofeistia miller*, *Shivacarpus johillensis* and *Maheshwariella bicornuta* are stalked seeds. Certain seeds are broader than long, viz., *Alatocarpus indicus, Alatocarpus johillensis* and *Shivacarpus latus. Buriadiospermum, Maheshwariella bicornuta, Maheshwariella spinicornuta* bear micropylar horns towards the micropylar ends. Certain seeds have a funnel-like structure towards the micropylar end, viz. *Cornuspermum* and *Stephanostoma. Otofeistia* and *Palaeocarpus* have sinuses at the centroterminal part. *Otofeistia, Palaeocarpus* and *Shivacarpus* exhibit massive integuments, which can be differentiated into sarcotesta (outer fleshy layer) and sclerotesta (inner stony layer). Some seeds show narrow sarcotesta, viz., *Cordaicarpus, Maheshwariella* and *Cornuspermum*. Some seeds display the medium thickness of sarcotesta, e.g. *Samaropsis*.

The distribution of seed species from the different formations of the Permian period is presented in Fig. 6. The highest number of species is described from the Karharbari Formation (27 species; 42%), followed by the Barakar Formation (14 species; 22%) and the Raniganj Formation (13 species; 20%) in second and third position, respectively. The distribution of seed species from different Gondwana basins and coalfields of India during the Permian period is presented in Figs 7 and 8, respectively. Out of which, South Rewa Basin has the highest number of seeds (24 species; 27%), followed by Giridih Basin (14 species; 16%) and Satpura Basin (11 species; 13%), and similarly, Giridih Coalfield and Birsinghpur Coalfield have the highest number of seeds (12 species and 15% each) followed by Pench Valley Coalfield (8 species; 10%) and Johilla Coalfield (7 species; 9%). The distribution of the seeds in different Lower Gondwana formations of India and in various Gondwana basins of India is presented in Tables 3 and 4 respectively.

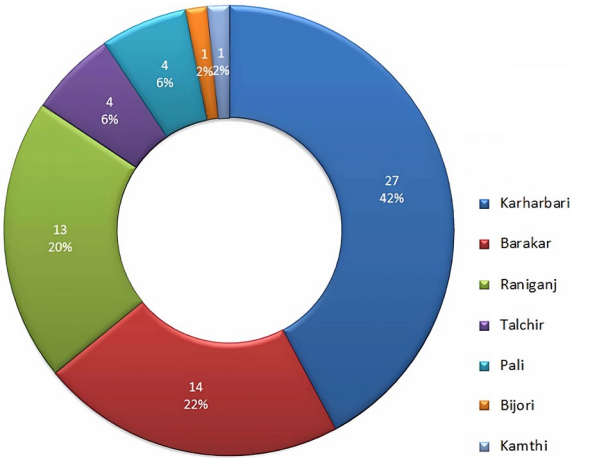

Figure 6. Distribution of seeds in different Indian Lower Gondwana (Permian) formations

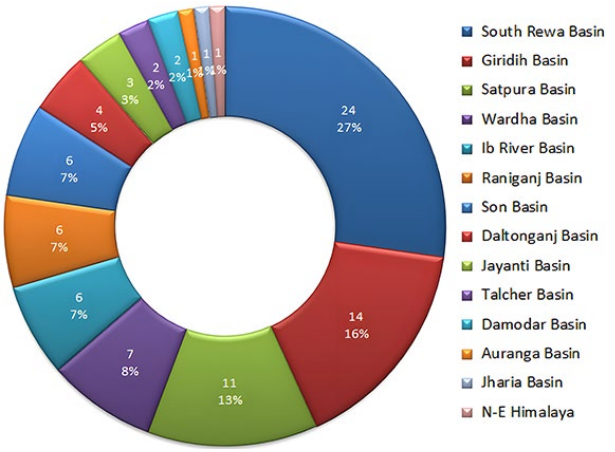

Figure 7. Distribution of seeds in different Indian Gondwana Basins

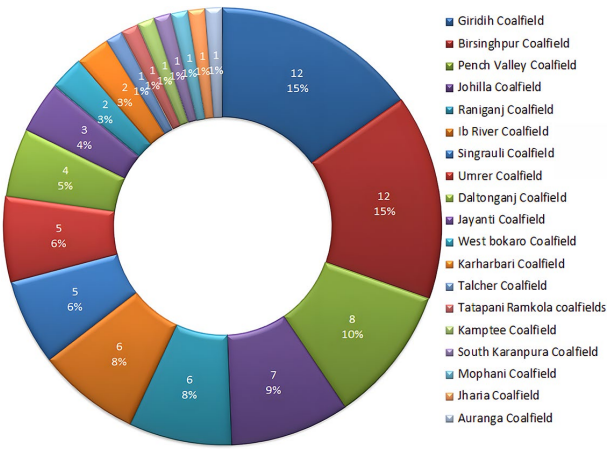

Figure 8. Distribution of seeds in different coalfields of India

If we analyse the reports of individual seeds from the Permian period, the genera *Cordaicarpus* and *Samaropsis* are the dominant forms of seeds of Lower Gondwana. The

Table 3. Distribution of seeds in different Lower Gondwana formations of India

Genera and species	Talchir	Karharbari	Barakar	Barren Measures	Raniganj	Pali
Alatocarpus indicus Lele 1968	.	+	+	.	.	.
A. johillensis Saksena 1955	.	+	+	.	.	.
Alatocarpus sp.	.	+	+	.	.	.
Birsinghia florinii Pant et al. 1995	.	+	.	.	.	.
Birsinghpuria indica Pant et al. 1985	.	+	.	.	.	.
Bulbospermum surangei Pant et al. 1985	.	+	.	.	.	.
Buriadiospermum sewardii Pant et al. 1984	.	+	.	.	.	.
Cardiocarpum sp.?	.	+	.	.	.	.
Cerviculospermum ovale Pant et al. 1998	.	+	.	.	.	.
Cordaicarpus chichariensis Lele 1963	.	.	+	.	.	.
C. cordai Geinitz 1862	.	.	+	.	.	.
C. furcata Surange et Lele 1956	+	.	.	.	.	.
C. indicus Zeiller 1902	.	+	.	.	.	.
C. karharbarense Maithy 1965	.	.	+	.	+	.
C. zeilleri Maithy 1965	.	+	+	.	+	+
Cordaicarpus sp.	.	+	+	.	+	+
Cornucarpus furcata Surange et Maithy 1957	+	+	+	.	.	.
Cornuspermum pennatus Banerjee 1969	.	.	.	.	+	.
Indocarpus elongatus Surange et Chandra 1972	.	.	.	.	+	.
Karharbariospermum surangei Srivastava et Chandra 1982	.	+	.	.	.	.
Maheshwariella bicornuta Pant et Nautiyal 1963	.	+	.	.	.	.
M. spinicornuta Maheshwari et Tewari 1986	.	+	.	.	.	.
Nummulospermum bowense Walkom 1921	.	+	.	.	.	.
Otofeistia milleri (Feistmantel) Pant et al. 1985	.	+	.	.	.	.
Palaeocarpus birsinghpurensis Pant et al. 1985	.	+	.	.	.	.
Palispermum ovalis Pant et al. 1985	.	+	.	.	.	.
Platycardia bengalensis Pant et Nautiyal 1960	.	.	.	.	+	.
P. jugus Maithy 1968	.	+	.	.	.	.
Pterygospermum raniganjense Pant et Nautiyal 1960	.	.	.	.	+	.
Retortistoma crystallina Pant et al. 1985	.	+	.	.	.	.
Rotundocarpus mucronatus Tewari et al. 2012	.	.	+	.	.	.
R. ovatus Maithy 1965	.	.	+	.	.	.
R. striatus Maithy 1965	.	+	+	.	+	+
Samaropsis feistmantelii Maithy 1965	.	+	+	.	+	+
S. ganjrensis Saksena 1955	.	+	+	.	+	.
S. goraiensis Surange et Lele 1956	+	+	+	.	+	+
S. johillensis Saksena 1955	.	.	+	.	.	.
S. millerii (Feistmantel) Seward 1917	.	+	.	.	.	.
S. penchii Pillai 2007	.	.	+	.	.	.
S. raniganjensis Seward et Sahni 1920	.	.	.	.	+	.
Samaropsis sp.	+	+	+	.	+	+
Shivacarpus johillensis Pant et al. 1985	.	+	.	.	.	.
S. latus Pant et al. 1985	.	+	.	.	.	.
Spermatites indicus Srivastava 1954	.	.	+	.	.	.
Stephanostoma crystallinum Pant et Nautiyal 1960	.	.	.	.	+	.
Stereocarpus emarginatus Surange 1957	.	.	.	.	+	.
Talchirospermum indicum Srivastava et Chandra 1982	+	.	.	.	.	.
Walkomiellospermum indicum Pant et Srivastava 1963	.	.	+	.	.	.

genus *Samaropsis* has the highest number of species (7 species; *S. feistmantelii, S. ganjrensis, S. goraiensis, S. johillensis, S. millerii, S. penchii* and *S. raniganjensis*), followed by *Cordaicarpus* (6 species; *C. chichariensis, C. cordai, C. furcate, C. indicus, C. karharbarense* and *C. zeilleri*) and *Rotundocarpus* (3 species; *R. mucronatus, R. ovatus* and *R. striatus*) in second and third position, respectively.

Lower Gondwana seeds are preserved as impressions or compressions, which are found either attached or detached. The attached

Table 4. Distribution of seeds in various Gondwana basins of India

Seed taxa (44)	Name of basins													
	South Rewa	Giridih	Satpura	Wardha	Ib River	Raniganj	Son	Daltonganj	Jayanti	Talcher	Damodar	Auranga	Jharia	NE Himalaya
Alatocarpus indicus Lele 1968	+	·	+	·	·	·	+	·	·	·	·	·	·	·
A. johillensis Saksena 1955	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Alatocarpus sp.	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Birsinghia florinii Pant et al. 1995	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Birsinghpuria indica Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Bulbospermum surangei Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Buriadiospermum sewardii Pant et al. 1984	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Cardiocarpum sp.?	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Cerviculospermum ovale Pant et al. 1998	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Cordaicarpus chichariensis Lele 1963	·	·	+	·	·	·	·	·	·	·	·	·	·	·
C. cordai Geinitz 1862	·	·	+	·	·	·	·	·	·	·	·	·	·	·
C. furcata Surange and Lele 1956	+	·	+	·	·	·	·	·	·	·	·	·	·	·
C. indicus Zeiller 1902	·	+	·	·	·	·	·	·	·	·	·	·	·	·
C. karharbarense Maithy 1965	·	+	+	·	+	·	·	·	·	·	·	·	·	·
C. zeilleri Maithy 1965	+	+	+	+	+	+	·	+	+	·	·	·	·	·
Cordaicarpus sp.	+	·	+	+	·	·	+	·	·	·	+	·	·	·
Cornucarpus furcata Surange et Maithy 1957	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Cornuspermum pennatus Banerjee 1969	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Indocarpus elongatus Surange et Chandra 1972	·	·	·	·	·	·	+	·	·	+	·	·	·	·
Karharbariospermum surangei Srivastava et Chandra 1982	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Maheshwariella bicornuta Pant et Nautiyal 1963	·	+	·	·	·	·	·	·	·	·	·	·	·	·
M. spinicornuta Maheshwari et Tewari 1986	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Nummulospermum bowense Walkom 1921	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Otofeistia milleri (Feistmantel) Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Palaeocarpus birsinghpurensis Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Palispermum ovalis Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Platycardia bengalensis Pant et Nautiyal 1960	·	·	·	·	·	+	·	·	·	·	·	·	·	·
P. jugus Maithy 1968	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Pterygospermum raniganjense Pant et Nautiyal 1960	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Retortistoma crystallina Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Rotundocarpus mucronatus Tewari et al. 2012	·	·	·	+	·	·	·	·	·	·	·	·	·	·
R. ovatus Maithy 1965	·	+	·	+	·	·	·	·	·	·	·	·	·	·
R. striatus Maithy 1965	+	+	·	·	+	·	·	+	·	·	·	·	·	·
Samaropsis feistmantelii Maithy 1965	+	+	·	+	+	·	·	·	+	·	·	·	·	·
S. ganjrensis Saksena 1955	+	+	+	+	+	+	·	·	·	·	·	+	·	+
S. goraiensis Surange et Lele 1956	+	+	+	·	+	·	·	+	+	·	·	·	·	·
S. johillensis Saksena 1955	+	·	·	·	·	·	·	·	·	·	·	·	·	·
S. millerii (Feistmantel) Seward 1917	·	+	·	·	·	·	·	·	·	·	·	·	·	·
S. penchii Pillai 2007	·	·	·	·	·	·	·	·	·	·	·	·	·	·
S. raniganjensis Seward et Sahni 1920	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Samaropsis sp.	+	+	·	+	·	·	+	·	·	·	·	·	·	·
Shivacarpus johillensis Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
S. latus Pant et al. 1985	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Spermatites indicus Srivastava 1954	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Stephanostoma crystallinum Pant et Nautiyal 1960	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Stereocarpus emarginatus Surange 1957	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Talchirospermum indicum Srivastava et Chandra 1982	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Walkomiellospermum indicum Pant et Srivastava 1963	·	·	·	·	·	·	·	·	·	+	·	·	·	·

compressed seeds include reproductive organs described under the names *Denkania* Surange and Chandra (1975) and *Partha* Surange and Chandra (1975). The structure of these seeds is unknown. Similarly, the seeds of the attached impression include *Maheshwariella bicornuta* Pant and Nautiyal (1963). *Platycardia* and *Pterygospermum* attached to *Ottokaria*-like fructification were described by Pant and Nautiyal (1965) and Pant (1977). Similarly, attached seeds were described for *Buriadia heterophylla* Pant and Nautiyal (1967). Seeds of *Cornuspermum* attached to the fructification of *Senotheca* were described by Banerjee (1969). The seeds of *Platycardia* and *Pterygospermum* are closely associated with *Dictyopteridium* Surange and Chandra (1973). The other seeds include *Talchirospermum indicum* and *Karharbariospermum surangei* described by Srivastava and Chandra (1982). *Maheshwariella spinicornuta* was reported by Maheshwari and Tewari (1986). *Birsinghia* was reported by Pant et al. (1995). All these seeds were described from India.

The seeds of detached impressions include *Cordaicarpus* Geinitz (1862); *Cornucarpus* Arber (1914); *Carpolithes* Feistmantel (1879); *Cardiocarpum* Feistmantel (1879); *Indocarpus* Surange and Chandra (1972); *Nummulospermum* Walkom (1921); *Samaropsis* Goeppert (1864); *Stereocurpus* Surange (1957) and *Rotundocarpus* Maithy (1965). Various authors reported these seeds from Indian Gondwana. In contrast, only a few detached compressed seeds have been reported from India. Surange (1957) reported *Stereocurpus* from Raniganj Coalfield. Srivastava (1954) described *Spermatites* Miner (1935) from the West Bokaro Coalfield of Damodar Basin and Pant and Nautiyal (1960) reported *Stephanostoma* from Raniganj Coalfield. Pant (1958) was the first person to describe the compressed Lower Gondwana seeds.

There is an ambiguity about the botanical affinities of seeds with any species or leaf of *Glossopteris* flora, since the seeds are preserved in dispersed conditions. Maithy (1965) considered seeds to be associated with Glossopteridales, Coniferales, Cordaitales, etc. but lacked the organic connection with the leaves. He also put forward that since all the seeds are different in their morphological characteristics, they belong to different genera and plant groups. White (1908) considered *Samoropsis* seeds to be associated with *Gangamopteris*. Plumstead (1963) inferred an angiospermic origin. Souza and Iannuzzi (2012) studied seeds from Lower Permian deposits in Rio Grande do Sul State, Brazil. They described the following seeds with undetermined botanical affinities: *Samaropsis gigas* (undetermined; Cordaitaleans?), *S. kurtzii* (undetermined; Cordaitaleans, Coniferous?), *S.* aff. *S. millaniana* (undetermined; Glossopterids, Ginkgoaleans?), *Cordaicarpus cerronegrensis* (undetermined), *C. truncate* (undetermined; Glossopterids?) and *C.* aff. *C. brasilianus* (Glossopterids). However, all the seeds described have no botanical affinities at the generic level. Only one seed, *Cordaicarpus* aff. *C. brasilianus*, is considered to have an affinity with Glossopterids due to its connection with a fructification of Arberia-type. McLoughlin et al. (2018) suggest that the sediments of Gondwana have a broad range of isolated and dispersed seeds with uncertain affinities. Hence, the IPSD database is deprived of the botanical affinities (mother-plants) of the seeds.

DISCUSSION

The IPSD can contribute significantly to Permian seed systematics by making data available to any researcher with access to a computer. It provides users access to state-of-the-art, validated and up-to-date information on the seeds of the Indian Gondwana basins via distributed databases in response to their own systematic and taxonomic searches. The IPSD facilitates computer-aided seed identification. In doing so, it enables both educational and research objectives. In addition, getting information about Permian seeds is simple, particularly for researchers with limited resources or no access to seed information, who study in very remote areas, and lack access to frequently updated specialised libraries and expertise (Govind et al., 2014). The IPSD is a pioneering and one-of-a-kind application arising from a global effort to create a comprehensive database on Indian Permian seeds and provides easy database access.

The IPSD has the potential to improve precision through computer-assisted identification of Permian seeds, thereby reducing/minimizing the unwanted information load due to new species creations based on incomplete or fragmented past knowledge. The photo-documentation of seeds offers a graphical perspective for scientific comparison and identification of old or

new species or genera. Photographs and data are also helpful for precisely identifying the Permian seeds. This programming will expedite the identification of seeds and the retrieval of their complete details. As a result, the entire procedure will be simple, rapid and accurate.

SALIENT FEATURES OF IPSD SOFTWARE

1. IPSD will be the pioneering software to display the holistic account of seeds described from the Permian period of Indian Lower Gondwana.

2. The purpose of the software is to save and organise information about Indian Lower Gondwana seeds collected over the past 140 years.

3. The researchers can get the details of the Permian seeds at their fingertips.

4. This will be assessed globally by the end user with the permission of the administrator (email: ssureshk_pillai@bsip.res.in).

5. This will help the researchers identify the seed species quickly.

6. After consulting the administrator, there is an option for modifying the data.

7. The software will provide testament and updated information on seeds of the Indian Lower Gondwana basins from the IPSD database to researchers seeking systematic and taxonomic queries for Permian seeds of India.

IPSD software is precise and promising in identifying seeds through computer-aided programmes. This software will help to minimize wrong and fragmented information while creating a new species as it has seed details with a graphical view, which is helpful for scientific comparison and identification of seeds from past records and creating new species. The software might be considered a model for creating similar software for other scientific areas.

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