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A Petrified Seed from the Deccan Intertrappean Beds of Ghatparasia, M.P, India

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Abstract

The present study describes a well-preserved petrified seed collected from the Deccan Intertrappean Beds of Ghatparasia, Chhindwara District, Madhya Pradesh, India. The specimen was studied for its morphological and anatomical characters. The seed is medium-sized, reniform to ellipsoidal, and measures about 5 mm in length. It is campylotropous and bitegmic, with a large embryo occupying almost the entire seed cavity. The embryo consists of two flat cotyledons, a long curved hypocotyl and a narrow pointed radicle. The seed coat contains aerenchymatous and parenchymatous cells, while vascular elements are also present in its inner region. The fossil was compared with previously reported fossil seeds and selected living angiosperm families. It shows a close resemblance to the living genus Stixis of the family Capparaceae. However, it differs from other known fossil seeds in some important characters. Therefore, it is proposed as a new fossil genus and species, Stixisspermumghatparasiaii gen. et sp. nov. This finding adds to the knowledge of fossil seed diversity in the Deccan Intertrappean flora.

Keywords: *Petrified seed, Deccan Intertrappean Beds, Ghatparasia, seed anatomy, fossil angiosperm, Capparaceae.*

Introduction

The Deccan Intertrappean Beds of Central India are well known for their rich and diverse fossil flora. These beds contain many well-preserved plant remains, including leaves, flowers, fruits, seeds and wood. These fossils provide valuable information about the plant diversity and vegetation of the geological past.Fossil seeds are important in palaeobotanical studies because their shape, size, seed coat and embryo structure help in understanding the characteristics of ancient plants. Their anatomical features are also useful for comparing fossil seeds with previously reported fossils and seeds of living plants.Several fossil seeds have been reported from the Deccan Intertrappean Beds, showing variations in their size, shape, seed-coat structure and embryo organization. Studies of these fossils have helped researchers understand the diversity of ancient flowering plants in this region.The present fossil seed was collected from Ghatparasia village, Chhindwara District, Madhya Pradesh. It is medium-sized and reniform to ellipsoidal in shape. The seed is bitegmic and contains a large, well-preserved embryo with two cotyledons, a long curved hypocotyl and a narrow radicle. The seed coat contains aerenchymatous and parenchymatous cells, along with vascular elements in its inner region.Adetailed comparison was made with previously reported fossil seeds and seeds of selected living angiosperm families. The study revealed some similarities as well as important differences in their morphological and anatomical characters.The present investigation focuses on the detailed study of the external morphology and internal anatomy of the fossil seed. It also aims to compare its characters with previously reported fossil seeds and living angiosperms to understand its systematic position and significance in the Deccan Intertrappean fossil flora.

Materials and Methods

The fossil seed was collected from the Deccan Intertrappean Beds of Ghatparasia village, Chhindwara District, Madhya Pradesh, India (Lat. 22.064435° N; Long. 79.044903° E). The specimen was preserved in fossiliferous chert. Anatomical details were studied from the exposed surface and its counterpart using the peel technique. The chertwas etched with hydrofluoric acid (HF) following Darrah (1936), and serial peels were prepared to study the internal anatomical features. The prepared peels were examined under a compound microscope. Measurements of the seed, seed coat, embryo and other anatomical structures were recorded in millimetres and micrometres.

Description

Seed Morphology

The seed is petrified and well preserved. The seed is differentiated into seed coat and large curved embryo. It is slightly curved in the center and divided into two parts. Lower portion is narrow as compared to the upper portion. The seed is ellipsoidal and reniform, measuring 5mm in length, 3.5mm in breadth in the upper half portion and 2mm in the lower half portion. The seed cavity measures 4584 µm in length and approximately 500 to 769 µm in breadth.

The seed is flat on one side. The embryo is very large and occupies the whole space of the seed cavity. The seed cavity is also flattened at the cotyledonary region and narrower at the radicle region. The seed is campylotropous (Plate 1.Figs.1-6; Text Figs. 1-7).

Anatomically the seed shows the following characters:

Seed coat

The seed coat is bitegmic but not very well differentiated. The testa is non-multiplicative. The outer wall of the testa is wavy and 3-6 layers in thickness and consists of aerenchymatous cells mixed with thick-walled parenchymatous cells (Plate 2 Fig. 4). The lower layer i.e. tegmen is made up of thin-walled parenchymatous cells (Plate 2 Fig. 5). Some xylem elements are seen in inner layer of seed coat. Xylem elements measure 9-11 µm in diameter and show vascular thickenings (Plate 1.Figs.1-6; Text Figs. 1-7).

Embryo

The embryo is well preserved and very large in size. It is curved with two flat cotyledons. The embryo is well differentiated into 3 parts, two flat cotyledons, long hypocotyl region and narrow pointed radicle (Plate 2 Fig. 4; Text Figs. 7-19). It Embryo occupies maximum space of the seed cavity. In between wall of the embryo, there is a narrow space all around. However, some thin-walled parenchymatous cells are still preserved in this nucellar region. The wall of embryo is made up of thin parenchymatouscells which are irregular in shape. Embryo measures about 4208 µm in length whereas the breadth of embryo varies in different regions. The two cotyledons are present on the seed. The cotyledons are flat and measures about 2076 µm in length and 1769 µm in breadth. The cells of cotyledons are present at some places only and are thin walled parenchymatous (Plate 2 Fig. 7). Hypocotyle in this seed is very long measuring about 1346 µm in length. It is curved by two bends on two sides into three parts. At some places thin-walled parenchymatous cells are preserved in hypocotyle region. As compared to cotyledons and hypocotyle, the radicle is very narrow. (Plate 2 Fig. 5). It measures about 17 to 82 µm in breadth and 1076 µm in length. The hypocotyleis made up of thin-walled parenchymatous cells and measures about 8.8 to 11 µm. They are preserved at only some places (Plate 1.Figs.1-6 ; Text Figs. 1-7).

Nucellus

Around the embryo, a narrow empty space is seen which represents the nucellus. Nucellar tissue is preserved at some places and is parenchymatous.

Discussion and Identification

The important diagnostic characters of the seed, based on the study of both the part and counterpart of the specimen, are as follows:

- Medium sized seed.
- Seed irregularly reniform and ellipsoidal.
- Testanon multiplicative. Outer layer unspecialized with aerenchymatous cells.
- Tegmen with thick-walled parenchymatous cells and 4–9 cells thick, campylotropous, exarillate, exalbuminous seed.
- Vascular supply in tegmen.
- Large embryo with long hypocotyl and narrow radicle.
- Cotyledons and radicle of various lengths.

Comparision with Reported Fossil Fruit and seed

Enigmocarponparijaii(Biradar and Mahabale, 1974), seeds (ovules) anatropous, bitegmic, crassinucellate, having short funiculus, whip-like epistase, saucer shaped hypostase, operculum, free nuclear endosperm and a well-developed dicotyledonous type of embryo in mature seeds. The embryo shows differentiation of dermatogen, periblem, plerome, shoot apex between the two cotyledons and a long hypocotyledonary region with a single vascular supply but present fossil seed is medium, reniform or ellipsoidal, campylotropous, dicotyledonous, bitegmic, exarillate and exalbuminous. Seed coat differentiated into testanon multiplicative.The embryo is well preserved and very large in size. It is curved with two flat cotyledons. The embryo is well differentiated into 3 parts, two flat cotyledons, long hypocotylar region and narrow pointed radicle. Hence the present seed is different from ***Enigmocarponparijaii.***

But the fossil seed differs from the seed of Capparis in minute anatomical characters of wall layers. In the seed of Capparis the outer layer of testa shows presence of stomata which is not seen in fossil seed under investigation. In the seeds of living Capparis the tegmen is fibrous and lignified and differentiated into an outer fibrous and lignified layer, a thin walled and unlignified mesophyll and a lignified endotegmen, (Corner, 1976). However, this differentiation of tegmenis not seen in fossil seed under investigation. The fossil seed has compared with the already described fossil seeds. Kumar (1984) described dicotyledonous seed under the name ***Clusiocarpusarillatus***. This seed shows presence of prominant wings and author had described presence of suspensor in her material as a vestigeal structure and so the ***C. Arillatus***is not comparable with the fossil seed which is exarillated and shows absence of suspensor. ***Deccanospermaarillata***(Juneja, 1993) is a small cordate seed with aril. However in the present fossil seed aril is absent. In ***Mahabalspermumminutum***(Juneja, 1993) testa is thin membranous without any distinct cellular composition.

Tegmenis differentiated into two zones and embryo is minute. Hence M. minutum is also not comparable with the fossil seed. The comparison is made with ***Clusiocarpusindicum***(Kolhe and Wazalwar, 1998). This seed resembles the fossil seed in having dicotyledonous exarillated, exalbuminous seed but in ***C. indicum***testa is made up of cuboid and elongated cells which are compactly arranged while in fossil seed under consideration testa shows aerenchymatous cells. The fossil seed also differs ***C. indicum***in nature of embryo

In *C. indicum*the hypocotyle is not very long while in fossil seed it is long and curved by two bends on two sides into three parts though adpressed to the testa to almost half of the length of the seed, the inner layer of the testa is membranous wheares in fossil seed under investigation it is parenchymatous, unspecilized and undifferentiated.

Ramakonospermussinghpuriidescribed by (Bhowal, 2003), is a dicotyledounous, exarillate seed in which the testa is mesotestal with thick-walled sclerotic cells, tegmen is hyline and papery, a gland like structure is present in the seed coat. All these characters are not seen in fossil seed under investigation. Thus, the fossil seed under consideration does not corelate with any fossil seeds described so far from these beds

Proboraginocarpusbalasinorensis(Mathur A. K. and Mathur U. B., 2011), seed is small, bilaterally symmetrical, ovoid trigonal, scar of attachment basal (posterior), circular with raised collar. Ventral side with knotty keel running from collar of attachment scar to apical end. Apically narrowed, basally inflated, but present seed is medium, reniform or ellipsoidal, campylotropous, dicotyledonous, bitegmic, exarillate and exalbuminous. So, it is different seed.

Capparisocarpusnagpurii(Konde and Kolhe, 2012), seed irregular and reniform and ellipsoidal testanon multiplicative but present seed differ in anatomy.

Sahniospermumtrapii(Pundkar et al., 2017), seed small, bitegmic, anatropous. The seed about 1.23 mm length and 1.73 mm in breadth. The seed cavity 1.19 mm x 1.68 mm in width. The seed coat differentiated into testa and tegmen. Testa consists of tangentially elongated with layer of fibres. Three-layer testa clearly seen i.e. exotesta, mesotesta and endotesta, while present seed is bitegmic but seed shape is ellipsoidal or reniform and also campylotropous therefore totally different seed.

Pinusarunachalensis(Khan and Bera, 2017), seeds winged, broadly oblong to oval in outline, 1.3 - 1.5 cm long and 0.4 - 0.6 cm broad (in the middle part), seed part broadly oval, 0.4 - 0.5 cm long, 0.1 - 0.2 cm broad, located basipetally and symmetrically to wing, wings 1.1 - 1.4 cm long, wing apex round-obtuse, cellular pattern of wing is seemingly undulatory and parallel with the long axis of the wing, wing is wrinkled perpendicular to the long axis, but present seed shape is ellipsoidal or reniform and present seed is without a wing therefore the present seed is different.

Singhpurospermumdeccanii(Nandeshwar and Narkhede, 2017), the seed shows unitegmic seed coat and large embryo. It is ovoid in shape measuring 3.8 mm in length and 2 mm in breadth showing stalk like structure at the base with a slit which might be representing micropyle. The seed coat is unitegmic having outer integument only. The embryo is very large and occupies the maximum space of the seed cavity. The seed coat is well preserved but not differentiated into testa&tegmen,tegmen is ill preserved consisting of testa only. It is broad at the upper region. Testais differentiated into two distinct zones, but present seed shape is ellipsoidal or reniform and bitegmic or unitegmic, hence present seed is different.

Polygalaceaeospermumsinghpurii(Meshram and Mohture, 2018), Seed small polygonal, bitegmic, dicotyledonous. Seed coat with testa and tegmen only. Embryo small well preserved with cotyledons, micropyle seen. Seed coat with testa and tegmen differentiated into outer single layered epidermis made by parenchymatous cells. Tegmen made by in soft parenchymatous cells. Endosperm tissue seen, while present seed is bitegmic but seed shape is ellipsoidal or reniform, hence it is different.

Junejospermumintertrappea(Pundkar et al., 2020), seed is small, oval, unitegmic measuring 0.249 mm long and 0.153 mm broad. Seed cavity measuring about 0.22 mm in length and 0.13 mm in width. Seed coat differentiated into testa and tegmen. Seed coat measuring 148 µm

Chitaleospermumpatanii(Ramteke et al., 2025), small, oval, orthotropous, dicotyledonous, unitegmic seed measuring 2.43 mm in length and 1.25 mm in width. Seed coat differentiated into Testa and Tegmen measuring about 133 µm in thickness. Testa is single celled, undifferentiated, 5-6 µm in thickness. Tegmenis single layered, compactly arranged sclerenchymatous cells measuring 20-30 µm in thickness, but present seed shape is ellipsoidal or reniform and bitegmic, hence this seed does not show resembles.

Comparision with Modern Families

According to **Eames** (1961), the suspensor undergoes considerable reduction during the embryogeny of angiosperms and is often absent in mature seeds. One of the most important diagnostic features for identifying angiosperm seeds is the presence of a bitegmic seed coat. In the present fossil seed, the seed coat is distinctly differentiated into an outer testa and an inner tegmen. The testa is non-multiplicative and composed of thick-walled parenchymatous cells intermixed with a few aerenchymatous cells, whereas the tegmen consists of thin-walled parenchymatous tissue. A well-preserved embryo is present with two flat cotyledons, a long hypocotyl curved into two bends, a narrow pointed radicle, and no evidence of a suspensor. These anatomical characters clearly indicate that the fossil seed is angiospermic and dicotyledonous in nature.

The fossil seed is characterized by a bitegmic seed coat, vascular supply in the tegmen, campylotropous orientation, exarillate and exalbuminous condition, and a well-developed embryo. Based on these characters, the fossil seed was compared with the seeds of extant angiosperm families described by Corner (1976), including **Aceraceae, Bixaceae, Burseraceae, Capparaceae (Capparidaceae), Malvaceae,** and **Theaceae**. Among these, the fossil exhibits the closest resemblance to the families **Theaceae** and **Capparaceae**.

The seed shares several features with members of **Theaceae**, including a medium-sized campylotropous, exarillate seed with non-multiplicative testa and tegmen, and a curved embryo possessing a long hypocotyl and flat cotyledons. However, the fossil differs from Theaceae in lacking a hypostase and mesotestalsclerenchymatous cells, both of which are characteristic features of seeds in that family (Corner, 1976). Therefore, its assignment to Theaceae is not justified.

The fossil seed shows much closer affinity with the family **Capparaceae**. It resembles the extant genus ***Stixis***, particularly ***Stixissuaveolens***, in possessing the following diagnostic features:

- Seed approximately 5 mm long.
- Seed irregularly reniform to ellipsoidal in shape.
- Seed campylotropous, exarillate, and exalbuminous.
- Testa non-multiplicative, with unspecialized outer cells containing a few intercellular air spaces.
- Tegmen thin-walled and traversed by vascular tissue.
- Embryo consisting of two thin, flat cotyledons inserted on one side of the hypocotyl.
- Hypocotyl long, stout, and curved by two bends into three portions.
- Radicle short, narrow, and apical.
- Nucellar tissue parenchymatous.
- Suspensor absent.

The presence of vascular tissue within the inner integument (tegmen) is regarded as a characteristic feature of angiosperm seeds (Corner, 1976), further supporting the angiospermous nature of the fossil. The absence of a suspensor in the mature embryo also agrees with the condition described for many angiosperms (Eames, 1961).

From the foregoing comparison, it is evident that the fossil seed exhibits its closest affinity with the family **Capparaceae**, particularly with the genus ***Stixis***, although it differs sufficiently from all known extant species to warrant the establishment of a new fossil taxon. Accordingly, the fossil seed is assigned to the new genus and species ***Stixisspermumghatparasiaii*** gen. et sp. nov. The generic name denotes its close affinity with the extant genus ***Stixis***, The species name *ghatparasiaii* refers to GhatParasia, Madhya Pradesh, the locality from which the fossil was collected.

Diagnosis

Stixisspermumgen.nov.

Fossil seed medium, reniform or ellipsoidal, campylotropous, dicotyledonous, bitegmic, exarillate and exalbuminous. Seed coat differentiated into testanon multiplicative, outer layer unspecialized with aerenchymatous cells. andtegmen is made up of thin-walled parenchymatous cells. Embryo very large with long hypocotyl and narrow radicle and well preserved with curved with two flat cotyledons.

Stixisspermumghatparaciaiigen.et.sp.nov.

Seed is medium, reniform and ellipsoidal, bitegmic, measuring 5mm length and 3.5 mm breadth. Seed cavity measuring about 4584 µm in length and 500 to 769 µm in breadth. The seed is campylotropous. Seed coats not differentiated into testa and tegmen. The testa is non - multiplicative. The outer wall of the testa is wavy and 3-6 layers in thickness and consists of aerenchymatous cells mixed with thick-walled parenchymatous cells. The lower layer i.e. tegmen, is made up of thin-walled parenchymatous cells. Embryo well preserved and very large in size. It is curved with two flat cotyledons, well differentiated into 3 parts, two flat cotyledons, long hypocotylar region and narrow pointed radicle.

Holotype: DSD/ Dicot Seed 2/ Deposited in the Department of Botany, RTMNU, Nagpur.

Horizon : Deccan Intertrappean series of Central India.

Locality : Ghatparasia, M.P., India.

Age: Upper Cretaceous?

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

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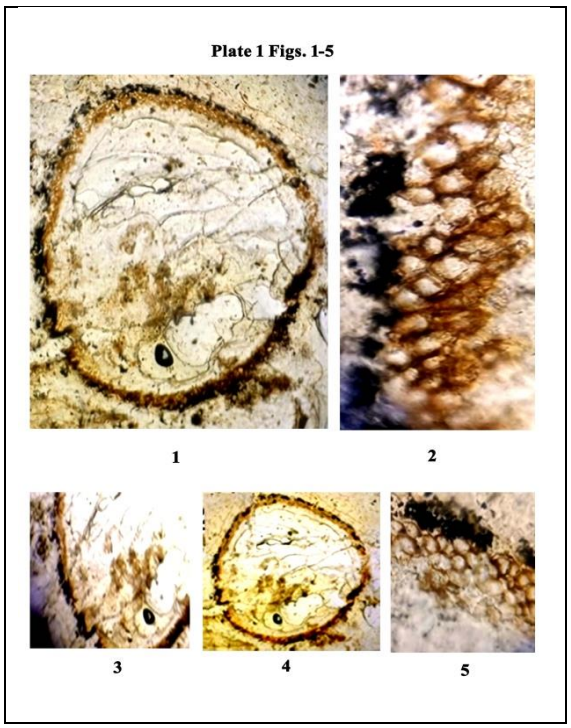
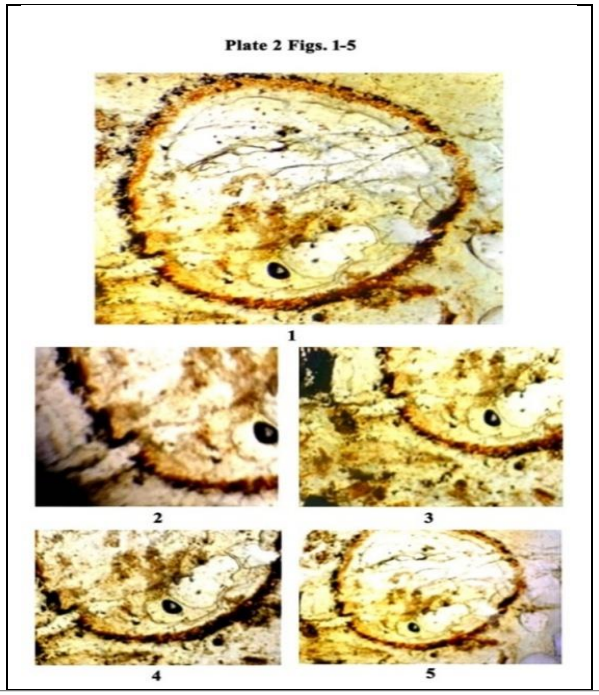


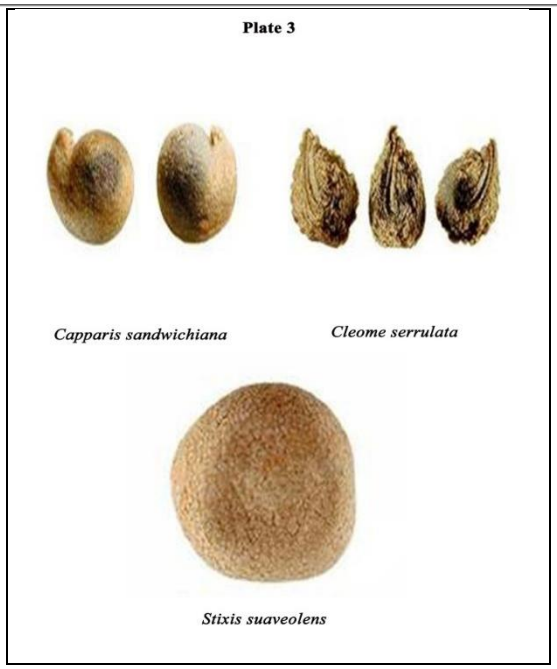
Explanation of Plate 1 Figs 1-5

Figs. 1-5: Serial section seed showing petrified, dicotyledonous, bitegmic and endospermic, irregularly reniform and ellipsoidal in shape.(100X) **Fig. 2:**Seed coat cellular details. (450X);**Fig. 4:**Complete seed. (100X); **Fig. 5:**Seed coat layers; Testa and Tegmen (1000X).



EXPLANATION OF PLATE 2 FIGS 1-5

Figs. 1-5: Serial section seed showing showing cellular details; **Fig. 1:** Complete seed shows petrified, dicotyledonous, bitegmic and endospermic, irregularly reniform and ellipsoidal in shape.(100X) **Fig. 2:** Seed coat cellular details. (450X); **Fig. 3,4:** Seed coat with embryo. (450X); **Fig. 5:** Complete seed. (100X).



EXPLANATION OF PLATE 3 FIGS. 1-3:

Fossil Seed compared with Family Capparaceae

Fig. 1: *Capparis sandwichiana*; **Fig. 2:** *Cleome serrulate;* **Fig. 3:** *Stixis suaveolens.*